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ANTIOXIDATIVE AND ANTIDIABETIC PROPERTIES OF SKUNK VINE (*Paederia foetida* L.)

T. K. GHOSH[1], T. HUSNA[2], Z. A. MERAJ[3] AND A. NAZRAN[4]

Abstract

This experiment was executed at the research field of Department of Crop Botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh during 2019 to 2020. In this study, methanolic extract of different plant parts was used for observing the antioxidant properties such as total phenolic, flavonoids, carotenoids and anthocyanins content in Skunk vine (*P. foetida)*. Results showed that, the total phenolic were more or less similar in leaf (357.62 µg/g) and stem (349.42 µg/g) and that were significantly higher than that of root extract (233.56 µg/g). The highest amount of flavonoid content (602.71 µg/g) was recorded in leaf extract and the content was more or less similar in stem (493.16 µg/g) and root extracts (501.86 µg/g). Maximum amount of anthocyanin content was recorded in leaf (42.04 µg/g) that was identical with that of stem extract (39.68 µg/g) and statistically the lowest amount in root extract (27.44 µg/g). The fresh leaf extracts contained higher carotenoid content (41.96 mg/g) than stem (25.58 mg/g). Total antioxidant activity in respect to percentage of DPPH ((2,2-diphenyl-1-picrylhydrazyl) scavenging efficiency, leaf extract showed 63.78% inhibition efficiency which were significantly higher than that of stem (45.75%) and root (24.19%). α-glucosidase activity was greatly inhibited (59.13%) by leaf extract at the concentration level of 1.5 mg/mL which was better than that of stem (45.60%). Inhibition of α-amylase activity was recorded up to 46.23 and 42.57% by leaf and stem extracts, respectively which were statistically similar. The present study suggests that medicinal plant Skunk vine *(P. foetida)* has both antioxidative and antidiabetic properties which would be the good source for producing safe natural drugs.

Keywords: Total phenolic content, flavonoid, carotenoid, anthocyanin, % DPPH, α- glucosidase and α-amylase, Skunk vine *(Paederia foetida).*

Introduction

Human beings greatly depend on medicinal plants for their food and health security. Among the plants present in nature, the medicinal plants are being considered for the most exclusive source of life saving drugs (Reddy and Reddy, 2008). The country like Bangladesh which is enriched with plant resources have long historical background for the therapeutic uses of medicinal plants (Nandkoni 2002; Khare 2007). Skunk vine *(Paederia foetida* L.) 'belonging' to the family

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'Rubiaceae', locally named as 'gandhabadali' and widely distributed throughout the Asia (Reddy and Reddy, 2008). The plant has lot of therapeutic uses such as leaf extract is used for maintaining stomach ailment, allergy, jaundice and physical weakness. However, the plant has been reported to be a reservoir of many of the important secondary metabolites like iridoid glycosides, sitosterol, stigmasterol, alkaloids, carbohydrates, proteins, amino acids and volatile oils (Nandkoni 2002; Khare 2007). In living organisms, Reactive Oxygen Species (ROS) generated during oxidative stress are very responsible for the degradation and degeneation of cellular materials like DNA, RNA, proteins and occurance of many important diseases like gastric disorder, ulcer, cancer, arthritis hepatic disorder etc. The enzymatic antioxidants such as super oxide dismutase, peroxidase and catalase etc. and non-enzymatic antioxidants like phenols, flavonoids etc. present in the plant that may neutralize oxidative stress generated in plants.

Though having lot of potentials of secondary metabolites, the little efforts were made in ROS scavenging capacity and antioxidant activity of medicinal plant Skunk vine *(P. foetida)*. Although, recent investigation reported the antioxidant activity in the leaf of Skunk vine (Nayak *et al.*, 2015), more efforts should be needed to clarify by using different plant parts. However, no report has been made yet in Bangladesh. Besides antioxidant activity, some medicinal plants have

been reported to show the inhibition of α-amylase and α -glucosidase enzymes, interference of which were supposed to cause diabetic disease type II (Mayur *et al*., 2010; Shai *et al.*, 2010). Both of those enzymes are key regulators for the digestion of starch and increasing blood glucose. Therefore, inhibitory efficiency of those enzymes are very crucial for the management of diabetic type II. Since therapeutic chemical drugs have several side effects (Chakrabarti and Rajagopalan 2002; Kimmel and Inzucchi 2005), the plant products showing inhibitory effect to those enzymes was suggested to use with minimal side effects (Tarling *et al*., 2008). Therefore, continuous searching of safer plant products in potential medicinal plant like Skunk vine would be very interesting and essential for treating patients having diabetic type II. Considering the facts, the present investigations were made to find out the antioxidative and antidiabetic properties of Skunk vine using different plant parts.

Materials and methods

The fresh and fully expanded leaves, stems and roots of Skunk vine were collected from the research field of the Department of Crop Botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh, during 2019 to 2020. After repeated washing, the collected materials were allowed for drying for 4-5 days at room temperature. The dried materials were chopped and crushed into powder using mortar and pestle and stored in air tight containers. Sample of 5 g of powder was mixed into 50 ml methanol and allowed to filtration. The extract was then concentrated using rotary evaporator and stored at -20°C until further use.

The extracted material was used for the determination of total phenolic contents using Folin ciocalteu method as described by Singleton and Rossi (1965). The absorbance of the reaction mixture was measured at 765 nm. The results were expressed as µg/g (Gallic Acid Equivalent, GAE).

The extract of plant materials was used for the determination of flavonoid contents using aluminium-chloride colourimetric assay (Biju *et al.*, 2014). Quercetin at different concentration was used as standard solution. The absorbance of the extracts and standard solutions was measured at 510 nm using a UV/Visible spectrophotometer. The results were expressed as microgram; Quercetin equivalents (QE) per gram of extracts (µg/g).

Anthocyanin content was determined using the method followed by Hughes and Smith (2007). The anthocyanin content was expressed as micrograms for cynadin-3-glucoside equivalent per gram of dry sample (µg/g).

Total carotenoid content was determined according to the procedure of Lachman *et al.*, (2003) with slide modification. Total carotenoid content was expressed as mg of lutein equivalent per gram of fresh weight sample (mg/g, LE).

The plant extract was allowed for showing DPPH radical scavenging activity by following the method of Xu *et al.* (2010). Ascorbic acid as antioxidant was used to make reference solution. The reaction mixture of plant extracts and DPPH (2,2-diphenyl-1-picrylhydrazyl) were kept in dark condition at room temperature for 30 min. Then the absorbance of samples was measured at 517 nm using a spectrophotometer. The absorbance of control and blank samples were also determined to make comparison with the absorbance of plant extract. The inhibition percentage was calculated by the following equation:

% DPPH radical scavenging activity = $[(A_0 - A_1)/A_0] \times 100$. Where A_0= absorbance of the control and A_1= absorbance of the sample.

The plant extracts was allowed for α-glucosidase inhibitory activity by following the method used by Laoufi *et al.* (2017). Different concentration of leaf and stem extracts (0.05, 0.1, 0.5, and 1.5 mg/mL) were used in reaction mixture containing α-glucosidase enzyme. Acarbose as commercial inhibitor at different concentrations (0.005, 0.01, 0.1 and 0.2 mg/mL) was used as positive control. The absorbance of the reaction mixture will be recorded at 405 nm using spectrophotometer. The enzyme inhibition rate expressed as percentage of inhibition was calculated using the following formula:

Inhibition of α -glucosidase activity (%) = ((Abs C - Abs S)/Abs C) X100, where Abs C is the absorbance of the control (100 % enzyme activity) and Abs S is the absorbance of the tested sample (plant extract or acarbose).

Inhibition of α -amylase activity of the plant's extracts was determined by analysing the reducing power of released oligosaccharide from soluble starch by following the method of Bernfeld (1955). Different concentration of leaf and stem extracts (0.05, 0.2, 0.5, 1.0 and 5.0 mg/mL) were used in reaction mixture containing porcine pancreatic α-amylase enzyme. Acarbose as commercial inhibitor at different concentrations (0.005, 0.01, 0.1 and 0.2 mg/mL) was used as positive control. Inhibition of α-amylase activity was determined by measuring the absorbance of the reaction mixture at 540 nm, using spectrophotometer. The enzyme inhibition rate expressed as percentage of inhibition was calculated using the following formula:

Inhibition of α -amylase activity (%) = ((Abs C - Abs S)/Abs C) X100, where Abs C is the absorbance of the control (100 % enzyme activity) and Abs S is the absorbance of the tested sample (plant extract or acarbose).

All the experiments were conducted by following CRD (Completely Randomized Design) with at least three replications. Student t-test was used for analyzing the data.

Results and Discussion

Since commercial drugs have long term side effects and lot of complications, searching of antioxidant potentials and plant based natural products in medicinal plant Skunk vine is very imperative for maintaining good health. The results of the experiments were discussed as following subheads.

Total phenolic content in Skunk vine

Higher phenolic content of the plant shows increased ability to the reduction of free radicals produced by the reactive oxygen species (ROS). It was determined of total phenolic in the methanolic extract of dried leaf, stem and roots of Skunk vine. The values of total phenolic were expressed as µg/g (GAE; gallic acid equivalent). Among the plant parts used, the total phenolic was statistically similar in leaf (357.62 µg/g) and stem (349.42 µg/g) and root contained lowest amount of polyphenols (233.564 µg/g) which was significantly different as compared to leaf and stem (Fig. 1). In another investigation, total polyphenol content of the leaf extract was reported in different cultivated and wildly grown Skunk vine and found the ranges of phenolic contents; 0.063-3.044 mg GAE/ml and the data of which are little bit different than that of present investigation (Sahoo and Bhatnagar, 2015). In previous investigation, three different traditional medicinal plants were screened for phytochemical analysis; where Skunk vine showed the highest phenolic content 138.33 ± 6.415 mg GAE/g (Devi *et al*., 2016). In another experiment Skunk vine showed comparatively lower phenolic content 165.81 mg GAE/100 g FW among seven different medicinal plants (Islam *et al*., 2018). The variation is due to the age, cultivar, climatic condition of the plant growing locations, extraction methods, assay techniques and chemical as well.

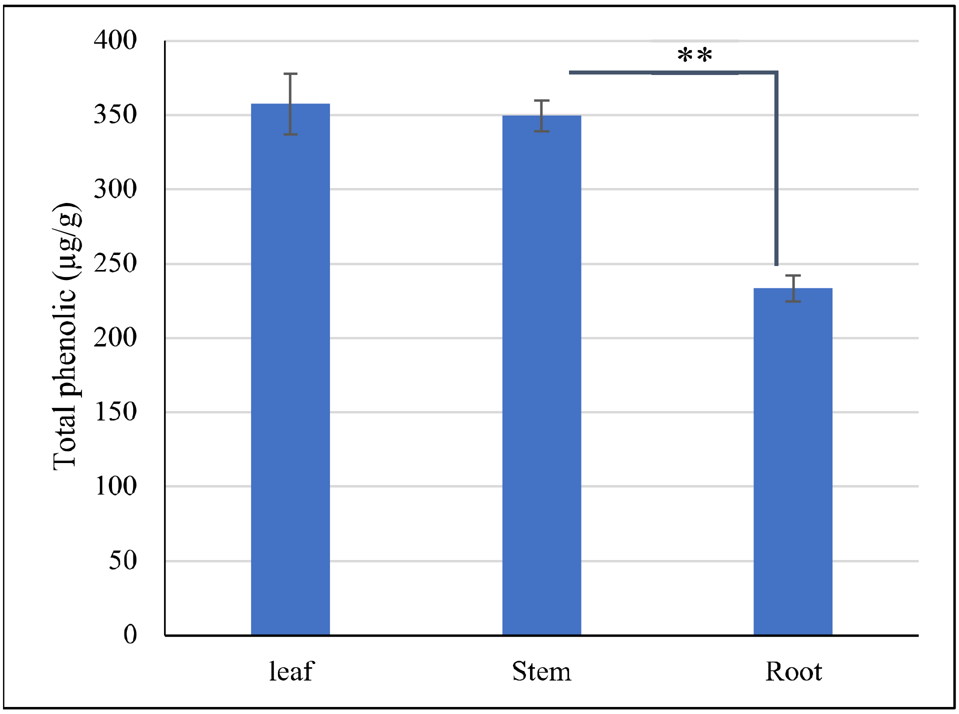

Fig. 1. Total phenolic content of leaf, stem and root extracts of Skunk vine. Error bars indicate the standard deviation (*n* = 3). Asterisks indicate significant difference (*P* < 0.01; t-test).**

Flavonoid content in Skunk vine

The flavonoids are very essential secondary metabolites acting as antioxidant and providing protection to cardiovascular disease by scavenging superoxide and hydroxyl radicals (Harborne, 1988). In this study, flavonoid content in different plant parts of Skunk vine was determined and identified the plant as the potential reservoir of this secondary metabolite. The content of flavonoids was expressed as µg/g (QE; Quercetin equivalent). The highest amount of flavonoid content (602.71 µg/g) was recorded in leaf extract and the amount of flavonoid content was significantly lower in stem (493.16 µg/g) and root extracts (501.86µg/g) (Fig.2). The flavonoid content of leaf extract of different cultivated and wild species of

Skunk vine were recorded as 0.627 mg QE/ml and 0.647/ml respectively (Sahoo and Bhatnagar 2015). The result is more or less consistent to the flavonoids content of leaf extract in our observation. The results also suggest that leaf is the best source of flavonoid content in Skunk vine.

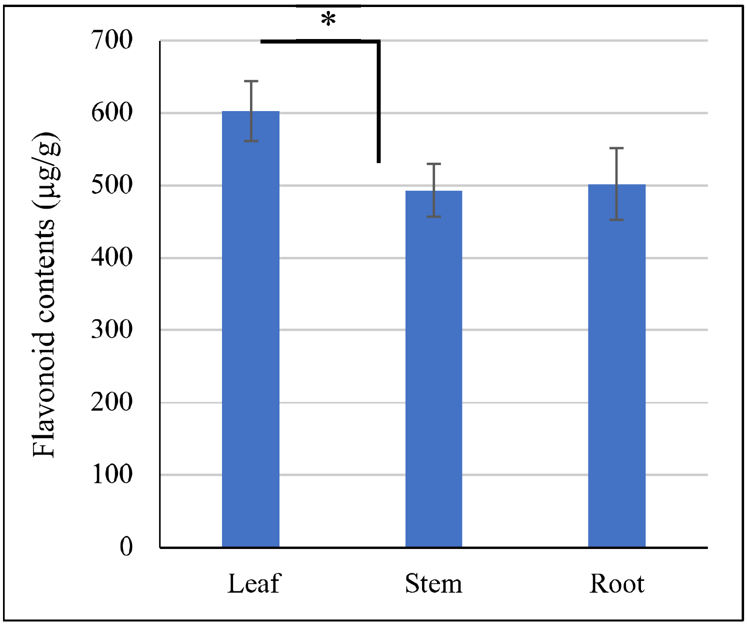

Fig. 2. Flavonoid content of leaf, stem and root extracts of Skunk vine. Error bars indicate the standard deviation (*n* = 3). Asterisk indicates significant difference (P* < 0.05, t-test).**

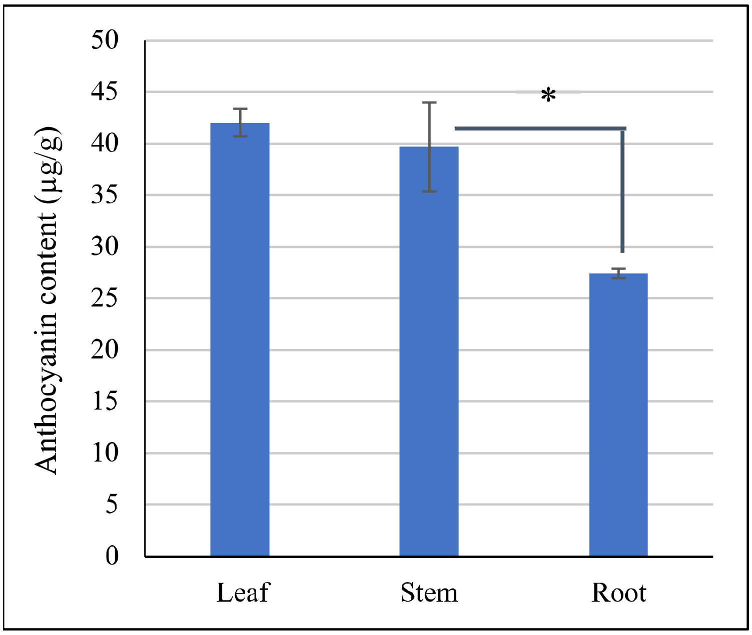

Fig. 3. Anthocyanin content of leaf, stem and root extracts of Skunk vine. Error bars indicate the standard deviation (*n* = 3). Asterisk indicates significant difference (P* < 0.05, t-test).**

Anthocyanin content in Skunk vine

Anthocyanins have an antioxidant potential twice than other known antioxidants, such as catechin vitamin E, BHA (butylated hydroxyanisole) and BHT (He and Giusti, 2010). In the present study, it was found that leaf and stem contained more or less similar amount of anthocyanin content such as 42.04 µg/g and 39.68 µg/g, respectively (Fig. 3). Among the plant parts used, significantly the lowest amount of anthocyanin content was recorded in root (27.44 µg/g). Although, anthocyanin content of the medicinal plants were reported in different medicinal plants (Mazandarani *et al.*, 2011; Asem *et al.*, 2015), the results of present study suggest that Skunk vine irrespective of leaf and stem are very good source of anthocyanins.

Carotenoid content in Skunk vine

Carotenoids play a great role in reducing risk for several human disorders, including various types of cancer, cardiovascular or ophthalmological diseases (Mayne, 1996). Along with phenols, flavonoids and anthocyanin, the carotenoids content was also analyzed in the fresh leaf and stem of Skunk vine and observed the plant as the rich source of carotenoids. Although both leaf and stem extracts contained carotenoids such as 41.96 mg/g and 25.58 mg/g, the leaf showed better performance than stem (Fig. 4). A lot of investigations reported that medicinal plant as the good source of carotenoids which has great value for scavenging increased ROS in the human body during health disorder. In previous investigation carotinoid content was reported in Skunk vine leaf as 2.805672±0.13424 mg/g (Nayak *et al*., 2015) which is much lower than that of present observation. The variation is due to the plant species, extraction materials and method of estimation.

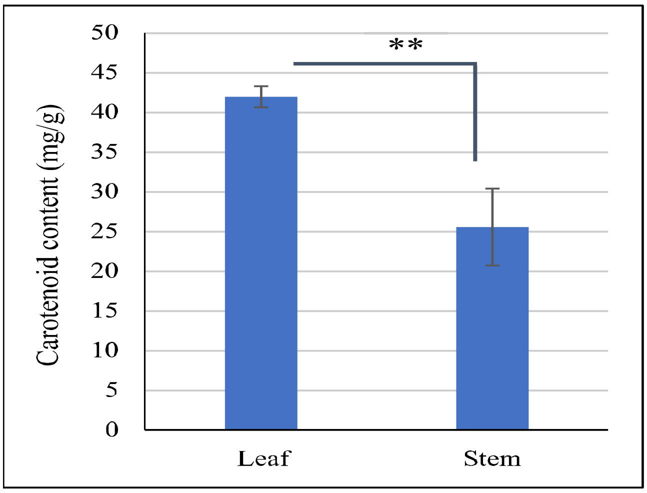

Fig. 4. Carotenoid content of leaf and stem extract of Skunk vine. Error bars indicate the standard deviation ($n = 3$). Asterisks indicate significant difference ($P < 0.01$; t-test).**

Total antioxidant activity

Total antioxidant activity was also analyzed through % DPPH (2,2-diphenyl-1-picrylhydrazyl) scavenging ability of the extracts of leaf, root and stem of Skunk vine. A great contribution of the plant parts was found for scavenging DPPH although root showed little performance in this respect. The leaf extract showed great performance; 63.78% inhibition which is significantly higher than that of stem extract (45.75%) (Fig. 5). Root showed the lowest performance (24.19%) than leaf and stem. Another observation with Skunk vine leaves showed the great efficiency for scavenging DPPH and it was about 80% (Upadhya, 2013). In an experiment, shade dried leaves of Skunk vine exhibits a dose dependent DPPH free radical scavenging manner, where about 60% inhibition was recorded by 500 □/ml Skunk vine extract (Uddin *et al.*, 2014). The antioxidant activity of fresh and dried plant extracts of Skunk vine and *Syzygium aqueum* were recorded using β-carotene bleaching and the 2,2-azinobis(3- ethyl-benzothiazoline-6-sulfonic acid) (ABTS) radical cation assay. The percentage of the antioxidant activity for the extract was between 58 and 80% (Osman *et al.*, 2009). The data ofwhich is more or consistent with that of present observation. Along with these, it is also indicated that Skunk vine has very good potential for total antioxidant.

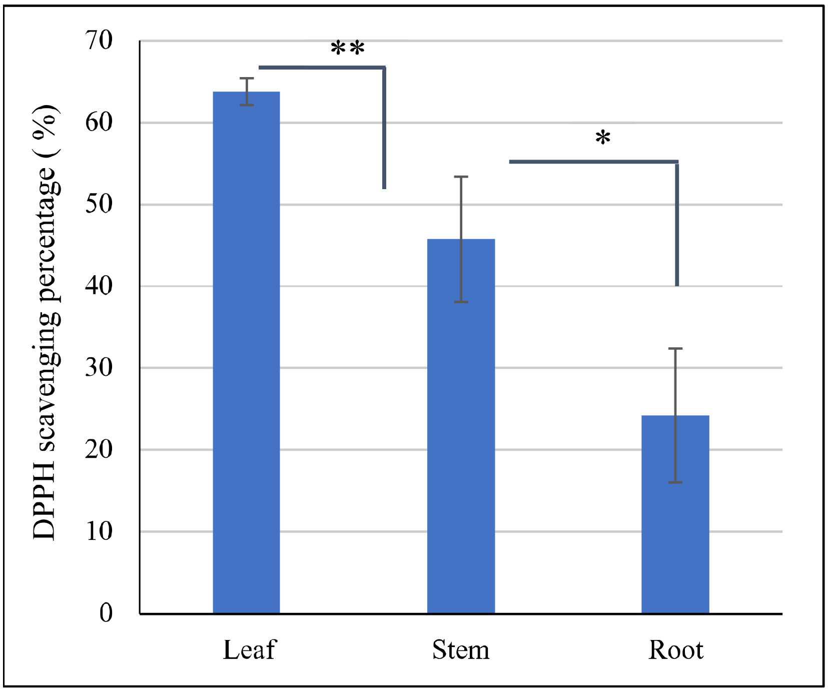

Fig. 5. % DPPH scavenging activity of extracts of different plant parts of Skunk vine. Error bars indicate the standard deviation (*n* = 3). Asterisks indicate significant difference (*$P < 0.05$, **$P < 0.01$; t-test).

Inhibition of α-glucosidase and α-amylase activity

Inhibition of digestive enzymes such as *α*-glucosidase and *α*-amylase reduce the amounts of monosaccharide, particularly glucose to be absorbed in the body. Medicinal plants have been considered as the potential source of inhibitor of those enzymes. Therefore, it was analyzed *α*-glucosidase and *α*-amylase inhibition efficiency of leaf and stem of Skunk vine and found positive responses of those plant parts to inhibit of those enzymes. Although, *α*-glucosidase activity was greatly inhibited by the extracts of both leaf and stem, leaf showed better performances than stem. At the concentration of 0.5 mg/mL and 1.5 mg/mL, the leaf extracts showed 39.64 and 59.13 % inhibition capacity of *α*-glucosidase activity which were higher than that of stem extracts which were 19.25 and 45.60% respectively (Fig. 6, a).

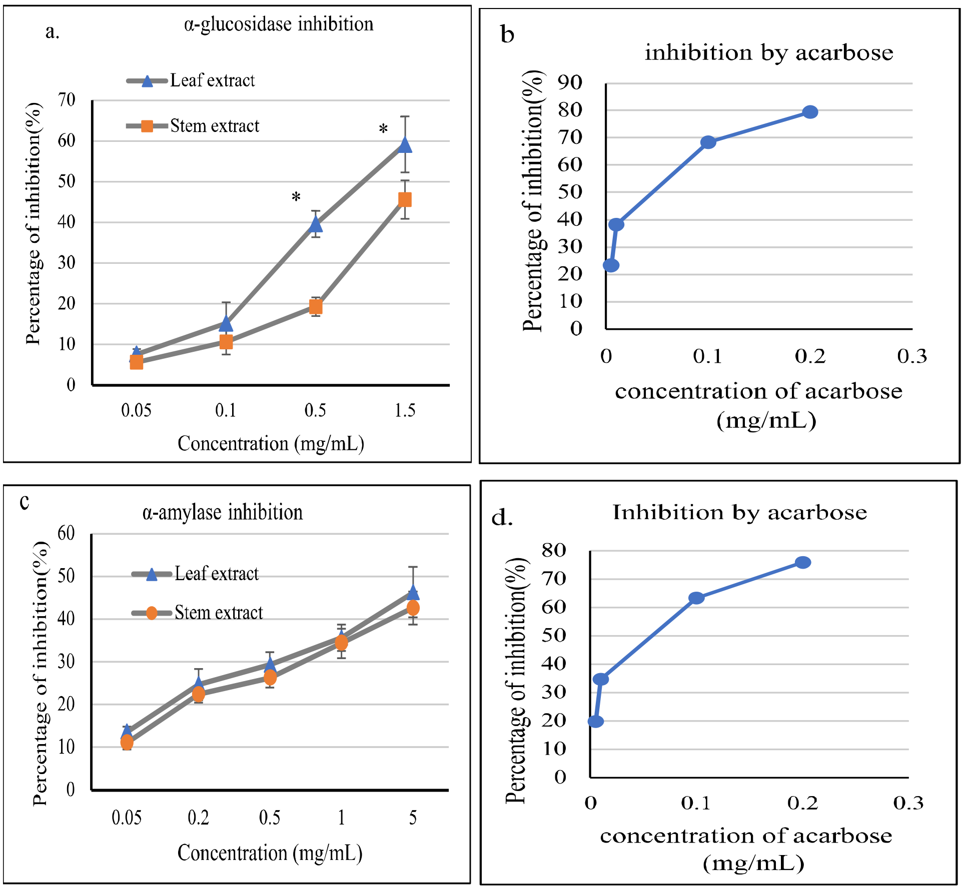

Fig. 6. ***α*-glucosidase and *α*-amylase enzyme inhibition efficiency of Skunk vine. % inhibition of α-glucosides activity by leaf and stem extracts (a) and acarbose (b). % inhibition of α- amylase activity by leaf and stem extracts (c) and acarbose (d). Error bars indicate the standard deviation (*n* = 3). Asterisk indicates significant difference (**P* < 0.05); t-test).**

The inhibition percentage was consistent to the positive control acarbose which showed up to 80% inhibition at the concentration level of 0.2 mg/mL (Fig. 6, b). In case of *α*-amylase activity, it was found more or less similar inhibition efficiency of leaf and stem extractswhich were 46.23 and 42.56%, respectively at the concentration level of 5 mg/mL (Fig. 6, c). The positive control acarbose showed about 76% inhibition which was consistent to the inhibition made by plant extracts (Fig. 6, d). Similar trend of results were reported in the leaf extract of Skunk vine by Bhatnagar and Sahoo (2016). Several studies reported the presence of antidiabetic role regarding inhibition of *α*-glucosidase and *α*-amylase enzymes in different medicinal plants (Tamil *et al*., 2010; Okoli *et al*., 2011; Mohammed and Atiku, 2012). Along with these, present results suggest that the medicinal plant Skunk vine has the potentials to inhibit *α*-glucosidase and *α*-amylase enzyme activity.

Conclusion

The plant parts of Skunk vine such as leaf, stem and root showed very good potentials of antioxidants. Leaf showed the best performance in the content of total phenolic, flavonoids, anthocyanins, carotenoids and exhibited highest antioxidant activity (DPPH scavenging ability). The leaf extract also showed higher inhibition of α-glucosidase and α-amylaseactivity. So, it can be concluded that, Skunk vine has both antioxidative and antidiabetic properties which may be considered as the valuable source of natural safe drug. However, further analysis by changing the extraction methods, assay techniques and application strategies towards animal model might clarify the future implication of this natural asset.

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References

Asem, I. D., R. K. Imotomba, P. B. Mazumder and J. M. Laishram. 2015. Anthocyanin content in the black scented rice (Chakhao): its impact on human health and plant defense. *Symbiosis*. **66**(1): 47-54.

Bhatnagar, S. and M. Sahoo. 2016. Cytotoxic and antidiabetic activity of leaf extracts of *Paederia foetida* L. *International journal of pharmacognosy and phytochemical research*. **8**(4): 659-662.

Bernfeld, P. 1955. α -Amylase and ß-Amylase.Methods in enzymology.Academic Press, NewYork. **1:** 149-158.

Biju, J., C.T. Sulaiman, G. Satheesh and V.R.K. Reddy. 2014. Total phenolic and flavonoids in selected medicinal plants from Kerala. *International Journal of Pharmacy and Pharmaceutical Sciences*. **6**: 406-408.

Chakrabarti, R. and R. Rajagopalan. 2002. Diabetes and insulin resistance associated disorders: Disease and the therapy. *Current Science*. **83**(12): 1533-1538.

Devi, U., T. I. Devi and T. C. Singh. 2016. Phytochemical screening on three traditional medical plants against piles. *International Journal of Research – Granthaalayah*. **4**(5): 99-105.

Harborne, J.B. 1988. The Flavonoids: Advances in research since 1980. Chapman and Hall Ltd, New York. 121.

He, J. and M.M. Giusti. 2010. Anthocyanins: natural colorants with health-promoting properties. *Annual Review of Food Science and Technology*. **1**(1):163-187.

Hughes, N.M. and W.K. Smith. 2007. Attenuation of incident light in Galaxurceolata (Diapensiaceae: concerted influence of adexial and abaxial anthocyanic layers on photoprotection. *American Journal of Botany*. **94**(5):784 -790.

Islam, A., M. I, U. Hoque, M. Ashrafuzzaman and M. N. Uddin. 2018. Leaf phenolics and pigments along with their antioxidative potential in some medicinal plants. Asian- *Australasian Journal of Food Safety and Security*. **2**(2): 86-92.

Khare, C.P. 2007. *Indian medicinal plants*. 459.

Kimmel, B. and S. Inzucchi. 2005. Oral agents for type 2 diabetes: An update. *Clincal Diabetes*. **23**(2): 64-76.

Lachman, J., K. Hamouz, A. Hejtmankova, J. Dudfak, M. Orsak and V. Pivec. 2003. Effect of white fleece on the selected quality parameters of early potato (*Solanum tuberosum*L.*)* tubers. *Plant Soil and Environment*. **49**(8): 370-377.

Laoufi, H., N. Benariba, S. Adjdir and R. Djaziri. 2017. Invitro α-amylase and α-glucosidase inhibitory activity of Ononis angustissima extracts. *Journal of Applied Pharmaceutical Science*. **7**(02): 191-198.

Mayne, S.T. 1996. Beta-carotene, carotenoids, and disease prevention in humans. *FASEB J*ournal. **10:** 690–701.

Mayur, B., S. Sandesh, S. Shruti and S. Sung-Yum. 2010. Antioxidant and α-glucosidase inhibitory properties of *Carpesium abrotanoides* L.. *Journal of Medicinal Plant Research*. **4**(15): 1547-1553.

Mazandarani, M., P. Zarghami Moghaddam, H. Baiat, M. R. Zolfaghari, E. A. Ghaemi and H. Hemati. 2011. Antioxidant activity, phenol, flavonoid and anthocyanin contents in various extracts of Onosma dichroanthum Boiss. in north of Iran. *Iranian Journal of Plant Physiology*. **1**(3): 169 - 176.

Mohammed, A. and M.K. Atiku. 2012. Antihyperglycemic and Antihyperglycemic effect of leaves and stem bark methanol extracts of *Senna siamea* in alloxan induced diabetic rats. *Current Research in Cardiovascular Pharmacology*. **1**: 10-17.

Nandkoni, K.M. 2002. Indian materia medica. Bombay Popular Prakashan, Mumbai. 892.

Nayak, R., A. Panda, L. Samanta and S. Sahoo. 2015. Characterization of antioxidant potential of Abutilon indicum L. and *Paederia foetida* L. *International Journal of Science, Technology & Management*. **4**(4): 95-104.

Okoli, C.O., I.C. Obidike, Ezike, P.A. Akah and O.A. Salawu. 2011. Studies on the possible mechanisms of antidiabetes activity of extract of aerial parts of *Phyllanthus niruri*. *Pharmaceutical Biology*. **49:** 248-255.

Osman, H., A.A. Rahim, N.M. Isa and N.M. Bakhir. 2009. Antioxidant activity and phenolic content of *P. foetida* and *syzygium aqueum*. *Molecules*. **14**: 970-978.

Reddy, K.N. and C.S. Reddy. 2008. First red list of medicinal plants of Andhra Pradesh, India-conservation assessment and management planning. *Ethnobotanical Leaflets*. **12**(1): 103-107.

Sahoo, M. and S. Bhatnagar. 2015. A comparative analysis of phytochemical and antioxidant profile of *P. foetida* L. wild and cultivated varieties. *World Journal of PharmaceuticalResearch*. **5**(1): 1329-1337.

Shai, L.J., P. Masoko, M.P. Mokgotho, S.R. Magano, A.M. Mogale, N. Boaduo and J.N. Eloff. 2010. Yeast alpha glucosidase inhibitory and antioxidant activities of six medicinal plants collected in Phalaborwa, South Africa. *South African Journal of Botany*. **76**(3): 465-470.

Singleton, L. and J. Rossi. 1965. Colorimetry of total phenolic with phosphomolybdic–phosphotungstic acid reagents. *American Journal of Enology and Viticulture*. **16**: 144-158.

Tamil, I.G., B. Dineshkumar, M. Nandhakumar, M. Senthilkumar and A. Mitra. 2010. *In vitro* study on the α-amylase inhibitory activity of an Indian medicinal plant, *Phyllanthus amarus*. *Indian Journal of Pharmacology*. **42**(5): 280–282.

Tarling, C.A., K. Woods, R. Zhang, H.C. Brastianos, G.D. Brayer, R.J. Andersen and S.G. Withers. 2008. The search for novel human pancreatic α-amylase inhibitors: high- throughput screening of terrestrial and marine natural product extracts. *Chembiochem*. **9:** 433-438.

Uddin, R., R. Akter, S. R. Hasan, E. H. Mazumder and M. A. Alam. 2014. In Vitro Free Radical Scavenging and Membrane Stabilizing Activity of *Paederia foetida* Leaves. *Journal of Pharmacology and toxicological studies*. **2**(1): 21-28.

Upadhya, S. 2013. Screening of phytochemicals, nutritional status, antioxidant and antimicrobial activity of *P. foetida* L. from different localities of Assam. *India. Journal of Pharmacy Research*. **7**: 139-141.

Xu, X., H. Xie, Y. Wang and X. Wei. 2010. A-Type proanthocyanidins from lychee seedsand their antioxidant and antiviral activities. *Journal of Agricultural and Food Chemistry*. **58**(22): 11667–11672.

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PERFORMANCE OF MANGO GERPLASM IN PATUAKHALI CONDITION

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N. AKHTAR[4] AND M. N. ISLAM[5]

Abstract

A study was conducted for four consecutive years from 2014 to 2917 at the Regional Horticultural Research Station (RHRS), Bangladesh Agricultural Research Institute (BARI), Lebukhali, Patuakhali. Six mango varieties, viz. BARI Aam-1, BARI Aam-2, BARI Aam-3, BARI Aam-4, BARI Aam-5, BARI Aam-8 developed by BARI and six popular cultivars Khirshapat, Langra, Mallika, Gopalbhog, Fazli and Pahutan were evaluation for their performance. The germplasm were planted in 2010. All the cultivars bloomed in 1st to 3rd week of February. Harvesting time ranged from 2nd week of May to 1st week of July and Gopalbhog and BARI Aam-4 were earlier while Fazli was late season cultivar. In the last year of study (2017), maximum number of fruits per plant was recorded 259 in BARI Aam-3 and minimum 11 in BARI Aam-1. Individual maximum fruit weight was 663.09g in BARI Aam-4 in 2016. Average, individual fruit weight ranged from 553.92 to 183.13g where Fazli was the maximum followed by 465.94g in BARI Aam-4. Minimum individual fruit weight was measured in BARI Aam-3. Total Soluble Solids percent (TSS%) ranged from 16.83 to 21 66% and BARI Aam-3 was maximum and BARI Aam-2 was minimum. Number of fruits per plant, individual fruit and sweetness (TSS%) of variety/and cultivar fluctuated in different year although the trend of results in the succeeding years was consistent.

Keywords: Mango variety, cultivar, growth behavior, fruiting, flowering.

Introduction

Mango production in Bangladesh is increasing day by day. According to Bangladesh Bureau of Statistics (BBS), the country has produced 1.2 million tons of mango from 95.16 thousand hectares of land in 2019-2020 (BBS, 2021). Good quality elite mangoes are produced in the north and north-western parts of Bangladesh. Mangoes grown in other parts of the country are mostly anonymous, propagated by seeds and quality is not as expected. Prevailing low temperature at flowering and fruit setting and warm to hot during fruiting favor the production of good quality mango in northern Bangladesh (Biswas et al., 2021). However, climate related changes has made mango cultivation possible

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in new areas of the country and the hilly areas in the south-east has become the new hot-spot for mango cultivation. In addition, existing varietal differences for their performances in wet and dry conditions will offer opportunities of expansion mango cultivation in more areas of Bangladesh particularly in the southern part (Rajan, 2016). This area consists of about 20 million hectares of arable lands of the country, enjoys a subtropical climate with high temperature, high humidity and heavy rainfall with occasionally gusty winds in April-September and less rainfall associated with moderately low temperature during October-March. Capacity to survive seasonal crops in this areas is largely irrelevant due to excessive soil salinity, inadequate irrigation facilities in dry season. Productivity of this area may be increased by introducing annual fruits in the production system. Mango might be one of the leading species for this region because of its wider climatic adaptation capability. Considering the aforesaid facts, the experiment was under taken with a view to evaluating the performance of elite mango cultivars and BARI developed varieties in southern region of Bangladesh.

Materials and methods

The study field was conducted at the Regional Horticultural Research Station (RHRS), Bangladesh Agricultural Research Institute (BARI), Lebukhali, Patuakhali Lebukhali, Patuakhali during 2014-2017. Geographical notation of the station is 22° 35" N latitude to 90° 31" E (Fig.1). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each plant was considered as a replication. Six BARI developed varieties BARI Aam-1, BARI Aam-2, BARI Aam-3, BARI Aam-4, BARI Aam-5, BARI Aam-8 and six commercial and exotic elite cultivars Pahutan, Khirshapat, Langra, Gopalbhog, Mollika and Fazli were included in this study. The saplings were planted on October, 2010 with a spacing of 8 m x 8 m. Regular training and pruning were done to provide good shape to the plants. Flowers were removed unto first three years to obtain a good plant vigor. Irrigation, fertilization and other intercultural operations were done as per recommended schedule by Chowdhury and Hossain (2013). Girth of the trunk was measured at a height of 15 cm from the ground level and canopy area was calculated following formula by Shaw (2005), such as $K = \pi ab$, where: K is projected crown area, a and b are the major and minor radius of the ellipse. Data on plant height, flowering and harvesting time, fruit weight, number of fruits per tree and TSS content were also recorded.

Fig. 1. Map of Patuakhali District

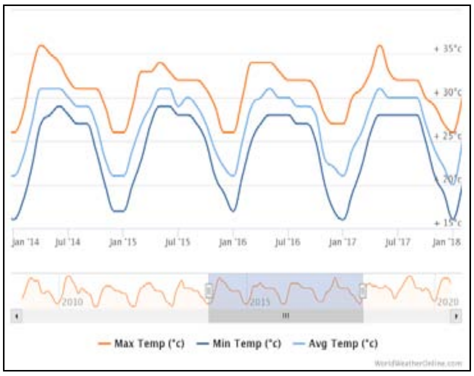

Fig. 2. Minimum and maximum temperature of Patuakhali during the study period

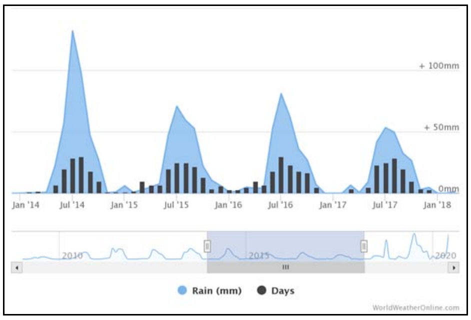

Fig. 3. Average rainfall in number of rainy days of Patuakhali during the study period

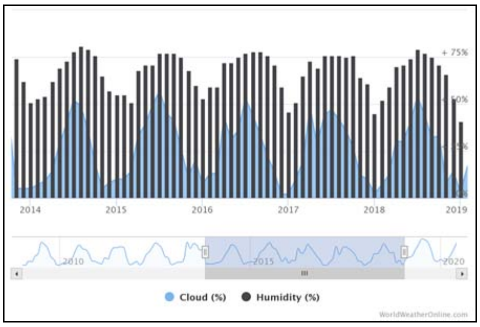

Fig. 4. Cloud and relative humidity (RH) of Patuakhali during the study period

Sources: [a] Google Map, [b] www.worldweatheronline.com

Results and Discussion

Physiography of the study location

Patuakhali is an administrative district in south-central part of Bangladesh, which is located at 22° 35" N latitude to 90° 31" E longitude with an altitude of 1.5 meter (Figure 1). The area falls under AEZ 13 which belongs to the Ganges tidal floodplain. Patuakhali enjoys a subtropical climate with high temperature, high humidity and heavy rainfall with occasionally gusty winds in April-September and less rainfall associated with moderately low temperature during October-March. The temperature, rainfall and relative humidity data during the study period are presented in figure 2-4. The whole area lies within the cyclone affected region and affected with tidal surge and medium to high salinity. Non-calcareous Grey Floodplain soil is the major component of general soil types (Ahmed and Hussain, 2009; BBS, 2021).

Flowering and harvesting time

A four year study revealed that flowering of genotypes under study occurred during 1st to 3rd weeks of February where BARI Aam-1 was consistently earlier. BARI Aam-4, BARI Aam-5, BARI Aam-8 and Pahutan flowered lately. Harvesting of fruits study started from 2nd week of May to 1st week of July and Gopalbhog was the earliest in all through the study years. In the 1st year of study it was observed that BARI Aam-1, Gopalbhog and Khirshapat were harvested in 1st week of June (earlier) while Fazli and Pahutan started harvesting in 1st week of July (Table 1). Although flowering and harvesting times of a particular variety found different from different years, the time intervals between different varieties were continued in every cropping season. Variation in air temperature, rainfall, number of rainy days, soil moisture might influence these sequences of phonological changes and harvesting period (Fig. 1-4). Rajan (2012) in a study of phonological response of mango to environmental changes similarly observed early or delay flowering in mango. Barua et al. (2013), Bally (2006) and Makhmale et al., (2016) also reported weather factors infuencing flowering and harvesting of mango.

Tree growth characteristics

Considering the plant height, trunk height, base girth and canopy area a rapid growth rhytm was observed among the genotypes. Tree stature of BARI Aam-8 was found bushy while BARI Aam-1, Mallika, Langra and BARI Aam-3 found taller (Table 2). However, oberved variations between the genotypes on tree stature and vegetative growth might be genetically determined (Rajan, 2012).

Fruit number, individual fruit weight and percent total soluble solids (TSS%) of pulp

BARI Aam-3 and BARI-Aam- 8 in the 1st year of study produced the highest number of fruits per plant. The lowest number of fruits per plant was recorded in BARI Aam-1 followed by Fazli, Gopalbhog and Khirshapat. No fruit was harvested in variety Mollica in the first year of study. It was observed that the number of fruits of the genotypes increased with increased of age of plant and the trend of fruit set between the genotypes was consistent in the succeeding years (Table 3).

Individual fruit weight ranged from 167g in BARI Aam-8 in 2014 to 663.09g in BARI Aam-4 in 2016. In an average, fruit weight 553.92g was measured maximum in Fazli followed by 465.94g in BARI Aam-4. Fruit weight 1883.13g in BARI Aam-3 was minimum (Table 3). It is to be noted that the weight of fruits of a particular variety/cultivar differed in different growing seasons. This variation might associated with climatic factors (Rajan et al., 2012). Normand et al., (2015) also explained that fruit size, shape, color and other qualitative traits are genetically controlled and which might be fluctuated by variability of growing environment.

Table 1. Flowering time and harvesting time of different mango cultivars/ varieties.

Variety	Flowering time				Harvesting time			
	2014	2015	2016	2017	2014	2015	2016	2017
BARI Aam-1	1st week of February	1st week of February	1st week of February	1st week of February	1st week of June	1st week of June	3rd week of May	1st week of June
BARI Aam-2	2nd week of February	2nd week of February	2nd week of February	2nd week of February	2nd week of June	2nd week of June	4th week of May	1st week of June
BARI Aam-3	2nd week of February	2nd week of February	2nd week of February	3nd week of February	3rd week of June	3rd week of June	1st week of June	3rd week of June
BARI Aam-4	3nd week of February	3nd week of February	3nd week of February	3nd week of February	4th week of June	4th week of June	3rd week of June	1st week of July
BARI Aam-5	3nd week of February	3nd week of February	3nd week of February	3nd week of February	1st week of June	1st week of June	4th week of May	4th week of May
BARI Aam-8	3nd week of February	3nd week of February	3nd week of February	3nd week of February	4th week of June	4th week of June	2nd week of June	3nd week of June
Gopalbhog	1nd week of February	2nd week of February	2nd week of February	2nd week of February	1st week of June	1st week of June	2nd week of May	3rd week of May
Pahutan	3nd week of February	2nd week of February	2nd week of February	2nd week of February	1st week of July	1st week of July	4th week of June	4th week of June
Mallika	2nd week of February	2nd week of February	1st week of February	2nd week of February	4rd week of June	4rd week of June	3nd week of June	3nd week of June
Langra	2nd week of February	2nd week of February	2nd week of February	2nd week of February	3rd week of June	3rd week of June	2nd week of June	2nd week of June
Fazli	2nd week of February	2nd week of February	2nd week of February	2nd week of February	1st week of July	1st week of July	1st week of July	1st week of July
Khirshapat	2nd week of February	1st week of February	2nd week of February	2nd week of February	1st week of June	1st week of June	3nd week of May	4th week of May

Table 2. Tree growth characteristics of different mango cultivars/ varieties.

Variety	Plant Height (cm)				Trunk height (cm)				Base girth (cm)				Canopy area (m^2)			
	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017	2014	2015	2016	2017
BARI Aam-1	283.30	346.67a-c	403.67b	491.00a	54.67de	73.70d-f	79.67de	82.00c	22.00d	31.33de	37.67f	40.67cd	3.51c	6.71de	10.37de	11.45ef
BARI Aam-2	275.00	316.00cd	410.67b	449.67a-d	45.67ef	53.30g	70.33e	71.00de	24.33d	36.00cd	44.67de	46.00bc	4.44b	8.35c	10.50c-e	12.31e
BARI Aam-3	266.70	346.67a-c	468.33a	470.67a-c	62.67cd	79.70de	100.67b	103.00b	22.33d	33.33de	57.67ab	63.33a	4.69b	11.24b	18.78a	20.37b
BARI Aam-4	193.30	268.67ef	316.33c	352.67e	71.00bc	82.30de	76.67e	82.67c	21.67d	29.33e	34.00f	44.00bc	2.76d	5.88ef	9.20ef	11.17ef
BARI Aam-5	273.00	366.67ab	429.33ab	433.00b-d	89.00a	107.00a	125.00a	162.67a	22.00d	29.66e	38.00ef	44.33bc	2.82d	4.33g	13.50b	17.74c
BARI Aam-8	286.70	318.33cd	405.00b	481.67ab	73.33b	85.30b-d	87.33cd	94.33b	30.00c	39.33c	54.67a-c	59.33a	6.92a	11.44b	16.99a	23.75a
Gopalbhog	226.00	336.67bc	310.00c	341.33e	43.33f	94.70b	70.33e	79.67cd	34.67bc	39.00c	49.67cd	50.67b	2.83d	6.42e	9.96ce	10.96ef
Pahutan	231.70	253.33f	398.33b	427.33cd	42.33f	70.70ef	52.00f	69.00e	23.67d	31.66de	41.33ef	44.00bc	3.17c	5.58ef	11.96b-d	15.44d
Mallika	225.00	250.00f	453.67a	474.33a-c	38.00fg	84.50cd	51.00f	57.00f	22.43d	28.00e	34.00f	36.67d	2.99cd	5.00fg	17.32a	18.87bc
Langra	312.00	340.00bc	401.67b	461.33a-d	85.00a	97.30ab	94.33bc	98.33b	41.67a	45.66a	57.00ab	61.33a	4.88b	11.14b	18.80a	19.67b
Fazli	292.50	376.67a	392.00b	419.67d	31.33g	65.50f	56.00f	64.67ef	39.50ab	50.33a	61.33a	63.00a	4.43b	12.67a	12.31bc	14.38d
Khirshapat	264.70	293.33de	323.33c	345.33e	69.33bc	78.30d	91.00bc	94.00b	30.00c	33.33de	44.67de	46.67bc	3.55c	7.83cd	7.85f	9.67f
Level of Sig.	ns	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
CV (%)	17.53	14.92	11.40	11.95	15.78	14.42	11. 28	11.04	17.49	14.30	14.09	12.80	o.64	1.16	1.85	1.81

Table 3. Fruit number, fruit weight and TSS of different mango cultivars/ varieties.

Variety	Fruit Number plant^{-1}					Average Fruit Weight (g)					TSS (%)				
	2014	2015	2016	2017	Average	2014	2015	2016	2017	Average	2014	2015	2016	2017	Average
BARI Aam-1	5.00g	5.66f	19.33f	10.67f	10.17	208.50ef	220.00ef	145.83h	285.67cd	215.00	18.50c-e	18.00cd	-	16.33b	17.61
BARI Aam-2	29.67e	48.66c	99.67c	48.33e	56.58	245.00cd	244.00e	233.34ef	204.00e	231.59	17.25de	17.00d	-	16.25b	16.83
BARI Aam-3	58.33a	186.67a	394.67a	395.00a	258.67	174.00gh	183.00g	186.50g	189.00e	183.13	22.33a	23.33a	-	19.33a	21.66
BARI Aam-4	36.33d	49.00c	79.00d	102.00c	66.58	264.00bc	409.00b	663.09a	527.67a	465.94	20.65ab	21.50ab	-	18.65a	20.27
BARI Aam-5	45.85c	12.00e	13.33g	39.67e	27.71	193.00fg	184.00g	198.00fg	312.67c	221.92	19.30bc	18.25cd	-	18.25ab	18.60
BARI Aam-8	53.00ab	96.66b	193.00b	196.00b	134.67	167.00h	208.00fg	180.55g	260.00d	203.89	20.00bc	20.00bc	-	18.00ab	19.33
Gopalbhog	23.00ef	12.00e	42.33e	93.67c	42.75	232.00de	244.00e	174.39gh	252.00d	225.60	16.72e	16.72d	-	18.76a	17.40
Pahutan	33.67de	48.33c	46.67e	76.67d	51.34	259.90bc	340.20c	355.00c	389.67b	336.19	19.15b-d	19.15c	-	17.72ab	18.67
Mallika	0.00h	0.00g	26.67f	66.67d	23.34	-	-	294.00d	393.67b	343.84	-	-	-	18.68a	18.86
Langra	46.00bc	10.00e	6.00g	74.67d	34.17	275.00b	283.00d	287.56d	289.00cd	283.64	21.43a	21.50ab	-	19.68a	20.87
Fazli	19.50f	10.00e	16.00fg	19.33f	16.21	650.00a	554.00a	523.00b	488.67a	553.92	18.76b-e	18.00cd	-	17.68ab	18.15
Khirshapat	23.67ef	22.00d	47.00e	86.67c	44.84	198.00fg	337.00c	239.15e	274.33cd	262.12	18.68c-e	18.28cd	-	19.15a	18.70
Level of Sig.	**	**	**	**	-	**	**	**	**	-	**	**	-	**	-
CV (%)	20.07	16.05	13.11	15.47	-	10.07	11.05	13.11	12.70	-	10.07	11.05	-	14.47	-

Table 4. Yield data of different mango cultivars/ varieties

Variety	Fruit Yield per Plant (kgPlant^{-1})					Fruit Yield per Unit Canopy Area (kg m^{2})				
	2014	2015	2016	2017	Average	2014	2015	2016	2017	Average
BARI Aam-1	1.04 c	1.25 d	2.82 fg	2.99 d	2.02	0.30i	0.19j	0.27g	0.26h	0.25
BARI Aam-2	7.27 bc	11.71 c	23.26 d	9.74 d	12.99	1.64f	1.40d	2.21c	0.79gh	1.51
BARI Aam-3	10.18 ab	34.22 a	63.61 a	74.57 a	45.64	2.17e	3.04b	3.39b	3.66b	3.06
BARI Aam-4	9.59 ab	20.00 b	52.38 b	53.77ab	33.93	3.47b	3.40a	5.69a	4.81a	4.34
BARI Aam-5	8.85 ab	2.21 d	2.64 fg	11.20 d	6.22	3.13c	0.51f	0.20g	0.63gh	1.12
BARI Aam-8	8.75 ab	20.11 b	34.85 c	50.64a-c	28.59	1.26g	1.76c	2.05c	2.13cd	1.80
Gopalbhog	12.65 a	2.93 d	7.38 f	23.58 cd	11.63	4.46a	0.46f	1.66d	2.72c	2.33
Pahutan	8.75 ab	16.32 bc	16.57 de	29.87b-d	17.88	2.76d	2.92b	0.94e	1.54ef	2.04
Mallika	0.0 d	0.0 e	7.84 f	26.08b-d	8.48	0.00j	0.00k	0.48f	0.51h	0.25
Langra	12.68 a	2.83 d	1.73 g	21.83 cd	9.77	2.60d	0.25fj	0.09g	1.11fg	1.01
Fazli	4.69 c	5.54 d	8.37 f	9.61 d	7.05	1.06h	0.44f	0.60f	1.64de	0.93
Khirshapat	5.34 bc	7.41 d	11.24 ef	23.85 cd	11.96	1.50f	0.95e	1.00e	2.70c	1.54
Level of Sig.	**	**	**	**	-	**	**	**	**	-
CV (%)	10.07	11.05	13.11	34.47	-	10.07	11.05	13.11	34.47	-

Percent of total soluble solid (TSS%) is the measure of the sweetness of fruits. TSS% of fruits of genotypes ranged from 16.72 to 23.33% during the study period. Minimum TSS% was recorded in Gopalbhog while it was maximum in BARI Aam-3 in harvesting season of 2015. Like fruit weight, it and was also observed that TSS% of individual variety fluctuated in different years (Table 3). Barua (2013) and Kobra et al., (2013) similarly reported fluctuation in fruit weight, fruit size and TSS% of same variety in different locations and different years. This variation might be correlated to environmental variables which are either spatial or temporal issues (Normand et al., 2015). However, overall performance of the genotypes in southern region was not found as per expectation (Sarkar et al., 2021). Similar findings were obtained from the reports of Barua (2013) and Kobra et al., (2013).

Fruit yield per plant and per unit canopy Area

At the onset of the study fruit yield per plant was measured maximum in Langra which was similar to Gopalbhog. Statistically similar yields were also measured in BARI-Aam-3, BARI Aam-5, BARI-Aam-8, BARI Aam-4 and Pahutan. Yield of fruit of individual plant was found to increase in the succeeding cropping seasons. Consistently higher yield per plant was recorded in BARIAam-3 and BARI Aam-4. Regarding fruit yield per unit area, BARI Aam-4 and BARI Aam-3 also performed better than other genotypes (Table 4). Like number of fruits, per plant yield was also fluctuated in different years due to prevailing growing environmental factors.

Conclusion

It is not possible to draw a conclusion on the basis of the findings of current study. Performance of the genotypes should be further evaluated considering regional and seasonal variability as well as soil and water salinity. However, BARI Aam-3, BARI Aam-4 and BARI Aam-8 may be considered capable to cope with the stress environment of the southern region on the basis of yield potentials and quality attributes.

References

Ahmed, A. U. and S. G. Hussain. 2009. Climate Change And Livelihoods: An Analysis of Agro-Ecological Zones of Bangladesh. Centre for Global Change, Dhaka.

Bally, I.S., 2006. *Mangifera indica* (mango). Species profiles for pacific island agroforestry, Permanent Agriculture Resources (PAR), Holualoa, Hawai. pp.1-25.

Barua, H., M. M. A. Patwary and M. H. Rahman. 2013. Performance of BARI Mango (*Mangifera Indica* L.) varieties in chittagong region. *Bangladesh J. Agril. Res.* **38**(2): 203–209.

BBS. 2021. Yearbook of Agricultural Statistics-2020. Bangladesh Bureau of Statistics (BBS) Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh. pp 198-199.

Biswas J.C; M**.** Maniruzzaman; M. M. Haque; M. B. Hossain; A.H N. Kalra. 2021. Major fruit crops production in Bangladesh and their relationships with socio-ecological vulnerabilities. *Journal of Food Science and Nutrition Research*. **4** (2021): 131-143.

Chowdhury, M. A. H. and M. S. Hassan (Eds.). 2013. Hand Book Of Agricultural Technology. Bangladesh Agricultural Research Council (BARC), Dhaka. pp. 107-113.

Kobra, K., M. Hossain, M. Talukder and M. Bhuyan. 2013. Performance of Twelve Mango Cultivars Grown in Different Agroecological Zones of Bangladesh. *Bangladesh J. Agril. Res.* **37**(4): 691–710.

Makhmale, S., P. Bhutada, L. Yadav and B.K. Yadav. 2016. Impact of Climate Change on Phenology of Mango-The Case Study. Ecology. *Environ. and Conservation.* **22**(9): 127–132.

Normand F., P. E. Lauri., J. M. Legave. 2015. Climate change and its probable effects on mango production and cultivation. Acta Horticulturae (1075):21-32

Rajan S. 2012. Phenological Responses to Temperature and Rainfall: A Case Study of Mango. Chapter. In Tropical Fruit Tree Species and Climate Change. Division of Crop Improvement and Biotechnology, Central Institute for Sub-tropical Horticulture, Lucknow, India. Pp. 71-96.

Sarker B. C; M. N. Islam; J. C. Barman; M. Islam; M. S. Uddin; 2021. Amer Jat O Adhunik Utpadan Projukti. (Mango Variety and Modern Cultivation Technique). Fruit Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur. Pp 190.

Shaw, J. D. 2005. Models for Estimation and Simulation for Crown and Canopy Cover. Proceedings of the Fifth Annual Forest Inventory and Analysis Symposium; 2003 November 18-20; New Orleans, La. Gen. Tech. Rep. Wo-69. Washington, Dc: U.S. Department of Agriculture Forest Service. **69:** 183–191.

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FERTILIZER MANAGEMENT OF GYPSOPHILA (*Gypsophila paniculata*)

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Abstract

A field experiment was conducted at the research field of Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) Gazipur under AEZ-28 during Rabi season of 2017-18 and 2018-19 to determine the suitable combination of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) for improving growth and cut flower bunch yield of gypsophila. There were 15 treatment combinations comprising four levels of nitrogen (0, 70, 100 and 130 kg ha^{-1}), four levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}), four levels of potassium (0, 60, 90 and 120 kg ha^{-1}) and four levels of sulphur (0, 10, 20 and 30 kg ha^{-1}) along with a blanket dose of $Zn_3B_{1.5}$ kg ha^{-1} and cow dung 5 t ha^{-1}. The experiment was laid out in randomized complete block design with three replications. The combination of $N_{100}P_{40}K_{60}S_{20}$ kg ha^{-1} produced significantly higher cut flower bunch yield. The said treatment produced the maximum mean cut flower bunch yield of 185010 nos. ha^{-1} which was 76.9% higher over control ($N_0P_0K_0S_0$). The maximum number of branches per plant (7.12 nos.) and maximum opened flower per plant (60.2 nos.) were recorded from the treatment combination of $N_{100}P_{40}K_{60}S_{20}$ kg ha^{-1}. Cost and return analysis indicated maximum net return and highest benefit cost ratio (1.91) was estimated from the same treatment. The results suggest that combined application of 100-40-60-20 kg ha^{-1} of N-P-K-S including 3 kg Zn ha^{-1}, 1.5 kg B ha^{-1} and 5 t ha^{-1} cowdung can improve the growth and cut flower bunch yield of gypsophila. From the regression analysis, the optimum treatment combination was calculated as $N_{91.8}P_{44.0}K_{80.7}S_{18.7}$ kg ha^{-1} for experimental area. Therefore, the optimum combination package $N_{91.8}P_{44.0}K_{80.7}S_{18.7}$ kg ha^{-1} along with the blanket dose of $Zn_3B_{1.5}$ kg ha^{-1} and 5 t cowdung ha^{-1} may be recommended for gypsophila cut flower cultivation in Gazipur area.

Keywords: Gypsophila, NPKS, cut flower, bunch yield, fertilizers, B:C ratio

Introduction

Gypsophila (*Gypsophila paniculata* L.) is an important common flower under 'Caryophyllaceae' family found in Eurosia, Africa, Australia, Iran and the Pacific Islands. Most of the gypsophila species are concentrated in Turkey, Caucasia, northern Iraq and northern Iran (Özdemir *et al*., 2010). The genus name is from the Greek gypsos (gypsum, calc) and philos (loving). Plants of the genus are known as baby's breath and used as cut flower to add as a filler to flower bouquets. A few species of gypsophila are commercially cultivated for several

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uses, including floristry, herbal medicine and food (Korkmaz and Özçelik, 2011). It is generally used as cut flower and has gained a great economic value in trade because of its prettiness (Wahome *et al.*, 2011; Petry, 2008). Gypsophila has also become an important commercial ornamental crop in Bangladesh. As a new crop, farmers of Bangladesh are hardly known about its cultivation technique. It is reported that gypsophila is highly exhaustive and responsive to inorganic fertilizers like N, P, K and S. Fertilizer contributes to achieve a high yield of crops (Dass and Mandal, 2016). Balanced doses of inorganic fertilizer improve the flower quality, growth performance and yield of many ornamental crops (Ahmed *et al*., 2017). Therefore, the present study was undertaken to determine the dose of nitrogen, phosphorus, potassium and sulphur for improving the growth and yield maximization of gypsophila.

Materials and Methods

A field experiment was conducted during Rabi season of two consecutive years 2017-18 and 2018-19 at the research field of Floriculture division under Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI) Gazipur. Initial nutrient statuses of the experimental plot are presented in Table 1. The initial soil (0-15 cm depth) sample of experimental plot was analyzed as outlined by Page *et al*. (1982). Weather data of Gazipur during the experimental period (2017-18 and 2018-19) are presented in Table 2.

Table 1. Initial soil nutrient status of the experimental site

Nutrient	Soil test value	Critical level	*Soil test interpretation
pH	6.5	-	Slightly acidic
Organic matter (%)	1.20	-	Low
Total N (%)	0.061	0.12	Very low
K (meq/100 g soil)	0.13	0.12	Low
Available P (ppm)	12.2	7	Medium
S (ppm)	12.5	10	Low
Zn (ppm)	0.73	0.6	Low
B(ppm)	0.17	0.2	Low

*Anonymous (2018)

Table 2. Weather data during the experiment period

Months	Avg. Temperature (°C)				Avg. Humidity (%)		Rainfall (mm)	
	2017-18		2018-19		2017-18	2018-19	2017-18	2018-19
	Min.	Max.	Min.	Max.				
November	18.1	30.8	18.5	24.0	80.9	78.6	88.6	90.0
December	15.2	26.9	20.5	26.7	84.1	76.4	92.1	91.0
January	13.2	23.9	13.1	23.7	76.6	80.5	0.0	29
February	15.3	29.0	14.3	28.1	70.3	71.3	18	88
March	19.6	33.2	18.8	31.2	68.7	70.6	29	21

Source: Weather centre, BARI, Gazipur

There were 15 treatment combinations comprising each of four levels of nitrogen (0, 70, 100 and 130 kg ha^{-1}), phosphorus (0, 20, 40 and 60 kg ha^{-1}), potassium (0, 60, 90 and 120 kg ha^{-1}) and sulphur (0, 10, 20 and 30 kg ha^{-1}) along with a blanket dose of $Zn_3B_{1.5}$ kg ha^{-1} and cow dung 5 t ha^{-1}over the treatments.

The treatment combinations were $T_1=N_0P_0K_0S_0$, $T_2=N_0P_{40}K_{90}S_{20}$, $T_3=N_{70}P_{40}K_{90}S_{20}$, $T_4=N_{100}P_{40}K_{90}S_{20}$, $T_5=N_{130}P_{40}K_{90}S_{20}$, $T_6=N_{100}P_0K_{90}S_{20}$, $T_7=N_{100}P_{20}K_{90}S_{20}$, $T_8=N_{100}P_{60}K_{90}S_{20}$, $T_9=N_{100}P_{40}K_0S_{20}$, $T_{10}=N_{100}P_{40}K_{60}S_{20}$, $T_{11}=N_{100}P_{40}K_{120}S_{20}$, $T_{12}=N_{100}P_{40}K_{90}S_0$, $T_{13}=N_{100}P_{40}K_{90}S_{10}$, $T_{14}=N_{100}P_{40}K_{90}S_{30}$ and $T_{15}=N_{130}P_{60}K_{120}S_{30}$ kg ha^{-1}. The experiment was laid out in randomized complete block design with three replications. The unit plot size was 3.7 m × 1.5 m. The blanket doses of Zn and B containing fertilizers as zinc sulphate and boric acid and decomposed cow dung were applied during final land preparation. Sources of N, P, K and S were urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum, respectively. Treatment wise 1/3 amount of urea, full of TSP, ½ of MoP, and full of gypsum were applied after final bed preparation while 2/3 of Urea and half of MoP was applied in two equal splits. First split was applied at 20 days after sowing (DAS) and second split was applied at 35 DAS. Seeds of gypsophila (BARI Gypsophila-1) were sown @ 2.5 kg ha^{-1} with a spacing of 25 cm × continuous on 30 November 2017 and 28 November 2018.

Weeding, irrigation and plant protection measures were taken as and when required. Data on growth and yield attributes were recorded from randomly selected 10 plants from each unit plot. Leaf chlorophyll content (SPAD value) was measured by a soil-plant analysis development (SPAD) chlorophyll meter (model: SPAD-502 plus, manufactured by Konica Minolta, Tokyo, Japan) after 45 days of sowing. The cut flower was harvested from two rows of each plot at 66 DAS. The eight to ten cut flowers together were made single flower bunch. Number of cut flower bunch size was made based on the number branches per plant. The bunch yield was converted into number of bunch per plot. Cut flower bunch yield per plot was converted into number of bunch ha^{-1}. Collected data were subjected to statistical analysis of variance (ANOVA) according to Statistix 10 software (www.statistix.com). The means of each treatment were compared using the least significant difference (LSD) test at significant level $p \leq 0.05$ (Statistix-10, 1985). The optimum dose of nitrogen, phosphorus, potassium and sulphur was calculated using the formula: $Y = -b/2c$ (Gomez and Gomez, 1984). Benefit cost ratio (BCR) was calculated for a hectare of land. Treatment wise management cost was calculated by adding the cost incurred for labours, plowing, irrigation and inputs of each treatment. The number of flower bunch (yield) of gypsophila was converted numerical ha^{-1}. This yield was utilized to calculate the gross return. The shadow prices (land rent, straw cost etc.) were not considered. The gross return was measured by multiplying the marketable unit price of flower bunch. Net return was calculated by subtracting management cost from gross return. Benefit cost ratio was calculated the gross return divided by the management cost.

Results and Discussion

Growth and cut flower yield contributing characters of gypsophila

The highest plant height (50.7 cm in 2017-18 and 52.3 cm in 2018-19) was recorded from the treatment T_8 in 2017-18 which was significantly different over the other treatments but statistically identical to T_{10}, T_7 and T_{13} treatments. The result was consistent in 2018-19 (Table 3). Ayemi *et al.* (2017) corroborated the similar result in gerbera. The primary branches per plant varied from 4.91 to 7.14 across the treatments where maximum number of primary branches per plant was noted from the treatment T_{10} followed by T_8, T_{13} and T_{14}. The results were consistent in both consecutive years (Table 3). The lowest plant height and minimum branches per plant were found in control T_1 (Table 3). The highest stem diameter of gypsophila 3.40 cm in 2017-18 was recorded significantly in T_8 treatment and lowest was in control T_1. Comparable trend in result was noted in 2018-19 (Table 3). Similar trend of plant growth was recorded in marigold (Sharma *et al*., 2017) and tulip (Khan *et al*., 2006).

Maximum number of internode per plant (7.57) was found in treatment T_{10} followed by T_5, T_{11}, T_4 and T_{14} treatments in 2017-18. The trend was followed in the 2nd year trial (Table 4). The increased internode length was found in T_8 treatment in 2017-18 which resembled with T_5 treatment in both the years and lesser internode length was in control T_1 (Table 4). As comparison to the growth of control (T_1) it can be assessed that NPK and S stimulated the nodal growth. Similar report was presented by Khan *et al.* (2012). Number of opened flower per plant varied from 33.5 to 59.4 among the treatments in the year 2017-18 where the maximum number was recorded from T_{10} followed by T_8, T_7 and T_{11} treatments. Similar trend in result was noticed in 2018-19 (Table 4). The result is in agreement with the findings of Senapati *et al*. (2020) in chrysanthemum and Sultana *et al.* (2006) in tuberose who reported that maximum number flowers per plant were obtained in combined application of fertilizers N, P and K.

Number of unopened flowers per plant, flower diameter and chlorophyll contents were found almost similar trend and influenced significantly by the application of different doses of N, P, K and S fertilizers. Their trends were consistent in both the years (Table 5). The results are in agreement with the findings of Ahmed *et al*. (2017).

Cut flower bunch yield of gypsophila

Maximum Cut flower bunch yield 180020 nos. ha^{-1} in 2017-18 was recorded from the treatment T_{10} which was identical to that of T_{15}, T_{13}, T_{14}, T_{11} and T_8 treatments. The trend in result was similar in 2018-19 (Table 6). Similarly Senapati *et al*. (2020), Ghaffoor *et al*. (2000) and Khan et al. (2006) reported maximum flower yield in chrysanthemum, rose and tulip. In the experiment, the highest bunch yield increment over control (76.9%) was calculated from T_{10} treatment and the lowest increment was from T_2 treatment (Table 6).

Table 3. Effect of nitrogen, phosphorus, potassium and sulphur on growth and yield contributing characters of gypsophila

Treatment	Plant height (cm)			No. of primary branch plant^{-1}			Stem diameter (cm)		
N-P-K-S (kg ha^{-1})	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
$T_1=N_0P_0K_0S_0$	33.7f	34.5f	34.1	4.91f	5.11e	5.01	2.48g	2.52h	2.50
$T_2=N_0P_{40}K_{90}S_{20}$	37.5ef	38.4e	38.0	5.65e	6.02d	5.84	2.94ef	2.96efg	2.95
$T_3=N_{70}P_{40}K_{90}S_{20}$	40.2de	41.5de	40.9	6.23cde	6.23d	6.23	3.09cde	3.09c-f	3.09
$T_4=N_{100}P_{40}K_{90}S_{20}$	40.8de	42.0de	41.4	6.51a-d	6.51bcd	6.51	3.30ab	3.32ab	3.31
$T_5=N_{130}P_{40}K_{90}S_{20}$	44.4bcd	45.0cd	44.7	6.41bcd	6.40cd	6.41	3.27abc	3.27abc	3.27
$T_6=N_{100}P_0K_{90}S_{20}$	44.8bcd	46.0bc	45.4	6.18de	6.18d	6.18	2.89ef	2.91fg	2.90
$T_7=N_{100}P_{20}K_{90}S_{20}$	48.4ab	49.1ab	48.8	6.67a-d	6.81abc	6.74	3.08cde	3.16b-e	3.12
$T_8=N_{100}P_{60}K_{90}S_{20}$	50.7a	52.3a	51.5	6.85ab	6.97ab	6.91	3.40a	3.42a	3.41
$T_9=N_{100}P_{40}K_0S_{20}$	42.5cd	44.2cd	43.4	6.36bcd	6.39cd	6.38	2.81f	2.83g	2.82
$T_{10}=N_{100}P_{40}K_{60}S_{20}$	48.8ab	50.4a	49.6	7.09a	7.14a	7.12	3.31ab	3.35ab	3.33
$T_{11}=N_{100}P_{40}K_{120}S_{20}$	42.5cd	42.8cd	42.7	6.31bcd	6.42cd	6.37	3.17bcd	3.16b-e	3.17
$T_{12}=N_{100}P_{40}K_{90}S_0$	43.2cd	42.9cd	43.1	6.27b-e	6.26d	6.27	2.79f	2.80g	2.80
$T_{13}=N_{100}P_{40}K_{90}S_{10}$	46.2abc	45.9bc	46.1	6.87ab	6.85abc	6.86	3.28abc	3.30ab	3.29
$T_{14}=N_{100}P_{40}K_{90}S_{30}$	42.4cd	41.8de	42.1	6.84abc	6.85abc	6.85	3.23a-d	3.24a-d	3.24
$T_{15}=N_{130}P_{60}K_{120}S_{30}$	41.3de	42.1de	41.7	6.36bcd	6.34cd	6.35	3.03de	3.06def	3.05
CV (%)	6.44	4.87	-	5.78	5.05	-	3.99	4.05	-
LSD (0.05)	4.65	3.58	-	0.62	0.54	-	0.21	0.21	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$)

Table 4. Effect of nitrogen, phosphorus, potassium and sulphur on growth and yield contributing characters of gypsophila

Treatment N-P-K-S (kg ha^{-1})	No. of internodes plant^{-1}			Internode length (cm)			No. of opened flower plant^{-1}		
	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
$T_1=N_0P_0K_0S_0$	5.18fg	5.82h	5.50	4.15i	4.18f	4.17	33.5e	36.3g	34.9
$T_2=N_0P_{40}K_{90}S_{20}$	6.34d-g	6.36e-h	6.35	4.67h	4.72e	4.70	45.0cd	45.9def	45.5
$T_3=N_{70}P_{40}K_{90}S_{20}$	6.79a-e	6.81b-f	6.80	5.13g	5.16d	5.15	45.1cd	45.8ef	45.5
$T_4=N_{100}P_{40}K_{90}S_{20}$	7.30abc	7.31a-d	7.31	6.32bcd	6.30c	6.31	44.0d	44.9f	44.5
$T_5=N_{130}P_{40}K_{90}S_{20}$	7.51a	7.48ab	7.50	6.76a	6.77a	6.77	43.2d	44.2f	43.7
$T_6=N_{100}P_0K_{90}S_{20}$	6.58c-f	6.60d-g	6.59	6.26c-f	6.30bc	6.28	44.2d	45.4f	44.8
$T_7=N_{100}P_{20}K_{90}S_{20}$	6.64b-e	6.71c-f	6.68	6.37bc	6.42bc	6.40	54.4ab	54.5abc	54.5
$T_8=N_{100}P_{60}K_{90}S_{20}$	7.05a-d	7.06b-e	7.06	6.86a	6.87a	6.87	59.1a	59.7ab	59.4
$T_9=N_{100}P_{40}K_0S_{20}$	5.76g	5.88gh	5.82	5.15g	5.34d	5.25	52.5abc	53.1b-e	52.8
$T_{10}=N_{100}P_{40}K_{60}S_{20}$	7.57a	7.86a	7.72	6.18c-f	6.73a	6.46	59.4a	60.9a	60.2
$T_{11}=N_{100}P_{40}K_{120}S_{20}$	7.41ab	7.40abc	7.41	6.28cde	6.36bc	6.32	54.5a	58.8ab	56.7
$T_{12}=N_{100}P_{40}K_{90}S_0$	6.05efg	6.13fgh	6.09	6.14def	6.22c	6.18	48.1bcd	48.7c-f	48.4
$T_{13}=N_{100}P_{40}K_{90}S_{10}$	6.90a-d	6.93b-e	6.92	6.52b	6.59ab	6.56	52.5abc	53.2bcd	52.9
$T_{14}=N_{100}P_{40}K_{90}S_{30}$	7.29abc	7.30a-d	7.30	6.10ef	6.17c	6.14	52.6abc	53.4bc	53.0
$T_{15}=N_{130}P_{60}K_{120}S_{30}$	6.47d-g	6.48e-h	6.48	6.05f	6.14c	6.10	48.8bcd	49.6c-f	49.2
CV (%)	6.97	6.68	-	2.19	2.90	-	9.51	8.75	-
LSD (0.05)	0.79	0.76	-	0.22	0.29	-	7.81	7.35	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$)

Table 5. Effect of nitrogen, phosphorus, potassium and sulphur on yield contributing characters of gypsophila

Treatment	No. of unopened flower plant^{-1}			Flower diameter (cm)			Chlorophyll (SPAD)		
N-P-K-S (kg ha^{-1})	2017-18	2018-19	Mean	2017-18	2018-19	Mean	2017-18	2018-19	Mean
$T_1=N_0P_0K_0S_0$	26.1h	26.7h	26.4	0.57i	0.58j	0.58	37.2f	36.6e	36.9
$T_2=N_0P_{40}K_{90}S_{20}$	34.0efg	34.7ef	34.4	0.75h	0.76i	0.76	35.8f	36.1e	36.0
$T_3=N_{70}P_{40}K_{90}S_{20}$	35.8e	36.1de	36.0	0.81g	0.82h	0.82	43.2de	43.7bcd	43.5
$T_4=N_{100}P_{40}K_{90}S_{20}$	38.4d	38.7d	38.6	0.89cde	0.89c-f	0.89	45.7bcd	46.3bcd	46.0
$T_5=N_{130}P_{40}K_{90}S_{20}$	31.7g	32.1g	31.9	0.85ef	0.86e-h	0.86	50.0a	51.5a	50.8
$T_6=N_{100}P_0K_{90}S_{20}$	28.0h	28.6h	28.3	0.84fg	0.84fgh	0.84	47.3b	46.6bcd	47.0
$T_7=N_{100}P_{20}K_{90}S_{20}$	35.5ef	36.2de	35.9	0.92bcd	0.93bcd	0.93	46.0bcd	46.5bcd	46.3
$T_8=N_{100}P_{60}K_{90}S_{20}$	33.2fg	33.5fg	33.4	0.93bc	0.94bc	0.94	47.0bc	47.3bc	47.2
$T_9=N_{100}P_{40}K_0S_{20}$	36.0de	36.6de	36.3	0.89de	0.88d-g	0.89	43.5de	43.8bcd	43.7
$T_{10}=N_{100}P_{40}K_{60}S_{20}$	41.3c	41.9c	41.6	0.95b	0.96ab	0.96	47.9ab	47.8ab	47.9
$T_{11}=N_{100}P_{40}K_{120}S_{20}$	33.1fg	34.1efg	33.6	0.92bcd	0.92bcd	0.92	43.9cde	46.9bcd	45.4
$T_{12}=N_{100}P_{40}K_{90}S_0$	44.2b	43.9bc	44.1	0.80g	0.84gh	0.82	43.0de	43.5bcd	43.3
$T_{13}=N_{100}P_{40}K_{90}S_{10}$	47.6a	47.0a	47.3	0.92bcd	0.93bc	0.93	41.9e	42.9d	42.4
$T_{14}=N_{100}P_{40}K_{90}S_{30}$	33.0g	34.2efg	33.6	1.00a	0.99a	1.00	41.4e	43.4cd	42.4
$T_{15}=N_{130}P_{60}K_{120}S_{30}$	45.2ab	45.5ab	45.4	0.90cd	0.91cde	0.91	47.5b	47.0bc	47.3
CV (%)	4.02	4.15	-	2.78	3.29	-	4.46	5.51	-
LSD (0.05)	2.43	2.55	-	0.04	0.05	-	3.27	4.12	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$)

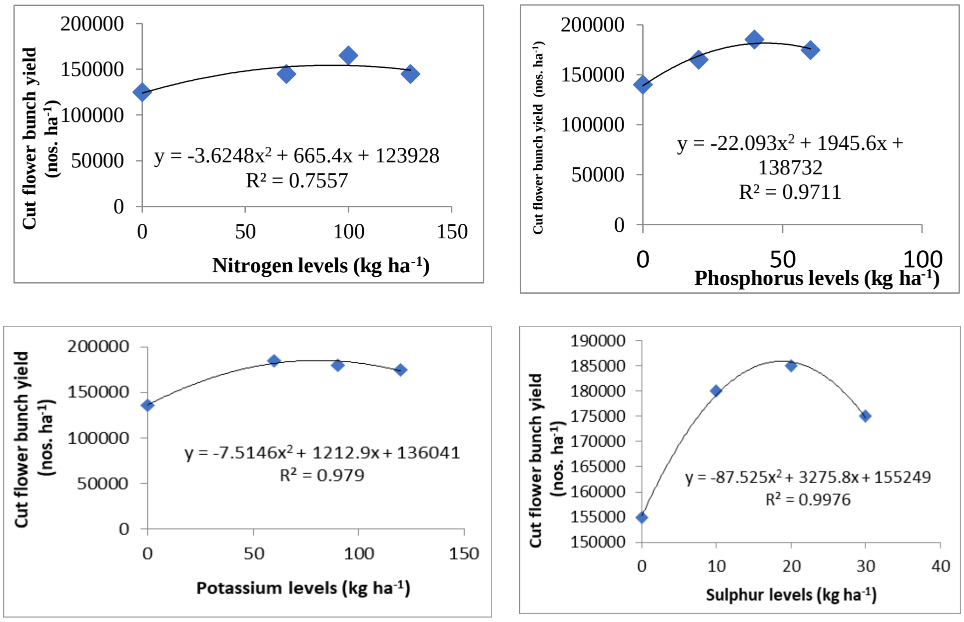
Table 6. Effect of nitrogen, phosphorus, potassium and sulphur on cut flower bunch yield of gypsophila

Treatment N-P-K-S (kg ha^{-1})	Cut flower bunch yield (number ha^{-1})			Bunch yield increment over control
	2017-18	2018-19	Mean	(%)
$T_1=N_0P_0K_0S_0$	100000g	109122g	104561	-
$T_2=N_0P_{40}K_{90}S_{20}$	120000f	130000f	125000	19.5
$T_3=N_{70}P_{40}K_{90}S_{20}$	140000de	149344de	144672	38.3
$T_4=N_{100}P_{40}K_{90}S_{20}$	160000bc	170123bc	165062	57.8
$T_5=N_{130}P_{40}K_{90}S_{20}$	140000de	150001de	145001	38.6
$T_6=N_{100}P_0K_{90}S_{20}$	135000e	145000d-f	140000	33.9
$T_7=N_{100}P_{20}K_{90}S_{20}$	160000bc	170000bc	165000	57.8
$T_8=N_{100}P_{60}K_{90}S_{20}$	170000ab	179321ab	174661	67.0
$T_9=N_{100}P_{40}K_0S_{20}$	130000ef	141000ef	135500	29.6
$T_{10}=N_{100}P_{40}K_{60}S_{20}$	180020a	190000a	185010	76.9
$T_{11}=N_{100}P_{40}K_{120}S_{20}$	170000ab	180000ab	175000	67.3
$T_{12}=N_{100}P_{40}K_{90}S_0$	150000cd	160000cd	155000	48.2
$T_{13}=N_{100}P_{40}K_{90}S_{10}$	175000a	185002ab	180001	72.1
$T_{14}=N_{100}P_{40}K_{90}S_{30}$	170000ab	180000ab	175000	67.3
$T_{15}=N_{130}P_{60}K_{120}S_{30}$	180000a	189000a	184500	76.4
CV (%)	4.56	5.95	-	-
LSD (0.05)	11596	16112	-	-

Values within the same column with a common letter do not differ significantly ($P \leq 0.05$)

Response of yield to to N, P, K and S fertilization

Regression analysis showed positive and quadratic response to mean cut flower bunch yield of gypsophila and applied N, P, K and S (Figure 1). The optimum estimated doses of N, P, K and S were calculated from the quadratic response function and were 91.8, 44.0, 80.7 and 18.7 kg ha^{-1}, respectively could be expected for Gazipur area (Table 7). However, the optimum economic doses of N, P, K and S were calculated as 96.6, 43.9, 80.6 and 18.7 kg ha^{-1}, respectively (Table 7).



Fi. 1. Response of cut flower bunch yield of gypsophila to N, P, K and S fertilization

Table 7. Response function of gypsophila to N, P, K and S application for cut flower bunch yield

Regression equation	Co-efficient of determination (R^2)	Optimum dose (kg ha^{-1})	Economic dose (kg ha^{-1})	Maximum bunch yield (nos. ha^{-1}) for optimum dose
N				
$y = 123928 + 665.4x - 3.6248x^2$	0.7557	91.8	91.6	154464
P				
$y = 138732 + 1945.6x - 22.093x^2$	0.9711	44.0	43.9	181572
K				
$y = 136041 + 1212.9x - 7.5146x^2$	0.979	80.7	80.6	184983
S				
$y = 155249 + 3275.8x - 87.525x^2$	0.9976	18.7	18.7	185899

Note: Gypsophila cut flower bunch = BDT 10 number^{-1}; N fertilizer = BDT 16 Tk. kg^{-1}; P fertilizer = BDT 24 Tk. kg^{-1}; K fertilizer = BDT 22 Tk. kg^{-1}; S fertilizer = BDT 12 Tk. kg^{-1}

Cost and return analysis

Maximum gross return BDT 1850100 ha^{-1} for cut flower bunch of gypsophila was counted from T_{10} treatment followed by T_{15} treatment. The minimum gross return was calculated from control (T_1) treatment. The highest benefit cost ratio 1.91 was recorded from T_{10} treatment. The lowest benefit cost ratio was recorded from control (T_1) treatment (Table 8).

Table 8. Cost and return analysis of cut flower of gypsophila cut flower cultivation as influenced by N, P, K and S application and other inputs (mean data of two years)

Treatment N-P-K-S (kg ha^{-1})	Cut flower bunch yield (nos. ha^{-1})	Gross return (BDT. ha^{-1})	Cultivation cost ((BDT. ha^{-1})	Net return (BDT. ha^{-1})	BCR
T_1=$N_0P_0K_0S_0$	104561	1045610	954500	91110	1.09
T_2=$N_0P_{40}K_{90}S_{20}$	125000	1250000	964235	285765	1.29
T_3=$N_{70}P_{40}K_{90}S_{20}$	144672	1446720	966735	479985	1.49
T_4=$N_{100}P_{40}K_{90}S_{20}$	165062	1650620	967707	682913	1.70
T_5=$N_{130}P_{40}K_{90}S_{20}$	145001	1450010	968749	481261	1.49
T_6=$N_{100}P_0K_{90}S_{20}$	140000	1400000	962907	437093	1.45
T_7=$N_{100}P_{20}K_{90}S_{20}$	165000	1650000	965407	684593	1.70
T_8=$N_{100}P_{60}K_{90}S_{20}$	174661	1746610	970407	776203	1.80
T_9=$N_{100}P_{40}K_0S_{20}$	135500	1355000	964647	390353	1.40
T_{10}=$N_{100}P_{40}K_{60}S_{20}$	185010	1850100	966687	883413	1.91
T_{11}=$N_{100}P_{40}K_{120}S_{20}$	175000	1750000	968747	781253	1.80
T_{12}=$N_{100}P_{40}K_{90}S_0$	155000	1550000	965832	584168	1.60
T_{13}=$N_{100}P_{40}K_{90}S_{10}$	180001	1800010	966832	833178	1.86
T_{14}=$N_{100}P_{40}K_{90}S_{30}$	175000	1750000	968731	781269	1.80
T_{15}=$N_{130}P_{60}K_{120}S_{30}$	184500	1845000	972473	872527	1.89

Note: nos.= numbers

Input prices: Urea= BDT 16 kg^{-1}, T.S.P= BDT 24 kg^{-1}, MoP= BDT 22 kg^{-1}, Gypsum= BDT 12 kg^{-1}, Zinc sulphate= BDT 140 kg^{-1}, Boric acid= BDT 150 kg^{-1}, Plowing = BDT 3000 pass^{-1}, Wage rate= BDT 600 day^{-1}, Bavistin= BDT 200/100g, Cowdung= BDT 2.0 kg^{-1}, Gypsophila seed= BDT 10000 kg^{-1}

Output price: Cut flower bunch = BDT 10 bunch^{-1}.

Gross returns were calculated on the farm gate price (Gazipur, Bangladesh)

Conclusion

The results of the present study indicated that gypsophila achieved higher cut flower bunch yield and exhibited better performance of growth and yield contributing characters in the plot receiving 100-40-60-20 kg NPKS ha^{-1}

including a blanket dose of 3.0-1.5 kg ZnB ha^{-1} and cowdung 5 t ha^{-1}. This combination of NPKS was also most economic. The results suggest that combination of NPKS levels of 100-40-60-20 kg ha^{-1} could be suitable for improving growth and cut flower bunch yield of gypsophila in terrace soils of Bangladesh.

Reference

Ahmed, R., M.J. Hussain, S. Ahmed, M. Karim, and M. Siddiky. 2017. Effect of Nitrogen, Phosphorus and Potassium Fertilizers on Yield and Yield Attributes of Marigold (*Tagetes patula* L.). *The Agriculturists*. **15**(1), 101-109.

Anonymous. 2018. Fertilizer Recommendation Guide-2018, Published by Bangladesh Agricultural Research Council, Dhaka, Bangladesh.

Ayemi, T.J., D. Singh and U. Fatmi. 2017. Effect of NPK on Plant Growth, Flower Quality and Yield of Gerbera (*Gerbera jamesonii* L.) cv. Ruby Red under Naturally Ventilated Polyhouse Condition. *Int. J. Curr. Microbiol. App.Sci*. **6**(8): 1049-1056.

Das, D, K. and M. Mandal. 2016. *Advance technology of fertilizer uses for crop production*. In Book: Fertilizer Technology-I Synthesis, (1st ed.), Studium Press, LLC, USA, 101-150 pp.

Ghaffoor, A., M. Shaheen, M. Iqbal, K. Waseem and M.A. Nadeem. 2000. Impact of Various Combinations of NPK on the Growth, Yield and Quality Parameters of Rose. *Pakistan Journal of Biological Sciences*. **3:** 1560-1562.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedure for agricultural research, 2nd edition, John Wiley and Sons, Inc. Singapore, 324 p.

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

Khan, F. U., A. Q. Jhon, F. A. Khan and M. M. Mir, 2006. Effect of NPK and Zn on growth, flowering and bulb production in tulip under polyhouse conditions in Kashmir. *J. Hort. Sci.* **1** (2): 129-134.

Korkmaz, M. and H. Özçelik. 2011. Economic importance of *Gypsophila* L., *Ankyropetalum* Fenzl and *Saponaria* L. (Caryophyllaceae) taxa of Turkey. *African J. Biotechnol.* **10**(47): 9533-9541.

Özdemir, C., M. Mustafa Özkan and A. Kandemir. 2010. The morphological and anatomical properties of *gypsophila lepidioides* boiss (caryophyllaceae) endemic to Turkey. *Int. Res. J. Plant Sci*. **1**(4): 069-074.

Page, A.L., R.H. Miller and D.R. Keeney (Eds.). 1982. Agronomy Series 9 ASA, SSSA. *Methods of Soil Analysis* (Part 2, 2nd ed., pp. 403-427). *Am. Soc. of Agron*., Madison, USA.

Petry, C., S. Bellé, and E.O. Calvete. 2008. Produção de gypsophila. pp. 172-178. In: Petry, C. (ed.). Plantas ornamentais aspectos para a produção. 2nd ed. Editora Universidade de Passo Fundo, Passo Fundo-RS, Brazil.

Senapati, S.K., T.K. Das and G. Pandey. 2020. Effect of Nitrogen, Phosphorus and Potassium Level on Floral Characteristics of Chrysanthemum (*Chrysanthemum morifolium* Ramat) cv. Bidhan Madhuri. *Int. J. Curr. Microbiol. App. Sci.* **9**(7): 2594-2601.

Sharma, G., P. S. Naresh and N. Shukla. 2017. Effect of Bio-Organic and Inorganic Nutrient Sources on Growth and Flower Production of African Marigold. *Horticulturae* MDPI, 3, 11; doi:10.3390/horticulturae3010011

Statistix 10. 1985. An Anlytical Software, Po Box 12185, Tallahassee, FL 32317, Copy right © 1985-2013

Sultana, S., F.N. Khan, M.A. Haque, S. Akhter and S. Noor. 2006. Effect of NPK on growth and flowering in tuberose. *J. Subtrop. Agric. Res. Dev.* **4**(2):111-113.

Wahome, P.K., T.O. Oseni, M.T. Masarirambi, and V.D. Shongwe. 2011. Effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower quality of gypsophila (*Gypsophila paniculata* L.). *World J. Agr. Sci.* **7**(6): 692-698.

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FEASIBILITY OF GROWING SELECTED VEGETABLES IN HANGING SAC WITH DIFFERENT LEVELS OF MANURE

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Abstract

Vegetable production in the waterlogged condition is the main challenge in Southwest Bangladesh and to address the problem the present investigation was undertaken to determine the prospect and profitability of hanging sack vegetable cultivation in the waterlogged condition under various levels of organic matter. The investigation comprised three of vegetables such as Brinjal, Tomato, and Okra in hanging sacs under three soil and organic matter combinations at Germplasm Center of Agrotechnology Discipline, Khulna University Bangladesh from November 2018 to March 2019. Three soil+cowdung combinations were $T_{0=}$ 100% soil, T_1= 50% soil+50% cowdung, T_2= 75% soil+ 25% cowdung, T_3=25% soil+ 75% cowdung replicated seven times to produce the less erroneous results. Brinjal in the hanging sac had significantly better biological yield (28.92 t/ha), net return (451,000Tk./ha)and benefit-cost ratio (BCR) (2.08)over okra or tomato when the sac was filled with 75% cowdung + 25% soil. The higher price plus advanced yield contributed to enhancing the profitability of brinjal. These results will inform decision-making about cropping system modification that can be adopted by vegetable growers of Southwest Bangladesh to considerably reduce fallow waterlogged areas and enhanced vegetable production in waterlogged conditions.

Keywords: Hanging sac, waterlogged, profitability, cowdung, BCR.

Introduction

Waterlogged is such a situation when water table increases in a certain height wherein the soil pores become inundated, thus dislocating the air from soil apertures (Barrett-Lennard, 2002) and hinders agricultural activity (Ahmed, 2005). Waterlogged is an acute problem in southwest Bangladesh due to special geographic location and climate. Khulna and Jessore districts of southwest Bangladesh cover about 8000 hectares of waterlogged land areas that made a devastating effect on livelihoods (Ali, 1996). Due to global warming, with the rise of sea level more areas will undergo waterlogging, as a result, cultivable lands gradually become unfit for crop production (BARC, 1991). This worrying situation directs the researchers to explore different adaptation practices viz.

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vegetable cultivation in a hanging sac, discharging the waterlogged water by fitting of drainage pump (Hsu *et al.,* 2000; Chandio *et al.,* 2012), downing water table by boost up groundwater (Singh, 2011) etc.

During monsoon season vegetable growing areas in waterlogged condition could be expanded by sac farming. Sac farming involves filling the sac with fertile soil, manures, and placed a few pebbles in bottom for proper drainage and keep few holes in-side for aeration and finally placed the plants in top and allow to grow. The main merits of sack farming are their portability, efficiency, productivity, and contributions to food security (Falguni, 2009) as well as reduce the risk of production (Ram *et al.,* 2007). Sac cultivation was highly effective in helping families adapt to salinity intrusion and waterlogging conditions (Angrish *et al.,*2006). Nutrient management system in sac cultivation is handy (Qureshi *et al.,* 2008). The system allows the more helpless families to cultivate vegetables otherwise they would struggle to buy and help to diversify their diet.

The farmers of Southwest Bangladesh face many challenges associated with a changing climate viz. waterlogging, salinization, flooding and so forth to meet up the food demand for increasing population. Vertical agriculture can address those challenges by maximizing the space around households by suspending organic horticulture production in sacks along bamboo structures over the water bodies. Now-a-days peoples demand for organic vegetables is growing gradually, but the supply is meager. Also, hanging sac vegetables cultivation allows women to better manage their own food security, nutrition and consumption of fresh vegetables. It is assumed that the extra cost of using hanging structure and organic manure may be compensated by greater yield and decreased intercultural costs. Therefore, the present study was designed to assess the prospect and profitability of hanging sac vegetable cultivation in waterlogged condition and to determine the impact of different levels of organic matter in sac.

Materials and Methods

The field trial was conducted at Germplasm Center of Agrotechnology Discipline, Khulna University, Khulna, Bangladesh from November 2018 to May 2019. The experimental site was located at 89°34' E Longitudes and 22°47' N Latitude (FAO, 1988).

To assess the profitability of selected three types of vegetables viz. brinjal (*Solanum melongena*), tomato (*Solanum lycopersicum*), okra (*Abelmoschus esculentus*) and to find out the suitable combination of soil and manure for sac, four different proportion viz. T_0= 100% soil, T_1= 50% soil + 50% cowdung, T_2= 75% soil + 25% cowdung, T_3= 25% soil + 75% cowdung were used as treatments. The single factor experiment was laid out in a Completely Randomized Design (CRD) with seven replications.

Seeds of brinjal, tomato and okra were used as planting material. Seeds of the selective vegetables were properly sun-dried and then treated with Provex-200 @ 2 g/kg of seeds before being placed in plastic cell tray for seedling preparation.

The sacks were filled with the mixture of soil and rotten cowdung according to the treatments leaving 5 cm unfilled from the brim. The individual sac was 50 cm × 40 cm in size and placed at spacing of 75 cm × 90 cm. The sacks were hanged from the bar by rope and iron wire. For easy access, intercultural operation and data collection in waterlogged conditions, a cork sheet boat was made. Recommended dose of cowdung (10,000 kg/ha) and chemical fertilizers were applied according to the respective crops such as Tomato (Urea: 280 kg/ha, TSP: 180 kg/ha, MoP: 220 kg/ha), Brinjal (Urea: 260 kg/ha, TSP: 180 kg/ha, MoP: 220 kg/ha), Okra (Urea: 150 kg/ha) (Azad *et al.*, 2019). However, no additional TSP and MoP fertilizers were applied in the sac of okra because okra was planted in tomato sac when the tomato plant was died.

The healthy thirty days old seedlings were transplanted in each sac. Irrigation was done daily until the plants were fully established. According to standard commercial practice, irrigation cycles were adjusted based on annual precipitation. Disease and pest infestation were monitored periodically, and its level was much below the action threshold level.

The fruits of tomato, brinjal and okra were harvested at mature stage. Cost of production was analyzed according to the procedure followed by Das*et al*. (2018) and Ozkan*et al*. (2004)to find out the most economic return under different treatment combinations. During growing period vegetable growers having prices for brinjal 30 Tk./kg, tomato 20 Tk./kg, okra 20 Tk./kg (DNCRP, 2019).

Recorded data were analyzed statistically using the GLIMMIX procedure of SAS and mean separation was done with Tukey-Kramer adjustment at $p \leq 0.05$ (SAS software Version 9.4, SAS Institute Inc, Cary, NC).

Results and Discussion

Yield and profitability of Brinjal

The economic yield of brinjal was significantly affected by different levels of cowdung in the sacs (Table 1). The highest yield of brinjal (28.92 t/ha) was found from 25% soil + 75% cowdung combination (T_3)and the lowest from control (soil) (15.5 4 t/ha) (T_0). Similar trend was found in the cost of production, gross return, net return and benefit-cost ratio of brinjal. The effect of different levels of cowdung was highly significant for the cost of production, gross return, net return and benefit-cost ratio of brinjal. The maximum cost was recorded from $T_3$and the lowest from T_0. Alike cost of production, the maximum gross return and net return were obtained from $T_3$and the lowest from T_0. Also, the highest benefit-cost ratio was obtained from T_3 (2.08) followed by T_1 and T_2 and the lowest from T_0 (1.88).

Table 1. Yield and profitability of Brinjal as affected by different levels of cowdung in sack

Treatment	Yield (t/ha)	Total cost	Gross return	Net return	BCR
		('000 Tk./ha)			
T_0 = 100% soil	15.54 c	248 c	466 c	218 c	1.88 b
T_1 = 50% soil + 50% cowdung	23.26 b	357 b	698 b	341 b	1.95 b
T_2 = 75% soil + 25% cowdung	19.74 b	312 b	592 b	280 b	1.89 b
T_3 = 25% soil + 75% cowdung	28.92 a	417 a	868a	451 a	2.08 a
LS	**	**	**	**	*

Means followed by the same letters within each column do not differ significantly whereas means having dissimilar letters differ significantly by Tukey-Kramer adjustment for multiple comparison. LS= Level of significance, BCR= Benefit cost ratio. *, ** significant at $p < 0.05$ and $p<0.01$, respectively.

Yield and profitability of Tomato

A significant difference in tomato yield was apparent due to various levels of cowdung (Table 2). The highest tomato yield (26.11 t/ha) was obtained from 25% soil + 75% cowdung combination (T_3). However, cost of production significantly differed with different cowdung levels. The highest cost of production (417,000 Tk./ha) was documented from T_3 followed by T_1 and T_2 and the lowest cost was calculated from T_0 (248,000Tk./ ha). Alike yield, different cowdung levels had significant effect on gross and net return. The highest gross and net return were attained from T_3 compared to other treatments. However, different cowdung levels had no significant effect on benefit-cost ratio.

Table 2. Yield and profitability of Tomato as affected by different levels of cowdung in Sack

Treatment	Yield (t/ha)	Total cost	Gross return	Net return	BCR
		('000 Tk./ha)			
T_0 = 100% soil	15.40 b	248 c	308 c	60 b	1.24
T_1 = 50% soil + 50% cowdung	20.74 b	357 b	415b	58 b	1.16
T_2 = 75% soil + 25% cowdung	17.21 b	312 b	344c	32 c	1.10
T_3 = 25% soil + 75% cowdung	26.11 a	417 a	522 a	105 a	1.25
LS	*	**	*	*	NS

Means followed by the same letters within each column do not differ significantly whereas means having dissimilar letters differ significantly by Tukey-Kramer adjustment for multiple comparison. LS= Level of significance, BCR= Benefit cost ratio, *, ** significant at $p < 0.05$, $p<0.01$, respectively, NS-Non-significant

Okra yield and profitability

Different cowdung levels significantly interacted with economic yield of okra (Table 3). The maximum yield of okra (23.10 t/ha) was observed in treatment T_3 (25% soil + 75% cowdung) while minimum yield was obtained from T_0 (14.10 t/ha) where no cowdung was used followed by T_2 and T_1. Similar inclination was found in total cost of production, gross return, net return. However, different cowdung levels had no significant effect on benefit cost ratio of okra. The highest total cost was recorded from $T_3$and the lowest cost was calculated from T_0. Similarly, the peak gross return of okra was found from T_3 and the least from T_0followed by T_2 and T_1, respectively. The highest net return of okra was obtained from treatment T_3 and the lowest net return was recorded from T_0.

Table 3. Yield and profitability of Okra as affected by different levels of cowdungin Sack

Treatment	Yield (t/ha)	Total cost	Gross return	Net return	BCR
		(‘000 Tk./ha)			
T_0 = 100% soil	14.10 b	221 c	282 c	61 b	1.28
T_1 = 50% soil + 50% cowdung	19.76 b	315 b	395 b	80 b	1.25
T_2 = 75% soil + 25% cowdung	17.18 b	282 b	344 b	62 b	1.22
T_3 = 25% soil + 75% cowdung	23.10 a	355 a	462 a	107 a	1.30
LS	**	**	**	**	NS

Means followed by the same letters within each column do not differ significantly whereas means having dissimilar letters differ significantly by Tukey-Kramer adjustment for multiple comparison. LS= Level of significance, BCR= Benefit cost ratio, *, ** significant at $p < 0.05$, $p<0.01$, respectively, NS-Non-significant

Average yield and profitability of brinjal, tomato and okra

The effect of different vegetables was non-significant for comparative average yield as well as total cost of production (Table 4). However, different vegetables had a significant effect on average gross and net return. The highest average gross and net return were found from brinjal followed by tomato and the lowest gross return was obtained from okra. Like gross and net return, benefit-cost ratio significantly differed among different vegetables. The highest benefit-cost ratio was obtained from brinjal (1.94) followed by tomato and the minimum from okra (1.13).

Table 4. Average yield and profitability of different vegetables cultivated in hanging Sack

Variety	Yield (t/ha)	Total cost	Gross return	Net return	BCR
		('000 Tk./ha)			
Brinjal	23.68	366	710 a	344 a	1.94 a
Tomato	21.86	366	437 b	71 b	1.19 b
Okra	19.03	336	381 c	45 c	1.13 b
LS	NS	NS	*	**	*

Means followed by the same letters within each column do not differ significantly whereas means having dissimilar letters differ significantly by Tukey-Kramer adjustment for multiple comparison. LS= Level of significance, NS, *, ** Non-significant or significant at $p < 0.05$, and 0.01, respectively

Hsu *et al.* (2000) reported that organic matter in the soil improves the biological activities viz. water retention capacity, infiltration rate, soil aggregate stability and cation- exchange capacity facilitating plant growth and yield. Again, Hossain *et al.* (2014) and Das *et al.* (2018) reported that soil fertility was restored by organic matter that enhanced vegetative growth ensuring more yield which supported this finding. Organic matter helps to increase availability of nutrients in the soil and a combination of organic (60%) + inorganic (40%) matter showed better performance for brinjal growth and fruit yield (Ullah *et al.*, 2008) which supports this finding. The results suggested that organic matter addition, more labor for intercultural operation facilitated to increase cost of production although gross and net return and BCR were highest from the same treatment due to advance yield and more price of brinjal. However, Keskin *et al.* (2010) informed that high labor cost increased total tomato production cost in turkey that was comparable with this finding. Also, per plant tomato production cost was higher in the organic system over conventional one reported by Santos *et al.* (2017). As par brinjal, Muqtadir *et al.* (2019) reported similar findings where they stated that okra yield increased by more organic and less inorganic fertilizer combination. Organic matter fosters the growth of various beneficial microbes that create a proper environment for plant growth and development (Bulluck *et al.,* 2002) which is comparable with this study. Also, the comparative results reveled that the brinjal performed better (>BCR) than tomato or okra in hanging sac at waterlogged condition because of higher yield and price.

Conclusion

In a nut shell, brinjal cultivation in hanging sac was profitable in terms of maximum benefit-cost ratio (2.08) in waterlogged condition compared to tomato or okra where per hanet return was Tk., 451,000. Similar trend was observed in average results. Out of four combinations of cowdung and soil, 75% cowdung +

25% soil in sac was the best for brinjal cultivation in waterlogged condition. Above all, production of brinjal in hanging sack with 3:1 ration of organic matter and soil is prospective and feasible for vegetable cultivation in waterlogged environment of southwest Bangladesh even though the ration can change with the types of vegetables. However, to establish consistency in the feasibility of vegetable cultivation in hanging sac in different waterlogged areas of Bangladesh, extensive research works are recommended.

References

Ahmed, A. U. 2005. Adaptation options for managing water related extreme events under climate change regime: Bangladesh perspectives. (In) climate change and water resources in South Asia [Mirza M M Q and Ahmad Q K (eds.)], Balkema Press, Leiden, Netherlands. pp. 255-278.

Ali, A. 1996. Vulnerability of Bangladesh to climate change and sea level rise through tropical cyclones and storm surges. *Water Air Soil Poll.***92**:171-179.

Angrish, R., O. P. Tokyand K. S. Datta. 2006. Biological water management: biodrainage. *Curr. Sci.* **90**(7): 897.

Azad, A. K., B. K. Goshwami, M. L. Rahaman, P. K. Malakar, M. S. Hasanand M. H. H. Rahaman. 2019. *Krishi Projukti Handbook.* 7th edition, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh. p. 189.

BARC (Bangladesh Agricultural research Council). 1991. Agro-ecological database, BARC Computer Centre, Bangladesh Agricultural Research Council, Dhaka.

Barrett-Lennard, E. G. 2002. Restoration of saline land through revegetation. *Agric. Water Manag.* **53**(1–3): 213–226. doi: 10.1016/S03783774(01)00166-4.

Bulluck, L. R., M. Brosiusand G. K. Evanylo. 2002. Organic and synthetic fertility amendments influence soil microbial, physical and chemical properties on organic and conventional farms. *Appl. Soil Ecol.19*: 147-160.

Chandio, A. S., T. S. Lee and M. S. Mirjat. 2012. The extent of waterlogging in the lower Indus Basin (Pakistan)- a modeling study of groundwater levels. *J. Hydrol.* **426–427:** 103-111. doi: 10.1016/ j.jhydrol.2012.01.017.

Das, A., P. K. Dashand M. A. Mannan. 2018. Performance of Indian Spinach under different combinations of organic and inorganic fertilizers. *Bangladesh J.Agric. Environ.* **14**(1): 19-28.

DNCRP (Directorate of National Consumer Rights Protection). 2019. Government of the People’s Republic of Bangladesh. https://dncrp portal gov bd/ Accessed November 20, 2019.

Falguni, A. 2009. Aila after Sidr. The Daily Star, Dhaka, Bangladesh. https://www.thedailystar.net/news-detail-90678. Accessed April 20, 2020.

FAO (Food and Agriculture Organization). 1988. Soil survey project of Bangladesh. Food and Agriculture Organization of United Nations soil Resources Technical Report. pp. 107-159.

Hossain, N., M. Islam, M. Alamgirand M. G. Kibria. 2014. Growth response of Indian Spinach to biogas plant residues. *J. Pharm. Biol. Sci* .**9**: 1-6.

Hsu, M. H., S. H. Chenand T. J. Chang. 2000. Inundation simulation for urban drainage basin with storm sewer system. *J. Hydrol.* **234**(1–2): 21-37. doi: 10.1016/S00221694(00)00237-7.

Keskin, G. F., F. Tatlidil and I. Dellal. 2010. An analysis of tomato production cost and labor force productivity in Turkey. *Bulg. J.Agrc. Sci.**16*** (6): 692-699.

Muqtadir, M. A., M. A. Islam, T. Haque and A. Nahar. 2019. Growth and yield of okra influenced by different types of fertilizers and netting. *Progress. Agric.* **30**(1): 1-9.

Ozkan, B., H. Akcaozand F. Karadeniz. 2004. Energy requirement and economic analysis of citrus production in Turkey. *Energy Convers. Manag.***45**:1821-1830.https://doi.org/10.1016/j.enconman.2003.10.002

Qureshi, A. S., P. G. McCornick, M. Qadir and Z. Aslam. 2008. Managing salinity and waterlogging in the Indus Basin of Pakistan. *Agric. Water Manag.* **95**(1):1-10. doi: 10.1016/j.agwat.2007.09.014.

Ram, J., V. K. Garg, O. P. Toky, P. S. Minhas, O. S. Tomarand J. C. Dagar. 2007. Biodrainage potential of Eucalyptus tereticornis for reclamation of shallow water table areas in north-west India. *Agrofor. Syst.* **69**(2):147-165. doi: 10.1007/s10457-0069026-5.

Santos, N. J. D., K. R. F. Schwan-Estrada, J. O. Alves de Sena, and T. T. Santos. 2017.Economic viability of tomato cultivation in organic farming system. *Braz. Arch. Biol. Technol.* **60**: 1-10.

Singh, A. 2011. Estimating long-term regional ground water recharge for the evaluation of potential solution alternatives to waterlogging and salinization. *J. Hydrol*. **406**(3–4): 245-255. doi: 10.1016/j.jhydrol.2011.07.004

Ullah, M. S., M. S. Islam, M. A. Islam and T. Haque. 2008. Effects of organic manures and chemical fertilizers on the yield of brinjal and soil properties. *J. Bangladesh Agril. Univ.* **6**(2): 271-276.

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EFFECT OF SOIL MOISTURE LEVEL ON YIELD AND NUTRIENT BALANCE SHEET OF BLACK CUMIN*

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Abstract

A field experiment was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during *rabi* season of 2016-17 to evaluate the effects of soil moisture levels on black cumin (BARI Kalozira-1). The study site belongs to Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract). The experiment was set up in randomized complete block design with three replications, comprised five treatments assoil moisture levels: irrigation at 90%, 80%, 70%, 60% and 50% field capacity. The required number and amount of irrigation were 11 and 113.1mm, 8 and 108.1mm, 6 and 104.2mm, 4 and 99.4mm and 0 and 22.4mm in irrigation at 90%, 80%, 70%, 60% and 50% field capacity, respectively. The maximum seed yield (1243.0 kg ha^{-1}) was recorded under the highest moisture regime in irrigation at 90% field capacity of soil moisture. The minimum yield (165.5 kg ha^{-1}) was noted at 50% field capacity (where no irrigation was required). Net nutrient balance of N, K and S showed negative balance but P was positive. The maximum water use efficiency (10.51 kg ha^{-1} mm^{-1}) for yield was noted with irrigation at 90% field capacity, which may be recommended for black cumin cultivation in the study area. The cost-benefit analyses also indicate that the maximum net income (Tk. 123503.00) of black cumin cultivation has been achieved by maintaining the highest soil moisture through irrigating the crop at 90% of field capacity.

Keywords: Black cumin, irrigation, nutrient balance sheet, seed yield and water productivity.

Introduction

Black cumin (*Nigella sativa* L. family-Ranunculaceae) is an annual herb. Around 22 spices of black cumin are grown in worldwide. Among these, the seed of *Nigella sativa*, *N. damescene* and *N. arvensis* are used as medicinal and spices purposes. The black cumin seeds contain more than 100 chemical constituents such as protein, carbohydrates, alkaloids (nigellicines and nigelledine), saponin (ά-hedrerin), fixed and essential oils, vitamins, minerals and bioactive compounds (thymoquinone, thymol) etc. (Rajsekhar and Kuldeep, 2011). The consumption of black cumin has increased with time, but the production has declined compared to other vegetables and spices crops due to lack of improved hybrid varieties, quality seeds, improved production technologies, inadequate marketing facilities, climate change and shortage of land due to *Boro* & *Rabi* crops.

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Water stress is well known as one of the most significant factors hampering plant growth by affecting cell elongation directly and more indirectly by nutrients uptake, allocation of especially photisynthesis and physiological processes in plants and this in turn is reflected on growth, development and yield. Water stress during budding, anthesis, flowering stages of plants causes the most reduction in number, yield and quality of seed (Ghanbary *et al*., 2008). The effective role of water supply on the growth and yield of black cumin was observed by many investigators and found that providing optimum amounts of water resulted in better growth and yield and water stress showed negative impact on growth, yield and quality attributes. Research review shows that the black cumin is able to tolerate moderate levels of water stress (Bannayan *et al.*, 2008). Moreover, deficit irrigation is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied where crop is exposed to a certain level of water stress either during a particular period or throughout the entire growing season. Optimizing irrigation management together with appropriate crops for cultivation is highly demandable (Ghorbanli *et al.*, 1999). In Bangladesh, acute shortage of irrigation water during dry season is affecting the crop production in general and spices production in particular. Thus, for ensuring the sustainable black cumin seed production and combating the water crisis during *rabi* season, it is very important to go for judicious use of irrigation water. Both over-irrigation and under-irrigation are detrimental for crop production and economic point of view. An optimum amount of irrigation water should be applied at proper time of the crop need. Based on the aforesaid importance of dry land agriculture due to water scarcity and sustaining the production of spice crops like black cumin in order to meet its increasing demands, the present study was undertaken to:(i) to observe the effect of different soil moisture regimes on the seed yield of black cumin. (ii) to determine the water requirement of the crop for achieving the maximum yield potential of the crop and (iii) to make a nutrient balance sheet for proper soil management of the crop.

Materials and Methods

A field experiment was carried out at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur during *rabi* season of 2016-17 in Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract). The order of the studied soil falls under Inceptisols in USDA Soil Taxonomy. The geographic coordinates of the experimental location is $24^0 09^/$ North Latitude and $90^0 26^/$ East Longitude with elevation of 8.2 m from mean sea level. A description of some basic properties of the experimental soil collected from a depth of 0-30 cm prior to application of fertilizers is presented in Table 1. The maximum effective rooting depth of black cumin was assumed to be confined within 20 cm.

Table 1. Soil properties of the experimental field

Soil characteristics	Analytical value	Analytical method
Physical properties		
Particle size distribution		Hydrometer method
Sand	17.30%	
Silt	45.80%	
Clay	36.90%	
Textual class	Silty clay loam	
Bulk density	1.38gcm^{-3}	Core sampling method
Particle density	2.63 gcm^{-3}	Pycnometer method
Porosity (%)	47.4	
Hydraulic conductivity (cm sec^{-1})	4.6 x 10^{-4}	Falling-head method
Field capacity (% by weight)	30.7	Gravimetric method
Initial moisture status (% by weight)	22.8	Gravimetric method
Chemical properties		
Soil pH	5.84	Soil: water=1:2.5
Total N (%)	0.09	Modified Kjeldhal Method
Organic C (%)	0.86	Wet oxidation method
C: N ratio	9.50	
Available P (ppm)	6.80	Bray and Kurtz method
Exchangeable K (meq100 g^{-1}soil)	0.06	N NH_4OAc extraction method
Exchangeable Ca (meq100 g^{-1} soil)	1.60	N NH_4OAc extraction method
Exchangeable Mg (meq100 g^{-1}soil)	0.71	N NH_4OAc extraction method
Exchangeable Na (meq100 g^{-1} soil)	0.38	N NH_4OAc extraction method
CEC (meq 100 g^{-1} soil)	9.00	N NH_4OAc extraction method
Available B (ppm)	0.19	Calcium chloride extraction method
Available Zn (ppm)	0.58	DTPA Extraction method
Available Cu (ppm)	0.19	DTPA Extraction method
Available Mn (ppm)	0.80	DTPA Extraction method
Available S (ppm)	7.8	Calcium dihydrogen phosphate extraction method

The experiment was set up in Randomized Complete Block Design (RCBD) with five treatment combinations were**:** I_1: Irrigation at 90% field capacity, I_2: Irrigation at 80% field capacity, I_3: Irrigation at 70% field capacity, I_4: Irrigation at 60% field capacity andI_5: Irrigation at 50% field capacity, having three replications. The experimental plot was fertilized with N, P, K, S, Zn and B @

80, 22, 60, 15, 1.7 and 1.2 kg ha^{-1}, in the form of urea, TSP, MoP, gypsum, zinc sulfate and boric acid, respectively with 5 t ha^{-1} cowdung on the basis of soil test value (STB). The cowdung used in the experiment contained 0.99% N, 0.19% P, 0.49% K, 0.11% S, 0.39% Ca and 0.20%Mg on dry basis. The whole amount of cowdung, TSP, MoP, gypsum, zinc sulfate and boric acid were applied as basal dose. Urea was applied in three equal installments at 5^{th}, 9^{th} and 11^{th} week after sowing. The seeds of black cumin cv. BARI Kalozira-1 were sown on 22 November 2016 in 3 m x 3 m plot at line to line distance of 20 cm. Seeds were soaked in water for 24 hours to facilitate germination. Then the seeds were dried and treated with Autostin (carbendazim) @ 2 g kg^{-1} seeds to minimize the primary seed-borne disease. The seeds were mixed with some loose soil to allow uniform sowing in rows @ 10 kg ha^{-1} of seed at about a depth of 1.0 cm. The seeds were covered with loose soil properly just after sowing and gently pressed by hands followed by light irrigation to enhance proper emergence. Continuous lines were made to maintain a plant to plant distance of 10 cm by thinning at 25 DAS and then the light irrigation was given immediately after thinning. The intercultural operations (three weeding and three times' spray of Autostin @ 2g l^{-1} of water spray for controlling damping off disease) were done in the whole cropping period. The observations on growth parameters like plant height and number of branches were recorded at 100 DAS. The crops were harvested on 20 March 2017, when about 50-60% of the capsules of plots were found visible to changing green to straw color. Ten plants were selected randomly from each treatment for recording some growth and yield contributing characters. The production of seed per plot was recorded from $1m^2$ of land to obtain the yield per hectare. The harvested plants were sun dried for four days and threshing was done by beating with wooden sticks. The seeds were winnowed and cleaned subsequently for recording data. Irrigation water was applied on the basis of soil moisture under each treatment to bring the soil moisture up to the field capacity level. Field capacity, having the maximum available water was considered to be the highest level of irrigation in order to avoid deep percolation loss of water.

Irrigation requirement was determined by using the following equation:

$IR = \{(M_{FC} – M_{PI}) / 100\} \times \rho b \times D$

Where,

IR = Irrigation requirement (cm)

M_{FC} = Soil moisture percentage at field capacity (weight basis)

M_{PI} = Soil moisture percentage in field prior to irrigation (weight basis)

ρb = Bulk density (g cm^{-3})

D = Rooting depth (cm)

Data on total number of irrigation, common irrigation (seed sowing to thinning) and total amount of irrigation water are presented in Table 2.

Table 2. Amount of irrigation water applied in different soil moisture levels for black cumin crop

No. of Irrigation	Rooting depth (cm)	Amount of irrigation water (mm) at different soil moisture levels treatment				
		I_1	I_2	I_3	I_4	I_5
1st	5	3.3	6.2	9.1	17.9	-
2nd	5	3.9	7.4	13.4	17.4	-
3rd	5	3.9	7.2	13.6	20.9	-
4th	7	5.8	12.0	13.1	20.8	-
5th	7	6.8	12.2	16.3	-	-
6th	7	6.8	10.9	16.3	-	-
7th	10	9.7	14.5	-	-	-
8th	10	11.0	15.3	-	-	-
9th	10	11.1	-	-	-	-
10th	12	14.2	-	-	-	-
11th	12	14.2	-	-	-	-
Common irrigation for seedling raising		22.4	22.4	22.4	22.4	22.4
Total		113.1	108.1	104.2	99.4	22.4

For calculating nutrient uptake, the ten plants selected and tagged earlier in each plot were cut at the bottom, chopped with sharp knife, air-dried in the laboratory and finally oven-dried for 72 hours at 65^0C. An electrically operated grinding machine was used to grind the oven-dried plant samples. The plant samples were then stored in polyethylene bag in desiccators for chemical analyses.

Nutrient uptake from the soil was calculated by using the formula:

Nutrient uptake = % A x Y / 100 kg ha^{-1}

Where,

% A = Nutrient content of plant in percent

Y = Total dry matter production of plant (kg ha^{-1})

Nutrient balance sheets were estimated by using the formula:

Nutrient balance (N, P, K, S) = Σ Input (N, P, K, S) – Σ Output (N, P, K, S)

Where,

Input: Chemical fertilizer, manure, BNF, deposition (rain), airborne, sedimentation

Output: Harvested crop parts, crop residues, leaching, gaseous losses, soil erosion

However, the nutrient balance in this study did not account for the addition of nutrients from rainfall, dry deposition, BNF and removal of nutrient by leaching, gaseous losses of N, or weed uptake of nutrients from the soil.

Harvest index was calculated by the following formula:

HI = EY / BY x 100

Where,

HI = Harvest index (%)

EY = Seed yield (kg)

BY = Biological yield (kg)

Total consumptive use of water was calculated by the using equation:

Wc = Iw + Sw + Pe

Where,

Wc = Total consumptive use of water (mm)

Iw = Total amount of irrigation water applied (mm)

Sw = Soil moisture contribution (mm)

Pe = Effective rainfall (mm)

Soil moisture contribution was determined by using the following equation:

$Sw = (M_S - M_H/100) \times \rho b \times D$

Where,

M_S = Soil moisture percentage at sowing (weight basis)

M_H = Soil moisture percentage at harvest (weight basis)

ρb = Bulk density (g cm^{-3})

D = Rooting depth (cm)

Effective rainfall (Pe) was calculated by the using equation:

Pe = 0.8P – 25 if P > 75 mm $month^{-1}$

Pe = 0.6P – 10 if P < 75 mm $month^{-1}$

Where,

Pe = Effective rainfall (mm)

P = Rainfall (mm)

Water use efficiency (WUE) was estimated by following formula:

WUE = Total dry biomass or seed yield (kg ha^{-1}) / total consumptive use of water (mm)

Economic evaluation of different soil moisture levels was done considering the following rates of the materials: Urea@16Tkkg^{-1}, TSP@22Tkkg^{-1}, MoP @15 Tk kg^{-1}, gypsum @10 Tk kg^{-1}, boric acid @180 Tk kg^{-1}, zinc sulfate @200 Tk kg^{-1}, cowdung @1.5 Tk kg^{-1}, irrigation @1000 Tk per irrigation per ha, black cumin seed 180 Tk kg^{-1}, labor cost @350 Tk per day per man, land rent 25000 Tk per ha (According to the market price of the year 2016-2017).

The data were subjected to statistical analysis by using *R* version 3.5.0 software to find out the significance of variation resulting from the experimental treatments.

Results and Discussion

Plant height

Irrigation treatments significantly influenced the plant height (Table 3). The mean tallest plant (65.8 cm) was recorded in treatment I_1 (irrigation at 90% field capacity) followed by I_2 (62.2 cm), I_3 (49.1 cm) and the smallest plant (23.3 cm) was noted in treatment I_5 (irrigation at 50% field capacity) (Table 3). Maintenance of the highest level of soil moisture in I_1 plot (90-100% of FC) might have contributed to higher nutrient mobility and uptake by the crop thus, resulting maximum growth. Similar results are reported by (Karim *et al*., 2017, Senyigit and Arslan, 2018).

Number of branches per plant

As shown in the Table 3, there was significant difference in number of branches per plant among the treatments, where the mean maximum number of branches per plant (7.5) being noted in treatment I_1 (irrigation at 90% field capacity) followed by I_2 (6.5), I_3 (6.1). The minimum number of branches per plant (4.3) was found in the treatment I_5 (irrigation at 50% field capacity). Higher soil moisture condition and higher availability of nutrients to crops in I_1 treatment might have favored in increasing the number of branches which ultimately contributed to the formation of additional number of capsules per plant. Thus, these parameters could act as good indicators for increasing yield potential in black cumin. These results were in agreement with the findings of Bannaya *et al.* (2008), Safaei *et al.* (2014) and Ghanespasanda *et al.* (2014).

Days to flower initiation

Results presented in Table 3 showed that the mean minimum period (60.67 days) was required for flower initiation in case of I_5 (irrigation at 50% field capacity) whereas the maximum period (65.67 days), was recorded in treatment I_1 (irrigation at 90% field capacity) which was statistically similar to treatment I_2 (irrigation at 80% field capacity) followed by I_3 and I_4. This result indicated that availability of insufficient soil moisture (irrigation at 50% of FC as in treatment

I_5) leads to restricted nutrient mobility and its' availability to crops resulting to early flowering and early maturity of crop. Similar result was noted by Norozpoor and Rezvani Moghaddam (2002).

Days to capsule setting

The reverse case was found in I_1 treatment where the maximum soil moisture was maintained that possibly favored in higher availability of nutrients and ultimately resulted in prolonged period (71.67 days) for capsule setting (Table 3).

Number of leaves per plant

Irrigation treatments significantly influenced the number of leaves per plant (Table 3). The mean maximum number of leaves per plant (36.1) was recorded in treatment I_1 (irrigation at 90% field capacity) and the minimum leaves per plant (11.0) was noted in treatment I_5 (irrigation at 50% field capacity). Higher number of leaves in plant can produce higher amount of photosynthate, thus produced higher carbohydrate. Similar result was reported by English and Raja (1996).

Table 3. Effect of soil moisture levels on different growth parameters of black cumin

Soil moisture levels	Plant height (cm)	No. of Branches per plant	Days to flower initiation	Days to capsule setting	No. of leaves per plant
I_1	65.8a	7.5a	65.7a	71.7a	36.1a
I_2	62.2b	6.5b	65.3a	71.0a	31.1b
I_3	49.1c	6.1b	63.3b	68.3b	27.4c
I_4	38.6d	5.3c	63.0b	67.3b	19.7d
I_5	23.3e	4.3d	60.7c	65.7c	11.0e
CV (%)	1.97	4.58	0.84	1.29	2.92

Number of umbellets per plant

The number of umbellets per plant differed significantly due to variation of soil moisture status (Table 4). The mean maximum number of umbellets per plant (52.0) was recorded in treatment I_1 (irrigation at 90% field capacity), while the minimum number of umbellets per plant (11.7) in treatment I_5 (irrigation at 50% field capacity). The number of umbellets per plant directly influenced the number of capsules per plant. This was probably due to maintenance of optimum moisture regime that favored adequate nutrient uptake by plant and led to production of more branches as well as more number of umbellets per plant. These results are in agreement with the results of Ghamarina *et al.* (2014), Senyigit and Arslan (2018).

Number of capsules per plant

Results presented in Table 4 exhibited that the mean maximum number of capsules (45.8) per plant was produced by treatment I_1 (irrigation at 90% field capacity) and the minimum values (4.7capsules per plant) in I_5 representing irrigation at 50% field capacity. Total number of capsules per plant appeared to be the most important component since it is closely related with seed yield. Increase in number of capsules per plant indicated production of more number of flowers per umbel, higher percentage of capsule set and reduced shedding of flowers and capsules which resulted in increased yield. Similar results were documented by Akbarinia *et al*. (2005) and Mozaffari *et al.* (2000).

Capsule size

Capsule size is represented by the length and diameter of the capsule (Table 4). The mean maximum length (1.62 cm) and diameter (0.94 cm) of single capsule was observed in treatment I_1, while the minimum length (0.65 cm) and diameter (0.63 cm) of capsule was found in treatment I_5. Capsule growth is largely dependent on the rate of water accumulation and the water flow into the capsule in turn is dependent on the water potential difference between the capsule and plant. Capsule size directly affects the number of seeds per capsule which in turn impacted yield. Bigger size capsule had higher number of seeds. These results of present study are similar with the findings of Karim *et al*. (2017), Senyigit and Arslan (2018).

Weight of single capsule

The weight of single capsule was affected by the irrigation treatments (Table 4). The heaviest capsule (0.69 g) was recorded when irrigation was given at 90% field capacity and the lightest capsule (0.24 g) was observed with irrigation at 50% field capacity. Heavier capsules indicated the higher amount of seed. The result is in agreement with the research findings of Akbarinia *et al.* (2005).

Table 4. Effect of soil moisture levels on different yield components of black cumin

Soil moisture levels	No. of umbellets per plant	No. of capsule per plant	Capsule size		Single capsule weight (g)
			Capsule length (cm)	Capsule diameter (cm)	
I_1	52.0a	45.8a	1.62a	0.94a	0.69a
I_2	45.6b	39.6b	1.48b	0.88ab	0.60b
I_3	37.0c	31.9c	1.38b0	0.84bc	0.38c
I_4	26.0d	21.1d	1.15c	0.77c	0.33c
I_5	11.7e	4.7e	0.65d	0.63d	0.24d
CV (%)	3.65	5.02	5.24	4.82	10.17

Number of seeds per capsule

The number of seeds per capsule was influenced by the irrigation treatments (Table 5). The highest mean number of seeds per capsule (126.6) was noted in I_1 treatment (irrigation at 90% field capacity) and the lowest number of seeds per capsule (52.9) being observed with irrigation at 50% field capacity. Higher number of seeds per capsule is the indicator of higher yield per plant. The same opinion was made by Gorbanli *et al*. (1999) and Mozaffari *et al.* (2000)

1000-seed weight

The weight of 1000-seed was significantly affected by the irrigation treatments (Table 5). The highest weight of 1000-seed (2.72 g) was recorded in treatment I_1 and the lowest weight (1.1 g) was noted in treatment I_5. The 1000-seed weight might have influenced by several factors such as variety, growing condition, climatic factors, and soil properties, cultural and nutrient management. Similar trends of results were obtained by Ghanespasanda *et al.* (2014) and Gorbanli *et al*. (1999).

Seed yield

The data presented in Table 5 revealed that irrigation treatments influenced the seed yield of black cumin. The maximum mean seed yield (1243.0 kg ha^{-1}) was obtained with the maximum soil moisture level in I_1 treatment (irrigation at the attainment of 90% field capacity) and the minimum seed yield (165.5 kg ha^{-1}) in I_5 treatment (irrigation at 50% field capacity). The higher seed yield of black cumin under higher soil moisture regimes may be attributed to higher availability of nutrients and attainment of improved yield contributing components which ultimately resulted in higher seed yield. The present results are in agreement with the results obtained by Bannayan *et al.* (2008) and Karim *et al.* (2017).

Biomass yield

Biomass yield of black cumin was significantly influenced by the irrigation treatments (Table 5). The maximum mean biomass yield (2595.0 kg ha^{-1}) was obtained when irrigation were applied at the attainment of 90% field capacity and the minimum biomass yield (727.0 kg ha^{-1}) in irrigation at 50% field capacity. Plant photosynthetic capacity and the pattern of carbon distribution among its organs are generally governed by moisture availability of soil. Similar results are reported by Gorbanli *et al*. (1999) and Mozaffari *et al.* (2000).

Harvest Index

Results stated in Table 5showed that the harvest index was influenced by the irrigation treatments. The maximum average harvest index (47.89%) was recorded underirrigation at 90% field capacity (I_1) followed by 44.74% at applied irrigation at 80% field capacity (I_2) and the lowest harvest index (22.76%) was observed with irrigation at 50% field capacity (I_5). It is clearly understood from the results that water stressed plant had a lower proportion of assimilates than well-watered plants. These results were in agreement with the research findings of Mozaffari *et al.* (2000). Maintenance of higher soil moisture resulted in better vegetative growth, which might have supported directly to the reproductive organs and contributed to a good harvest index of the crop. After pollination, the materials are transmitted to seeds and the water plays an important role in transmission process of materials. So, lack of optimum soil moisture, transmission process of water decreased, resulting in the reduced harvest index as have also been opined by Safaei *et al*. (2014) and Mozzafari *et al.* (2000).

Table 5. Effect of soil moisture levels on yield components, seed yield, biomass yield and harvest index of black cumin

Soil moisture levels	No. of seeds per capsule	1000-seed weight (g)	Seed Yield (kg ha^{-1})	Biomass Yield (kg ha^{-1})	Harvest Index (%)
I_1	126.6a	2.72a	1243.0a	2595a	47.89
I_2	111.8b	2.47b	993.4b	2220b	44.74
I_3	98.0c	2.19c	734.0c	1936c	37.91
I_4	65.7d	1.53d	563.5d	1580d	35.66
I_5	52.9e	1.10e	165.5e	727e	22.76
CV (%)	1.64	3.59	7.17	7.37	-

Nitrogen uptake

Nitrogen uptake by black cumin under different soil moisture levels was studied to understand the movement of N in black cumin plants under different soil moisture conditions (Table 6). Significant difference in N uptake of black cumin occurred by different soil moisture levels. Increased soil moisture led to increased N uptake by plant, which contributed vigorous growth of plants. The maximum uptake of N (134.14 kg ha^{-1}) was observed under higher frequency of irrigation in I_1 treatment followed by I_2 (101.92 kg ha^{-1}), I_3 (65.99 kg ha^{-1}) and I_4 (51.23 kg ha^{-1}) and the minimum uptake (15.07 kg ha^{-1}) in T_5 (irrigation at 50% field capacity). Maintenance of optimum soil moisture levels in soil had favored in better plant growth as well as transpiration rate, thus the N movement was also higher. Similar result is found by English and Raja (1996).

Residual soil N after crop harvest

The data presented in Table 6 revealed that irrigation treatments affected the residual N fertility status of soil. The maximum value of residual N (1793.3 kg ha^{-1}) was recorded in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (1789.7kg ha^{-1}), I_3 (1782 kg ha^{-1}) and I_2 (1771.7 kg ha^{-1}) and the minimum value (1766.3 kg ha^{-1}, respectively) was noted treatment I_1 (irrigation at 90% field capacity). It can be inferred from the results that higher moisture availability led to higher N mining and ultimately resulted in less N reserves in soil. It may also be calculated that the amount of nutrient (N) up taken by crops is inversely related to the amount of nutrients reserve in soil. These results are in agreement with the research findings of Ahmadian *et al.* (2011)**.**

Apparent N balance

Apparent N balance was influenced by irrigation treatments (Table 6). The minimum negative apparent N balance (-29.06 kg ha^{-1}) was recorded at treatment I_1 (irrigation at 90% field capacity) and the maximum negative apparent N balance (-120.5 kg ha^{-1}) was noted in in I_5 treatment (irrigation applied at 50% field capacity).

Net N balance

Nitrogen balance may also be termed as N budget or N audit in cultivated land to maintain higher soil productivity in the future. Positive balance indicated the N accumulation and negative balance shows N depletion. To achieve N sustainability, the quantity of N inputs and outputs should be equal. Negative N balance may eventually cause soil degradation and adversely affect crop production. On the other hand, excess N accumulation may lead to soil and water pollution. The irrigation treatments created considerable impact on soil fertility (Table 6). Negative balance of N was increased with increasing soil moisture level. The minimum negative net N balance (-6.7 kg ha^{-1}) was observed in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (-10.3 kg ha^{-1}), I_3 (-18 kg ha^{-1}) and I_2 (-28.3 kg ha^{-1}) and the maximum negative net N balance (-33.7 kg ha^{-1}) was recorded at treatment I_1 (irrigation at 90% field capacity). Maintenance of higher soil moisture in I_1 treatment has led to higher mobility and translocation of nutrients (N) that might have resulted in maximum exhaustion of N in soil and exhibited the maximum negative balance of N.

Table 6. Effect of soil moisture levels on N balance sheet after harvest of black cumin

Soil moisture levels	Initial soil N status	Added N through fertilizer	N uptake	Residual soil N after harvest	Apparent N balance	Net N balance
	A	B	C	D	D-{(A+B)-C} =E	D-A=F
	(kg ha^{-1})					
I_1	1800	129.5	134.14a	1766.3e	-29.06	-33.7
I_2	1800	129.5	101.92b	1771.7d	-55.88	-28.3
I_3	1800	129.5	65.99bc	1782.0c	-81.51	-18
I_4	1800	129.5	51.23c	1789.7b	-88.57	-10.3
I_5	1800	129.5	15.70c	1793.3a	-120.5	-6.7
CV (%)	-	-	5.97	0.10	-	-

Phosphorus uptake

Phosphorus uptake by black cumin was studied to understand the translocation of P in black cumin plants under different moisture regimes (Table 7). Significant difference in P uptake of black cumin occurred due to different soil moisture levels. Increased soil moisture led to increased P uptake by plant, which contributed to vigorous growth of plants. The maximum uptake of P (12.28 kg ha^{-1}) was observed under higher frequency of irrigation in I_1 treatment followed by I_2 (9.12 kg ha^{-1}), I_3 (6.21 kg ha^{-1}) and I_4 (4.36 kg ha^{-1}) and the minimum uptake (0.58 kg ha^{-1}) in T_5 (irrigation at 50% field capacity).

Residual soil P after harvest

The data presented in Table 7 revealed that irrigation treatments affected the residual P fertility status of soil. The maximum value of available P after harvest (16.2 kg ha^{-1}) was recorded in I_5 treatment (irrigation applied at 50% field capacity) followed by $I_4$15.8 kg ha^{-1}), I_3 (15.6 kg ha^{-1}) and I_2 (15 kg ha^{-1}) and the minimum value (14.4 kg ha^{-1}) was noted treatment I_1 (irrigation at 90% field capacity). It can be inferred from the results that higher moisture availability led to higher P mining and ultimately resulted in less P reserves in soil.

Apparent P balance

The minimum negative apparent P balance (-18.42 kg ha^{-1}) was recorded in I_1 treatment (irrigation at 90% field capacity) followed by I_2 (-20.98 kg ha^{-1}), I_3 (-23.29 kg ha^{-1}) and I_4 (-24.94 kg ha^{-1}) and the maximum negative value (-28.82 kg ha^{-1}) was recorded at I_5 treatment (irrigation at 50% field capacity).

Table 7. Effect of soil moisture levels on P balance sheet after harvest of black cumin

Soil moisture levels	Initial soil P status	Added P through fertilizer	P uptake	Residual soil P after harvest	Apparent P balance	Net P balance
	A	B	C	D	D-{(A+B)-C} =E	D-A=E
	(kg ha^{-1})					
I_1	13.6	31.5	12.28a	14.4c	-18.42	0.8
I_2	13.6	31.5	9.12b	15.0bc	-20.98	1.4
I_3	13.6	31.5	6.21b	15.6ab	-23.29	2.0
I_4	13.6	31.5	4.36b	15.8a	-24.94	2.2
I_5	13.6	31.5	0.58c	16.2a	-28.32	2.6
CV (%)	-	-	12.79	2.61	-	-

Net P balance

The irrigation treatments created considerable impact on P reserve in soil (Table 7). The maximum net P balance (2.6 kg ha^{-1}) was recorded in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (2.2kg ha^{-1}), I_3 (2.0kg ha^{-1}) and I_2 (1.4kg ha^{-1}). The minimum P balance (0.8 kg ha^{-1}) was calculated at treatment I_1 (irrigation at 90% field capacity). It may be due to higher soil moisture availability might have caused higher P availability to plants and ultimately higher P mining from soil.

Potassium uptake

Potassium uptake by black cumin under different soil moisture levels were studied (Table 8). Significant difference in K uptake by black cumin occurred under different soil moisture levels. Increased soil moisture led to increased K uptake by plant, which contributed increased growth and yield. The maximum uptake of K (89.12 kg ha^{-1}) was observed under higher frequency of irrigation in I_1 treatment followed by I_2 (69.40 kg ha^{-1}), I_3 (37.94 kg ha^{-1}) and I_4 (35.97 kg ha^{-1}) and the minimum uptake (11.69 kg ha^{-1}) in T_5 (irrigation at 50% field capacity).

Residual soil K after harvest

The data presented in Table 8 showed that irrigation treatments affected the residual K fertility status of soil. The maximum value of residual K (42.6 kg ha^{-1}) was recorded in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (38.4 kg ha^{-1}), I_3 (35 kg ha^{-1}) and I_2 (34.3 kg ha^{-1}) and the minimum value (32.5 kg ha^{-1}) was noted treatment I_1 (irrigation at 90% field capacity). It can be inferred from the results that higher moisture availability led to higher K mining and ultimately resulted in less K nutrients reserves in soil.

Apparent K balance

The minimum negative apparent K (-0.18 kg ha^{-1}) was recorded in I_1 treatment (irrigation at 90% field capacity) followed by I_2 (-18.1 kg ha^{-1}), I_4 (-47.43 kg ha^{-1}) and I_3 (-48.86 kg ha^{-1}) and the maximum negative (-67.51 kg ha^{-1}) was recorded at I_5 treatment (irrigation at 50% field capacity).

Net K balance

The irrigation treatments created considerable impact on soil K fertility (Table 8). Negative balance of K increased with increasing soil moisture level. The minimum negative net K balance (-4.2 kg ha^{-1}) was observed in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (-8.4 kg ha^{-1}), I_3 (-11.8 kg ha^{-1}) and I_2 (-12.5 kg ha^{-1}). The maximum negative net K balance (-14.3 kg ha^{-1}) was recorded at treatment I_1 (irrigation at 90% field capacity). It may be due to higher availability of soil moisture as well as higher mobility and exhaustion of K.

Table 8. Effect of soil moisture levels on K balance sheet after harvest of black cumin

Soil moisture levels	Initial soil K status	Added K through fertilizer	K uptake	Residual soil K after harvest	Apparent K balance	Net K balance
	A	B	C	D	D-{(A+B)-C} =E	D-A=E
	(kg ha^{-1})					
I_1	46.8	75	89.12a	32.5d	-0.18	-14.3
I_2	46.8	75	69.40b	34.3c	-18.1	-12.5
I_3	46.8	75	37.94c	35.0c	-48.86	-11.8
I_4	46.8	75	35.97cd	38.4b	-47.43	-8.4
I_5	46.8	75	11.69d	42.6a	-67.51	-4.2
CV (%)	-	-	1.48	1.10		-

Sulfur uptake

Sulfur uptakes by black cumin under different soil moisture levels are presented in the Table 9. Significant difference in S uptake by black cumin have been recorded under different soil moisture regimes. Increased soil moisture led to increased S uptake by plant, which ultimately contributed growth and yield of black cumin. The maximum uptake of S (11.82 kg ha^{-1}) was observed under higher frequency of irrigation in I_1 treatment followed by I_2 (8.73 kg ha^{-1}), I_3 (5.92 kg ha^{-1}) and I_4 (3.71 kg ha^{-1}). The minimum uptake (0.65 kg ha^{-1}) of S was noted under water stress condition in T_5 treatment (irrigation at 50% field capacity closed to wilting point) might have led to the maximum S reserve in soil.

Residual soil S after harvest

Post-harvest S contents in soil varied significantly with the variation of irrigation levels (Table 9). The maximum value of residual S (15.1 kg ha^{-1}) was recorded in I_5 treatment (irrigation applied at 50% field capacity) followed by I_4 (14.3kg ha^{-1}), I_3 (13.0 kg ha^{-1}) and I_2 (11.9 kg ha^{-1}). The minimum value (11.3 kg ha^{-1}) being documented in treatment I_1 (irrigation at 90% field capacity). It can be inferred from the results that higher moisture availability led to higher S mining and exhaustion and ultimately led to minimum S reserves in soil.

Apparent S balance

The minimum negative apparent S (-2.99 kg ha^{-1}) was recorded in I_5 treatment (irrigation at 50% field capacity) followed by I_1 (-12.98 kg ha^{-1}), I_2 (-15.47kgha^{-1}) and I_3 (-17.18kgha^{-1}) and the maximum negative (-18.09 kgha^{-1}) value was recorded in I_4 treatment (irrigation at 60% field capacity).

Net S balance

Balance of S was reduced with increasing soil moisture level (Table 9). All irrigation treatments showed negative balance of S and in the order I_5 (0.5 kgha^{-1})> I_4 (-1.3kg ha^{-1}) >I_3 (-2.6kg ha^{-1}) >I_2 (-3.6 kg ha^{-1}). The maximum S depletion or net negative S balance (-4.3 kg ha^{-1}) was recorded at treatment I_1 (irrigation at 90% field capacity). It is clear that higher the soil moisture availability higher is the S mobility, translocation and maximum use of S by the crop.

Table 9. Effect of soil moisture levels on S balance sheet after harvest of black cumin

Soil moisture levels	Initial soil S status	Added S through fertilizer	S uptake	Residual soil S after harvest	Apparent S balance	Net S balance
	A	B	C	D	D-{(A+B)-C} =E	D-A=E
	(kg ha^{-1})					
I_1	15.6	20.5	11.82a	11.3d	-12.98	-4.3
I_2	15.6	20.5	8.73ab	11.9d	-15.47	-3.7
I_3	15.6	20.5	5.92b	13.0c	-17.18	-2.6
I_4	15.6	20.5	3.71b	14.3b	-18.09	-1.3
I_5	15.6	20.5	0.65c	15.1a	-2.99	-0.5
CV (%)	-	-	13.46	3.07	-	-

Table 10. Total amount of irrigation water, soil moisture contribution and effective rainfall during the cropping period of black cumin under different soil moisture levels

Soil moisture levels	Common irrigation for seedling establishment (mm)	No. of irrigation	Amount of imposed irrigation water (mm)	Total amount of irrigation (mm)	Soil moisture (mm)	Effective rainfall (mm)
I_1	22.4	11	90.7	113.1	3.7	1.53
I_2	22.4	08	85.7	108.1	4.6	1.53
I_3	22.4	06	81.8	104.2	5.7	1.53
I_4	22.4	04	77.0	99.4	6.8	1.53
I_5	22.4	-	-	22.4	7.3	1.53

Soil moisture contribution and effective rainfall

Data on soil moisture contribution and effective rainfall are given in Table 10. The minimum soil moisture contribution (3.7 mm) was recorded under higher frequency of irrigation in treatment I_1 (irrigation at 90% field capacity). The maximum value (7.3 mm) being noted in treatment I_5(irrigation at 50% field capacity). Most of the water demand of the crop in I_1 treatment (the highest irrigation level) has been fulfilled by the irrigation water that has led to minimum use or contribution of soil water, but the crop grown under the lowest moisture level in I_5 treatment has undergone water stress condition and led to the maximum exhaustion or use of soil moisture.

Consumptive use of water and water use efficiency

The total consumptive use of water and water use efficiency of the crop have been presented in Table 11. The highest consumptive use of water (118.33 mm) was marked under treatment I_1 followed by I_2 (114.23 mm), I_3 (111.43 mm), I_4 (107.73 mm) and the lowest value (31.23 mm) being noted in treatment I_5. In case of irrigation treatments, the maximum water use efficiency (21.94 and 10.51 kg ha^{-1} $mm^{-1}$for biomass and seed yield, respectively) was documented in treatment I_1 (irrigation at 90% field capacity) followed by I_2 (19.47 and 8.69 kg ha^{-1} $mm^{-1}$for biomass and seed yield, respectively), I_3 (17.37 and 6.59 kg ha^{-1} $mm^{-1}$for biomass and seed yield, respectively) and I_4 (14.67 and 5.23 kg $ha^{-1}mm^{-1}$for biomass and seed yield, respectively). It is important to note here that the treatment I_5 (irrigation at 50% field capacity, equivalent to wilting point) did not receive any irrigation at all. The total water use (from soil moisture contribution and rainfall) was only 31.23 mm that has led to attain the highest water use efficiency (23.28 k $gha^{-1}mm^{-1}$) on the basis of biomass yield of only 727.0 kg ha^{-1} (the lowest) as compared to the highest yield of 2595.0 $kgha^{-1}$ under the highest irrigation regime in I_1 treatment. But in case of seed yield of black cumin the highest water use efficiency (10.51 kg $ha^{-1}mm^{-1}$) was recorded under the highest irrigation frequency in I_1 treatment. Thus, considering the seed yield and water use efficiency of black cumin the treatment I_1 (irrigation at 90% field capacity) may be selected for cultivation of the crop in the studied area.

Table 11. Total consumptive use of water and water use efficiency of black cumin as affected by soil moisture levels

Soil moisture levels	Total consumptive use of water (mm)	Biomass yield (kg ha^{-1})	Seed yield (kg ha^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})	
				On the basis of biomass yield	On the basis of seed yield
I_1	118.23	2595.0	1243.0	21.94	10.51
I_2	114.23	2220.0	993.4	19.43	8.69
I_3	111.43	1936.0	734.0	17.37	6.59
I_4	107.73	1580.0	563.5	14.67	5.23
I_5	31.23	727.0	165.5	23.28	5.29

Cost-benefit analysis of irrigation forblack cumin

The results of cost-benefit analysis related with application of different soil moisture levels are presented in Table 12. Generally, the benefits of application of irrigation water exceed the non-irrigated treatment both in yield and return. The highest net income (123503 Tk) was recorded in I_1(Irrigation at 90% field capacity) followed by I_2 (86675 Tk) and the negative net income (-400747 Tk) in I_5 (Irrigation at 50% of field capacity). The highest marginal rate of returns (74.79%) was notedinI_4 (Irrigation at 60% field capacity) followed by44.82% inI_2treatment (Irrigation at 80% field capacity) (Table 13).

Table 12. Cost benefit analysis of black cumin as affected by soil moisture levels

Treatment	Variable cost (Tk)				Income (Tk)		Rank
	Input cost	Labor cost	Fixed cost	Total variable cost	Gross income	Net income	
	A	B	C	D=A +B+C	E	F= E-D	
I_1	37337	32900	30000	100237	223740	123503	1
T_2	31337	30800	30000	92137	178812	86675	2
T_3	27337	29400	30000	86737	132120	45383	3
T_4	23337	28000	30000	81337	101430	20093	4
T_5	15337	25200	30000	70537	29790	-40747	5

Table 13. Marginal rate of return (MRR) in black cumin cultivation as affected by soil moisture levels

Treatment	Variable cost (TK)	Net income (TK)	MRR (%)	Rank
I_5	70537	-40747	-	-
I_4	81337	20093	74.79	1
I_3	86737	45383	29.16	4
I_2	92137	86675	44.82	2
I_1	100237	123503	36.74	3

Conclusion

It may thus be concluded from the results of the present study studies that seed yield of black cumin increased with the increased soil moisture level. The highest seed yield potential (1243.0 kg ha^{-1}) with the highest water use efficiency (10.51 $kgha^{-1}mm^{-1}$) of the crop may be achieved in the Shallow Red-Brown Terrace Soil of Salna Series under the highest soil moisture regime (irrigation at 90% of field capacity). The total requirement of irrigation water was 113.1 mm which was applied through 11 irrigations. Nutrient mining or negative nutrient balance of N, P, K and S were observed in the study. So, for achieving equilibrium nutrient balance and maintaining sustainable increased soil productivity, proper management of soil fertility was recommended.

Reference

Ahmadian, A., A. Tavassoli and E. Amiri. 2011.The interaction effect of water stress and manure on yield components, essential oil and chemical compositions of cumin (*Cuminumcyminum*L.). *African J. Agric. Res.*,**6(10)**: 2309-2315.

Akbarinia, A., M. Khosravifard, A. Ashorabadi and P. Babakhano. 2005. Effect of irrigation on yield and agronomic characteristics of black cumin (*Nigellasativa*). *J. Medici. Aroma. Plants*, **21(1)**: 65-73.

Bannayan, M., F. Nadjafib, M. Azizia, L. Tabrizia and M. Rastgoo. 2008. Yield and seed quality of *Plantago ovate* and *Nigella sativa* under different irrigation treatments. *Industrial Crops Prod.,* **27(1)**: 11-16.

English, M. and S.N. Raja. 1996. Perspectives of deficit irrigation. *J. Agric. Water Manag.,* **32**: 1–14.

Ghamarnia, H., E. Miri and M. Ghobadei. 2014. Determination of water requirement, single and dual crop co-efficient of black cumin (*Nigella sativa* L.) in a semi-arid climate. *Irrig. Sci.,* **32**: 67–76.

Ghanbary, M.E., M. J. Mirhadi, R. A. H. Shirani and B. Delkhosh. 2008. The effect of no irrigation from stem elongation on agronomic traits, seed yield and oil content of rapeseed. *Plant Ecosyst*., **16**: 69-85.

Ghanespasanda, F., G. Noormohamadi, M. R. Haj SeyedHadi and M. T. Darzi.2014. Influence of manure application and nitrogen fixing bacteria on yield and yield components of black cumin (*Nigellasativa* L.). *Intl. J. Adv. Biol. Biom. Res*., **2(3)**: 628-635.

Gorbanli, M., A. Babaie, B. Babakhanloo and M. Mirza. 1999. Effect of water stress on (*Nigella sativa* L.) growth and development, quantity, and quality of essential oil and amount of seed oil. *Iranian J. Agric. Sci.,* **30(3)**: 585-593.

Karim, M., R. M. Himel, J.Ferdush and M .Zakaria. 2017. Effects of irrigation levels on yield performance of black cumin. *Intl. J. Environ. Agric. Biotech.*,**2(2)**: 960-966.

Mozaffari, F.S., M. Ghorbanli, A. Babai and M. F. Sepeher. 2000. The effect of water stress on the seed oil of black cumin (*Nigella sativa* L.). *J. Essential oil Res.*,**12(1)**: 36-38.

Norozpoor, G. and P. Rezvani Moghaddam. 2002. Effect of different irrigation intervals and plant density on yield and yield components of black cumin (*Nigellasativa* L.). *Pajoushesh & Sazandegi*, **73**: 133-138.

Rajsekhar, S. and B.Kuldeep. 2011. Pharmacognosy and pharmacology of *Nigella sativa* - a review. Int. Res. J. Pharm., **2(11)**: 36-39.

Safaei, Z., M.Azizi, Y. Maryam, H. Aroiee and G. Davarynejad. 2014. The effect of different irrigation intervals and anti-transpiration compounds on yield and yield components of black cumin (*Nigell asativa*). *Intl. J. Adv. Biol. Biomed. Res.,* **4(2)**: 326-335.

Senyigit, U. and M.Arslan. 2018. Effect of irrigation progress formed by different approaches on the yield and water consumption of black cumin (*Nigella sativa* L.) under Transiitia zone in the west Anatolia conditions. *J. Agril. Sci.,* **24**: 22-32.

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SCREENING OF BETELVINE CULTIVARS AGAINST *SCLEROTIUM ROLFSII* CAUSING FOOT AND ROOT ROT DISEASE

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Abstract

Thirteen betelvine cultivars (PB 001 to PB 013) collected from different locations of Bangladesh showed remarkable variations in disease reaction to foot and root rot caused by *Sclerotium rolfsii*. The lowest incubation period 8 days was required for the cultivars PB 005 (BARI line), PB 006 (Misti pan), PB 009 (BARI Pan-1) and PB 010 (Bangla pan) and the highest incubation period 22 days was required for the cultivars PB 001 (Laldingi pan) and PB 013 (Gayasur pan) for appearance of 1st disease symptoms. The disease incidence ranged 8.33 to 100% at 30 days after inoculation. The lowest disease incidence was recorded in PB 001 (Laldingi pan), while the highest disease incidence was recorded from PB 002, PB 003 (Chalitaguti pan), PB 004 (Sanchi pan), PB 005, PB 006 (Misti pan), PB 007, PB 008, PB 009 (BARI Pan-1), PB 010 (Bangla pan) and PB 012 (Bhabna pan) followed by PB 011 (Jhal pan) and PB 013 (Gayasur pan). Based on incidence of foot and root rot on those cultivars, PB 001 (Laldingi) was graded as resistant, PB 011 (Jhal pan) and PB 013 (Gayasur pan) as moderately susceptible and rest of the cultivars as susceptible.

Keywords: Betelvine, cultivars, foot and root rot, resistance

Introduction

Betelvine (*Piper betle* L.) is an important cash crop mainly for its leaves, which are used for chewing purpose (Maity and Shivashankara, 1998). Total cultivated area under the crop in Bangladesh in 2016-17 was about 23,803.20 hectares and the total annual production was about 2,14,252 metric tons. The average yield per hectare is 9.0 metric tons (BBS, 2018). Betelvine is one of the least land-intensive and highly labour- intensive crops (Sen and Roy, 1984). This crop has great market value both inside and outside Bangladesh and its export started to Europe in 1974-75 and to Saudi Arabia in 1991. Bangladesh annually exports betel leaves worth around TK.123 crore to Saudi Arabia. The country exported 4,984 tons betel leaves in the year 2017-18 mainly to Middle East countries including Saudi Arabia (Jasim Uddin, 2018). Betelvine is a dioecious plant, propagated vegetatively for commercial cultivation. There are about 100 varieties of betelvine across the world, out of which 30 varieties are from West Bengal and Bangladesh (Guha and Jain, 1997). The origin of betelvine is thought to be Malayasia (Das *et al*., 2016). Betel leaves contain some vitamins, enzymes,

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thiamine, riboflavin, tannin, iodine, iron, calcium, minerals, protein, essential oil and medicine for liver, brain and heart diseases (Chopra *et al*., 1956).

Despite of the tremendous potential of the crop, cultivation of betelvine is highly risky and returns are uncertain because of its vulnerability to several pests and diseases, aggravated by the moist and humid conditions in the plantation. Among them foot and root rot caused by *Sclerotium rolfsii* is the major constraints for cultivation of the betelvine crop (Goswami *et al.,* 2002). The fungus *S. rolfsii* is a facultative parasite and can maintain continuity of its generation under adverse situation by the formation of resting structure called sclerotia. In severely infected field, loss ranges from 10 to 25% and sometimes, it reaches up to 80% (Mehan and McDonald, 1990).

Detection of *S. rolfsii* resistance betelvine cultivars is of paramount importance for betelvine improvement and cost-effective cultivation. Till date, there is limited information on the resistance source of betelvine against *S. rolfsii* causing foot and root rot disease. The present study was conducted to evaluate the response of betelvine entries against *S. rolfsii* for the identification of resistance sources in available genotypes in Bangladesh.

Materials and Methods

A total of 13 betelvine cultivars were collected from different betelvine growing areas of Bangladesh as described in Table 1. The cultivars were screened for their resistance against *S. rolfsii,* causal pathogen of foot and root rot of betelvine. The experiment was conducted *in-vivo* in earthen pot in a betelvine yard, commercially known as 'baroj'. The baroj was constructed in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh. The experiment was conducted during March, 2016 to March, 2017. The experiment was laid out in a randomized complete block design (RCBD) with 4 replications. Data were recorded on various resistance components and analyzed statistically by using computer package program (Statistix 10).

Table 1. List of betelvine cultivars used in screening experiment against *Sclerotium rolfsii* causing foot and root rot disease

Entry	Name of Cultivar	Location of collection (Upazilla and Zilla)
PB 001	Laldingi pan	Pakundia, Kishoreganj.
PB 002	-	Spices Research Centre, BARI, Bogura.
PB 003	Chalitaguti pan	Gouronadi, Barisal.
PB 004	Sanchi pan	Kaliganj, Jhenaidah
PB 005	-	Spices Research Centre, BARI, Bogura.
PB 006	Misti pan	Mohanpur, Rajshahi
PB 007	-	Spices Research Centre, BARI, Bogura.
PB 008	-	Spices Research Centre, BARI, Bogura.
PB 009	BARI Pan-1	RARS, Barisal.
PB 010	Bangla pan	Mirpur, Kushtia.
PB 011	Jhal pan	Sitakunda, Chattogram.
PB 012	Bhabna pan	Kaligonj, Jhenaidah
PB 013	Gayasur pan	Pakundia, Kishoreganj.

Growing betelvine plants

Apparently healthy betelvines of different cultivars were used to prepare cuttings. Forty centimeter long cutting having five nodes each was prepared and grown in 14 inches diameter earthen pots containing potting medium at one plant per pot. The pots were placed inside the betelvine orchard (baroj) and allowed to grow providing necessary care and management practices. One to two internodes below the bud point was dipped into the soil, kept touching with surface soil. Potting medium was prepared by mixing soil, sand and well decomposed cow-dung in the proportion of 2:1:1 by volume and were sterilized with formaldehyde. Formalin solution (4%) @ 200 ml/cft soil was mixed with the soil heap and the soil was covered with a polythene sheet for 48 hours for sterilization. After 7 days, surface sterilized earthen pots were filled with the sterilized soil (Dashgupta, 1988). Betelvine plants were fasten with bamboo sticks used in the baroj.

Inoculum preparation and inoculation

A virulent isolate of *S. Rolfsii* was multiplied on barley grains (Gupta and Kolte, 1982). Barley grains were soaked in 2% sucrose solution overnight, drained off excess solution and boiled in fresh water for 30 minutes and drained off again. The grains were transferred into 250 ml conical flasks @ 80 g per flask and autoclaved at 121.6^0C under 1.1 kg/cm^2 pressures for 20 minutes. The conical flasks were allowed to cool at room temperature and the grains inside were inoculated with 5 mm discs of 3 to 4 days old culture of *Sclerotium rolfsii* grown on PDA. Seven discs were added into each flask and the flasks were incubated for three weeks at 25 ± 2^0C.

After twelve months of plantation the betelvine cultivars were inoculated with freshly multipled isolate of *S. rolfsii*. The cultivars were prepared for inoculation by removing top soil within 5 cm of the stem to a depth of 2 cm. A table spoon (5 g) of inoculum was placed in direct contact of entire circumference of the exposed stem. Finally, the inoculum was lightly covered with top soil for infection and disease development. The symptomatology was studied to screen the betelvine entries for resistance to foot and root rot disease.

Data collection and grading of cultivars

Data on days to appearance of visible symptom and incidence of foot and root rot on different cultivars including susceptible check were recorded at 10, 15, 20, 25 and 30 days after inoculation. The tested cultivars were graded as resistant (R), moderately resistant (MR), moderately susceptible (MS) and susceptible (S) based on disease incidence determined on a 1 - 4 scale, where disease incidence 0-10% (scale 1) = resistant (R), 11-30% (scale 2) = Moderately resistant (MR), 31-60% (scale 3) = Moderately susceptible (MS) and more than 61% (scale 4) = Susceptible (S).

The incidence of the disease was computed based on the following formula:

$$\% \text{ Disease incidence} = \frac{\text{Number of infected plant in the area covered}}{\text{Number of inspected plant}} \times 100$$

Results and Discussion

Days to appearance of disease symptom

The time interval required for appearance of first disease symptoms after inoculation differed considerably among the betelvine cultivars. The lowest incubation period of 8 days was required for the cultivars PB 005, PB 006 (Misti pan), PB 009 (BARI Pan-1) and PB 010 (Bangla pan). The highest incubation period of 22 days was required for the cultivars PB 001 (Laldingi pan) and PB 013 (Gayasur pan) (Table 2 and Plate 1). The incubation period for other cultivars ranged 9-20 days.

Disease incidence

Among the 13 betelvine cultivars, no disease symptom was observed in cultivars PB 001, PB 002, PB 003, PB 007, PB 008, PB 011 and PB 012 after 10 days f pathogen inoculation whereas PB 009 showed 66.66% disease incidence at the same days after inoculation (Table 2).

At 15 days after inoculation of pathogen, 100% disease incidence was observed in cultivar PB 009 (BARI Pan-1), no disease incidence (0%) was found in PB 001, PB 011 and PB 013.

At 20 days after inoculation, the highest disease incidence was observed in PB 005, PB 006, PB 009 and PB 010, followed by PB 007 and the lowest disease incidence was recorded in PB 001 and PB 013 followed by PB 011.

At 25 days after inoculation, the betelvine cultivars showed more or less similar disease incidence as observed at 20 days after inoculation. The minimum disease incidence was recorded in PB 001 (Laldingi) (8.33%) which was followed by PB 008, PB 011 and PB 013. The maximum disease incidence (100%) was recorded from PB 005, PB 006, PB 007, PB 009 and PB 010.

The final disease incidence recorded at 30 days after inoculation showed remarkable variations among different cultivars. The lowest disease incidence (8.33%) was recorded in cultivar PB 001 (Laldingi pan). The highest disease incidence (100%) was observed in PB 005, PB006, PB 007, PB 009 and PB 010 which was followed by PB 004, PB 012, PB 002, PB 003, PB 008, PB 011 (58.33%) and PB 013 (49.99%) (Table 2).

Grading of cultivars

The betelvine cultivars were graded into different categories of response to foot and root rot disease based on final disease incidence. Among the cultivars, only one cultivar PB 001 (Laldingi pan) showed resistant reaction (R), while cultivars PB 011 (Jhal pan) and PB 013 (Goyasur pan) displayed moderately susceptible response and rests of the cultivars were found susceptible (Table 2 and Plate 1)). The results revealed that the sources of resistance response to foot and root rot disease are limited in the available cultivars of betelvine in Bangladesh.

Table 2. Response of different betelvine cultivars of foot and root rot disease caused by *Sclerotium rolfsii*

Betelvine cultivars	Days to appearance of symptom	Percent disease incidence at different days after inoculation (DAI)					Disease reaction[ɵ]
		10	15	20	25	30	
PB 001 (Laldingi pan)	22	0.00c[α] (0.083)[β]	0.00f (0.083)	0.00d (0.083)	8.33d (8.56)	8.33d (8.56)	R
PB 002	12	0.00c (0.083)	33.33e (34.017)	33.33c (34.017)	66.66b (52.79)	83.33ab (69.81)	S
PB 003 (Chalitaguti pan)	11	0.00c (0.083)	66.66cd (52.799)	66.66b (52.799)	66.66b (52.80)	83.33ab (69.81)	S
PB 004 (Sanchi pan)	9	41.66b (38.71)	58.33de (48.104)	66.66b (52.799)	66.66b (52.80)	91.66a (78.32)	S
PB 005	8	41.66b (38.71)	75.00bc (65.115)	100a (86.822)	100a (86.82)	100a (86.82)	S
PB 006 (Misti pan)	8	58.33a (48.10)	91.67ab (78.316)	100a (86.822)	100a (86.82)	100a (86.82)	S
PB 007	11	0.00c (0.083)	66.66cd (52.799)	91.67a (78.316)	100a (86.82)	100a (86.82)	S
PB 008	11	0.00c (0.083)	33.33e (34.017)	33.33c (34.017)	33.33c (34.02)	66.66bc (52.80)	S
PB 009 (BARI Pan-1) (Control)	8	66.66a (52.79)	100a (86.822)	100a (86.822)	100a (86.82)	100a (86.82)	S
PB 010 (Bangla pan)	8	33.33b (34.02)	83.33b (69.811)	100a (86.822)	100a (86.82)	100a (86.82)	S
PB 011 (Jhal pan)	20	0.00c (0.083)	0.00f (0.083)	8.33d (8.56)	33.33c (34.02)	58.33c (48.10)	MS
PB 012 (Bhabna pan)	11	0.00c (0.083)	49.99de (43.408)	66.66b (52.799)	75.00b (61.31)	91.66a (78.32)	S
PB 013 (Gayasur pan)	22	0.00c (0.083)	0.00f (0.083)	0.00d (0.083)	25.00c (25.91)	49.99c (43.41)	MS

[α]Values within the same column with a common letter(s) do not different significantly (P=0.01).

[β] Data within parenthesis are square root or arc-sine transformed values

[ɵ] Disease reaction : R= Resistant, MS= Moderately susceptible, S= Susceptible

A B

C Susceptible plant Resistant plant D

Plate 1. *Sclerotium rolfsii* inoculated plant (A), mycelia formation on inoculated earthen pot (B), susceptible and resistant plant against *Sclerotium rolfsii* (C) and lesion on foot and root of betelvine plant (D).

Conclusion

Most of the betelvine cultivars screened in the present study were found susceptible to foot and root rot disease, only Laldingi pan (PB 001) was found resistant and Jhal pan and Gayasur pan showed moderately susceptible reaction. The information generated from the present study will help development of betelvine against foot and root rot disease.

References

BBS. 2018. Year Book of Agricultural Statistics of Bangladesh-2017, 29th Series. Bangladesh Bureau of Statistics, Statistics and Informatics Division, Ministry of Planning, Government of the Peoples' Republic of Bangladesh. 197 pp.

Chopra, R.N., Nayar, S.L. and Chopra, I.C. 1956. Glossary of Indian Medicinal Plants. CSIR, New Delhi, 194 p.

Dashgupta, M.K. 1988. Principles of Plant Pathology. Allied Publisher Private Limited. New Delhi, India. pp.700.

Das, S., Paridal, R., Sandeep, S., Nayak, S. and Mohanty, S. 2016. Biotechnological intervention in betelvine (*Piper betle* L.): A review of recent advances and future prospects. *Asian Pacific J. Tropic. Medicine*. 9(10):938-946.

Goswami, B.K., Kader, K.A., Rahman, M.L., Islam, M.R. and Malaker, P.K. 2002. Development of leaf spot of betelvine caused by *Colletotrichum capsici*. *Bangladesh J. Plant Pathol*. **18**(1&2): 39-42.

Guha, P. and Jain, R.K. (1997). Status Report on Production, Processing and Marketing of Betel Leaf (*Piper betle* L.). Agricultural and Food Engineering Department, IIT, Kharagpur, India, pp. 15-22.

Gupta, S.C and Kolte, S.J. 1982. A comparative study of isolates *Macrophomina phaseolina* from leaf and root of groundnut. *Indian Phytopathol.* **35**: 619-623.

Jasim Uddin. 2018. Govt. suspends betel leaf exports to KSA amid Saudi warning, Oct 09, Newage Business, Published by the Chairman, Editorial board on behalf of media newage ltd., Hamid plaza (4th floor), 300/5/A/1, Bir Uttam CR Datta Road, Hatirpool, Dhaka-1205.

Available: http://www.newagebd.net/article/52678/govt-suspends-betel-leaf-export-to-ksa-amid-saudi-warning

Maiti, S. and shivasankara, K.S. 1998. Betelvine Research Highlights (1981-1997*).* All India Coordinated Research Project on Betelvine, Bangalore, India, 21 p.

Mehan, V.K. and Mc Donald, D. 1990. Some important diseases of groundnut, sources of resistance and their utilization in crop improvement. Paper Presented in Country Training Course on Legumes Production, 9-17 July, Sri Lanka.

Sen, N.A. and Ray,A.K. 1984. Crisis in betelvine economy and trade inWest Bengal. In Proc. of Group Discussion on Improvement of Betelvine Cultivation. Eds. Khanduja, S.D. and Balasubrahmanyam, V.R.; National Botanical Research Institute, Lucknow, India, pp. 133-135.

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EFFECT OF DIFFERENT MULCHES AND PLANTING BEDS ON GROWTH AND YIELD OF BITTER GOURD IN COASTAL SALINE SOILS

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Abstract

A field experiment was carried out in coastal saline soils of Bangladesh in 2018, 2019 and 2020 to evaluate the effect of different kinds of mulches and planting beds to reduce salt accumulation in the soil and to increase the yield of bitter gourd. The experiment was laid out in a factional randomized complete block design having two kinds of mulches: *viz*. rice straw mulch and polythene mulch along with no mulch control and three kinds of planting beds: *viz*. convex bed, flat bed and concave bed. The polythene mulch treatment had highest fruit yield of 21.86, 27.20 and 20.49 t ha^{-1}, respectively followed by rice straw mulch and no mulch control treatment in 2018, 2019 and 2020, respectively. Polythene mulch reduced electrical conductivity of soil by 31% and soil sodium content by 42% compared to no mulch treatment. Polythene mulch also increased soil temperature and gravimetric soil moisture content which promoted plant growth. The convex bed method produced highest mean fruit yield of 18.37, 20.06 and 15.18 t ha^{-1} followed by the flat bed and concave bed method in the year 2018, 2019 and 2020, respectively. Combined use of polythene mulch and convex bed planting could provide greatest benefit to the farmers. The polythene mulch along with convex bed planting is therefore, recommended to get higher yield of bitter gourd and to reduce detrimental effect of salt on crop in coastal saline soils.

Keywords: Bitter gourd, convex bed; Na:K ratio; polythene mulch; saline soil.

Introduction

Salinity is a widespread environmental stress for crop plants in arid and coastal regions. Salinity in the soil and irrigation water restricts yield in about 20% of the global irrigated area which covers about 45 million ha (FAO, 2008). Increased salinity significantly reduced the growth and yield of crops including maize, mustard, sweet gourd, potato, chilli etc. (Haque *et al*., 2014; Ahmed *et al*., 2017; Haque *et al*., 2018). Huge effort has been made to develop saline soil management practices and different kinds of tillage systems so far developed. Among them raised bed planting with alternate furrow irrigation is gaining importance for row crops (Sayre, 2007; Devkota *et al*., 2013).

However, evaporation of water during the drying periods in raised bed alternate furrow irrigation system results in salt accumulation on the tops and side slopes of the raised beds (Richards, 1954). Such salt movement to the centre of the bed

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may damage young plants grown there (Brady and Well, 2013). The microsprinkler irrigation is another option which could be successfully used to cultivate plants for the reclamation of coastal saline land (Chu *et al*., 2015). However, furrow irrigation, flood irrigation or sprinkler irrigation requires huge amount of fresh water which is scarce in coastal saline areas; as such, water-saving irrigation regimes are needed (Sun *et al*., 2017). Growing high value vine crops in convex or concave pits and irrigate only in the foot of the crop may dilute the salt concentration in the root zone area which ultimately may contribute to higher crop yield.

Combining mulching and shape of the pit could be very effective because it changes the distribution of soil moisture and salinity in the vicinity of the crop root zone. Mulched drip irrigation has been shown to decrease soil evaporation considerably (Qi *et al*., 2018). Mulching technologies have also been shown to reduce total evapotranspiration, effectively promoted the growth of crops and increased the water use efficiency compared with the check (Li *et al*., 2018).

Mulching with crop residues in raised beds planting system has previously been shown to have great potential to reduce soil salinity in salt-affected areas (Devkota, 2011). However, crop residues are not always available in sufficient quantities for mulching due to their high demands as feed and fuel (Kienzler *et al*., 2012).

Polythene mulching along with convex or concave bed planting could be the powerful tool to manage saline soil. Because, polythene mulching significantly increased top layer soil temperature in early growth stage, reduced soil evaporation in the early stage and increase transpiration, accelerated plant growth and advanced maturity and help to reach higher yield and water use efficiency (Yang *et al*., 2018). Polythene mulching along with root zone irrigation can provide an alternative option to prevent the risk of soil salinization leading to land degradation, and enhance crop productivity in the arid regions (Tan *et al*., 2017).

The cucurbit vegetables are very much susceptible to salinity. Due to severe soil and water salinity the cucurbit vegetable production in the coastal areas are very small. Soil salinity also influenced some nutritional quality parameters including proline, sugar, sodium, potassium contents etc. The experiment is therefore undertaken to evaluate different kinds of mulch materials and different shapes of planting beds to increase bitter gourd yield in coastal seasonal fallow lands.

Materials and Methods

The experiment was conducted in the farmers fields during rabi seasons of 2018, 2019 and 2020, respectively at Kalapara upazila of Patuakhali district, and Taltali and Amtali upazila of Barguna district, Bangladesh. Experimental field was medium high land under the AEZ 13, Ganges Tidal Flood Plain Soil. Texturally the Kalapara upazila soil was loam having 11.6 % sand, 65.0 % silt and 23.4 % clay. The composite initial soil contained 5.66 pH, 0.09 % total nitrogen (N), 6.4 mg kg^{-1} available phosphorus (P) and 181.9 mg kg^{-1} available sulphur (S), and 37.84 meq $100g^{-1}$ soil exchangeable sodium (Na) and 0.35 meq $100g^{-1}$ soil exchangeable potassium (K), electrical conductivity determined in 1:5 soil water suspension was 0.67 dS m^{-1}. The Taltali upazila soil was silty clay loam having 32% clay, 65% silt and only 3% sand. The initial soil had 4.78 pH, 0.95 dSm^{-1} electrical conductivity ($EC_{1:5}$), 0.075% total N, 4.25 ppm available P, 141.4ppm available S contents. Regarding Amtali upazila texturally soil was again silty clay loam having 38% clay, 60% silt and only 2% sand. The initial soil had 4.54 pH, 0.71 dSm^{-1} $EC_{1:5}$, 0.050% total N, 2.83 ppm available P, 157.1ppm available S contents.

The experiment was laid out in a factional randomized complete block design with four replications. First factor for the experiment was the mulching methods having three levels comprising no mulch, rice straw mulch and polythene mulch; the second factor being three kinds (shapes) of seedling transplanting beds like convex bed, flat bed and concave bed. The raised bed and flat bed planting are widely used for crop cultivation in Bangladesh; few coastal farmers also practiced concave bed planting as they believe that in the concave bed the salt accumulation is lower and keep higher soil moisture content. Therefore, the said three kinds of planting beds were taken as treatment in the experimental. The nine treatment combinations were randomly distributed to the plots in each block. The test crop was bitter gourd and the crop variety was Lalteer hybrid Korola-Tia.

The whole land was prepared by ploughing followed by laddering three times. For planting of seedlings one meter diameter circular area was further prepared by a spade to make soil fine. In the experiment three kinds of seedling planting beds were prepared. In the flat bed type there was no change in soil surface and it was parallel to the field soil. The convex bed type was prepared by making the bed at least 5 cm high than the field soil level. The center of concave bed was at least 5 cm lower than the field level. The shape of different kinds of seedling planting beds is shown in Fig. 1. In polythene mulch system the seedling transplanting bed (pit) soil was covered with a one square meter size blue colour polythene sheet. In rice straw mulch system the seedling planting beds were covered with rice straw @ 5 t ha^{-1}.

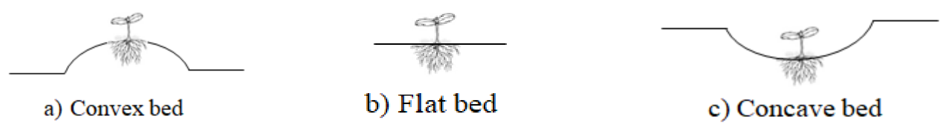

Fig. 1 Structure of different kinds of seedling planting beds.

Seedlings were raised in 10cm polybags. Fully decomposed cowdung was mixed with the soil and the polybag were filled with soil-cowdung mixture. One sprouted seed was sown in each polybag. The seedlings in the polybags were watered whenever necessary. Twenty day old healthy seedlings were used for transplanting. In polythene mulch system the seedlings were transplanted in soil within the 5 cm diameter round-cut portion in the center of the polythene sheet on 08 January 2018, 05 January 2019 and 01 January 2020, respectively. Plant spacing for all the treatments was 2m × 2m.

The land was fertilized with N, P and K @ 75, 30 and 50 kg ha^{-1}, respectively. The source of N, P and K were urea, triple super phosphate (TSP) and muriate of potash (MoP), respectively. In all the experimental plots TSP and MoP were applied during final land preparation. Urea was applied in three equal splits at 10, 25 and 45 days after transplanting. An amount of 1000 ml irrigation water twice in a week was given in the foot of each plant.

Data on soil temperature were recorded on 06th March 2018 at 1.00 pm. Soil samples were collected in the same date from the foot of each plant and analyzed for determination of pH in 1:2.5 soil water suspension, electrical conductivity in 1:5 soil water suspension, and chloride and bicarbonate ion contents by volumetric analysis method following standard procedures. The mature fruits were harvested four times with one week interval. The yield data were expressed as fresh weight basis. The mature fruits were chemically analysed for proline (Bates *et al*. 1973), total sugar (Dubois *et al.,* 1956), and sodium and potassium contents (Yoshida *et al*., 1976). The fruit chemical analysis data were presented as fresh weight basis. The chemical analysis of plant and soil samples was done in the laboratory of the Department of Soil Science, Patuakhali Science and Technology University, Bangladesh. Data recorded on soil and crop characters were subjected to statistical analysis through computer based statistical program STAR (Statistical Tool for Agricultural Research).

Results and Discussion

Fruit yield of bitter gourd

Fruit yield of bitter gourd was significantly and consistently influenced by mulching and planting bed types in 2018, 2019 and 2020 (Table 1); the interaction effect was significant only in 2019 and 2020 (Table 2). Based on the three years results mulch treatments had significantly higher fruit yield over no mulch control treatment. Among the mulches polythene mulch showed significantly higher performance than rice straw mulch treatment. The polythene mulch treatment had highest fruit yield of 21.86, 27.20 and 20.49 t ha^{-1}, which was 13.16, 17.51 and 11.71 t ha^{-1} in rice straw mulch treatment, and that of 6.71, 12.04 and 8.99 t ha^{-1} in no mulch control treatment in the year 2018, 2019 and

2020, respectively (Table 1). The polythene mulch treatment had fruit yield 225, 126 and 128 % higher than no mulch treatment, and 66, 55 and 75 % higher than rice straw mulch treatment in 2018, 2019 and 2020, respectively (data not shown in table). Considering single effect of planting beds the convex bed planting had significantly higher fruit yield than concave bed planting. The flat bed planting had intermediate fruit yield of convex bed and concave bed. In value the convex bed produced mean fruit yield of 18.37, 20.06 and 15.18 t ha^{-1}; the flat bed produced 12.99, 19.40 and 13.54 t ha^{-1}, and concave bed produced 10.36, 17.29 and 12.47 t ha^{-1} in the year 2018, 2019 and 2020, respectively. If we consider the interaction effect it was found that across the planting bed system polythene mulch had the highest performance. In the experiment polythene mulch along with convex bed planting consistently had the highest fruit yield (Table 2).

The increased yield in polythene mulch treatment was the outcome of increased vegetative and reproductive growth in this treatment (Table 1). Li *et al*. (2018) also found highest yield and water use efficiency in polythene mulch treatment compared to other tested seven mulch materials. Comparatively lower yield in no mulch and straw mulch treatment was due to development of salinity in the soil. The flat bed and concave bed could not give favorable soil environment for optimum plant growth. In supporting the findings Li *et al.* (2017) described that ridge planting will be more sustainable and effective than flat planting for reclamation of saline soils in coastal regions.

Table 1. Single effect of mulching and planting bed on fruit yield of bitter gourd in 2018-20

Treatments	Fruit yield in 2018 (t ha^{-1})	Fruit yield in 2019 (t ha^{-1})	Fruit yield in 2020 (t ha^{-1})
Mulching			
No mulch	6.71 c	12.04 c	8.99 c
Straw mulch	13.16 b	17.51 b	11.71 b
Polythene mulch	21.86 a	27.20 a	20.49 a
Significance level	***	***	***
Planting bed			
Convex bed	18.37 a	20.06 a	15.18 a
Flat bed	12.99 b	19.40 b	13.54 ab
Concave bed	10.36 c	17.29 c	12.47 b
Significance level	***	*	**
%CV	10.23	11.43	11.80

Means within each column showing similar letter are not significantly different.

Table 2. Interaction effect of mulching and planting bed on fruit yield of bitter gourd in 2018-2020

Treatments	Convex bed	Flat bed	Concave bed
Fruit yield in 2018 (t ha^{-1})			
No mulch	11.80	5.11	3.21
Straw mulch	16.89	12.50	10.09
Polythene mulch	26.42	21.38	17.78
Significance level	Not significant		
Fruit yield in 2019 (t ha^{-1})			
No mulch	14.63 bA	13.55 cA	7.94 cB
Straw mulch	17.70 bA	17.40 bA	17.43 bA
Polythene mulch	27.84 aA	27.25 aA	26.50 aA
Significance level	Significant at 5% level		
Fruit yield in 2020 (t ha^{-1})			
No mulch	9.29 bA	9.32 cA	8.37 cA
Straw mulch	11.52 bA	12.41 aA	11.21 bA
Polythene mulch	24.71 aA	18.91 bB	17.84 aB
Significance level	Significant at 5% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Growth and yield contributing characters

Significantly highest stem length of 1.64m, number of branches per plant of 13.5, number of leaves per plant of 31.8, number of fruits per plant of 11.5, and fruit length of 23.7 cm were found in polythene mulch treatment (Table 3). Most of the cases rice straw mulch treatment had statistically similar but little bit higher results of no mulch treatment. Over the growth and yield parameters convex bed planting had significantly higher performance than concave and flat bed planting. When we consider the combined effect it was found that with one exception (in number of leaves per plant) every case the polythene mulch plus convex bed planting had the outstanding performance (Table 4). Equivalent results were also reported by Haque *et al*. (2018).

Table 3. Single effect of mulching and planting bed on growth and yield contributing characters of bitter gourd in 2018

Treatments	Primary stem length (m)	Branches per plant (no.)	Leaves per primary stem (no.)	Fruits per plant (no.)	Fruit length (cm)
Mulching					
No mulch	1.52 ab	10.5 b	27.7 b	6.2 b	20.7 b
Straw mulch	1.38 b	8.4 c	25.3 b	5.6 b	20.8 b
Polythene mulch	1.64 a	13.5 a	31.8 a	11.5 a	23.7 a
Significance level	***	***	***	***	***
Planting bed					
Convex bed	1.85 a	14.1 a	31.5 a	10.6 a	23.1 a
Flat bed	1.42 b	11.4 b	28.3 a	6.4 b	21.1 b
Concave bed	1.28 b	6.9 c	24.9 b	6.3 b	20.9 b
Significance level	***	***	***	***	***
%CV	6.62	10.81	7.85	11.41	4.43

Table 4. Interaction effect of mulching and planting bed on growth and yield contributing characters of bitter gourd in 2018

Treatments	Convex bed	Flat bed	Concave bed
	Primary stem length (m)		
No mulch	1.81 a A	1.51 a B	1.25 b C
Straw mulch	1.83 a A	1.17 bB	1.13 bB
Polythene mulch	1.90 aA	1.58 aB	1.45 aB
Significance level	Significant at 5% level		
	Branches per plant (no.)		
No mulch	13.3 b A	11.8 bA	6.5 bB
Straw mulch	13.8 abA	7.8 cB	3.8 cC
Polythene mulch	15.3 a A	14.8 aA	10.5 aB
Significance level	Significant at 0.1% level		
	Leaves per primary stem (no.)		
No mulch	31.0 aA	29.3 bA	22.8 bB
Straw mulch	30.8 aA	22.0 cB	23.0 bB
Polythene mulch	32.8 aA	33.5 aA	29.0 aB
Significance level	Significant at 1% level		
	Fruits per plant (no.)		
No mulch	9.5 bA	4.8 bB	4.3 bB
Straw mulch	9.3 bA	3.3 bB	4.3 bB
Polythene mulch	13.0 aA	11.3 aB	10.3 aB
Significance level	Significant at 5% level		
	Fruit length (cm)		
No mulch	21.4 bA	20.3 bA	20.4bA
Straw mulch	21.5 bA	20.4 bA	20.5 abA
Polythene mulch	26.4 aA	22.8 aB	21.9 aB
Significance level	Significant at 1% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Fruit quality parameters

The fruit proline, total sugar, sodium and potassium content, and the ratio of Na:K content were significantly influenced by single effect of mulch and bed systems, and their interactions. The mean proline content in control treatment was as 43.55 mg 100^{-1}g fruit which was significantly higher than rice straw mulch and polythene mulch treatment. The lowest proline content (22.57 mg $100g^{-1}$ fruit) was found in polythene mulch treatment which was statistically at par with rice straw mulch treatment (Table 5). Among the planting beds the lowest proline content (27.16 mg $100g^{-1}$ fruit) was recorded at convex bed planting system. If we consider the interaction effect it was found that at all the bed systems no mulch treatment had the highest poline content (Table 6). Similarly lowest proline content was consistently found in polythene mulch treatment. Proline is an important amino acid used to osmotic adjustment making plants stress tolerant especially in saline condition (Dar *et al*., 2016). During salt stress plants accumulate large amount of proline in cell sap. Thus higher accumulation of proline is the indicative of growing plants in excessive saline conditions. In the experiment lowest proline content in polythene mulch treatment indicates that these plants were not affected or less affected by salinity. Similarly lowest proline content in convex bed planting indicates its comfortable soil environment.

Total sugar content was found increased due to use of polythene mulch (2.44 g $100g^{-1}$ fruit) compare to no much treatment (1.41 g $100g^{-1}$ fruit). Bed system also had a positive effect having highest total sugar content in convex bed planting (2.14). Among the treatment combinations the polythene mulching along with convex bed planting had highest fruit sugar content of 3.09 g $100g^{-1}$ fruit (Table 6).

The fruit Na content in no mulch, rice straw mulch and polythene mulch treatment was 1.56, 1.19 and 0.64 %, respectively (Table 5). Therefore, rice straw much and polythene mulch reduced Na content by 24 and 59 %, respectively compared to no mulch treatment. Among the planting beds convex bed had lowest fruit Na content of 0.84%. The flat bed and concave bed had statistically similar fruit Na content. Considering interaction effect across the planting bed systems polythene much had the lowest Na content. Furthermore, polythene mulch with convex bed planting had lowest fruit Na content of 0.441%. The lower Na content was one of the major reasons of higher yield in convex bed planting system.

Unlike Na, K content of fruit was increased due to use of mulch materials. The K content significantly higher in straw mulch (0.371%) compare to control (0.328%), and significantly higher in polythene much compared to straw mulch treatment (0.431%) (Table 5). Among the planting beds, convex bed had highest fruit K content (0.393%). The flat bed and concave bed had statistically similar K content. The single effect of mulching and planting beds had a positive effect on interaction effect; highest K content (0.488%) is therefore found in polythene mulch and convex bed planting combination (Table 6).

The fruit Na:K ratio is an important indication which determining the level of Na toxicity in plants, higher the value indicates higher toxicity in plants. In the experiment the control, straw mulch and polythene mulch treatment had Na:K ratio of 4.768, 3.249 and 1.528 which clearly indicates that under polythene mulch treatment plants faces very minimum level of Na toxicity. Among the planting beds convex bed planting had lowest Na:K ratio of 2.411 (Table 5). When combined effect was considered it was found that polythene mulching along with convex bed planting had the lowest fruit Na:K ratio of 0.906, which means that in this treatment combination K ion successfully dominated over Na ion in the salt affected soils (Table 6).

It has been reported previously that higher Na:K ratio makes plant Na toxic and deficient in K (Almeida *et al.* 2017). In the present experiment polythene mulch had Na:K ratio several fold lower than both straw mulch and no mulch treatment. Similarly convex bed treatment had significantly lower Na:K ratio than flat bed and concave bed treatment. Thus under the polythene mulch and convex bed planting treatment combination plants enjoy least saline environment which might have been safer for growing bitter gourd.

Table 5. Single effect of mulching and planting bed on fruit nutritional quality characters of bitter gourd in 2018

Treatments	Fruit proline content (mg $100g^{-1}$ fruit)	Fruit total sugar content (g $100g^{-1}$ fruit)	Fruit Na content (%)	Fruit K content (%)	Fruit Na:K ratio
Mulching					
No mulch	43.55 a	1.41 c	1.56 a	0.328 c	4.768 a
Straw mulch	23.61 b	1.58 b	1.19 b	0.371 b	3.249 b
Polythene mulch	22.57 b	2.44 a	0.64 c	0.431 a	1.528 c
Significance level	***	***	***	***	***
Planting bed					
Convex bed	27.16 b	2.14 a	0.84 b	0.393 a	2.411 c
Flat bed	31.97 a	1.63 b	1.26 a	0.370 b	3.550 b
Concave bed	30.60 a	1.67 b	1.29 a	0.367 b	3.584 a
Significance level	***	***	***	***	***
%CV	5.65	4.79	4.20	3.45	5.75

Means within each column on showing similar letter are not significantly different

Table 6. Interaction effect of mulching and planting bed on fruit nutritional quality characters of bitter gourd in 2018

Treatments	Convex bed	Flat bed	Concave bed
	Fruit proline content (mg $100g^{-1}$ fruit)		
No mulch	39.57 aB	48.94 aA	42.13 aB
Straw mulch	21.28 bB	24.57 bA	24.98 bA
Polythene mulch	20.62 bB	22.40 bAB	24.68 bA
Significance level	Significant at 1% level		
	Fruit total sugar content (g $100g^{-1}$ fruit)		
No mulch	1.48 cB	1.64 bA	1.11 cC
Straw mulch	1.85 bA	1.36 cC	1.54 bB
Polythene mulch	3.09 aA	1.88 aC	2.35 aB
Significance level	Significant at 0.1% level		
	Fruit Na content (%)		
No mulch	1.382 aC	1.838 aA	1.471 aB
Straw mulch	0.688 bC	1.491 bA	1.397 aB
Polythene mulch	0.441 cB	0.461 cB	1.014 bA
Significance level	Significant at 0.1% level		
	Fruit K content (%)		
No mulch	0.304 cB	0.341 bA	0.338 cA
Straw mulch	0.388 bA	0.363 bB	0.363 bB
Polythene mulch	0.488 aA	0.405 aB	0.400 aB
Significance level	Significant at 0.1% level		
	Fruit Na:K ratio		
No mulch	4.550 aB	5.395 aA	4.358 aB
Straw mulch	1.776 bB	4.116 bA	3.855 bA
Polythene mulch	0.906 cB	1.141 cB	2.538 cA
Significance level	Significant at 0.1% level		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Soil physical and chemical properties

The mulch treatments significantly influenced the temperature of soil having mean 39.4ºC in polythene mulch, 32.1ºC in straw mulch and 33.3ºC in control (no mulch) treatment (Table 7).Therefore, the results clearly indicated that polythene much helps to keep soil warm and rice straw mulch keeps soil cool compare to unmulched conditions. The planting beds had no significant effect on soil temperature, although convex bed planting had to some extent increased soil temperature. Considering the combined effect it was found that the polythene mulch along with convex bed planting had highest soil temperature of 42.3ºC (Table 8). Due to high soil temperature the soil nutritional and biological property is improved which ultimately increased the yield of crop. Soil temperature is an important factor for growing crops especially in winter season. Dong *et al.* (2018) reported that polythene mulch is an effective strategy for promoting crop emergence and rapid growth of crops because it can modify the soil microclimate by increasing the soil temperature.

A highly significant effect of using mulch on gravimetric soil moisture content having 6.2, 12.1 and 18.5 % in no mulch, straw mulch and polythene mulch treatment, respectively was found (Table 7). Rice straw mulch and polythene mulch increased moisture content by 95 and 198 % over control (no mulch) treatment. Looking interaction effect it was found that convex bed planting had comparatively lower moisture content in no mulch and straw mulch treatment. However, convex bed planting with polythene mulch combination conserve a highest (20.5%) soil moisture content (Table 8). Li *et al*. (2018) tested 7 mulching materials to grow maize crop and stated that all the mulches saved water and accelerated maize growth in the middle and later stages; highest performance being in polythene mulches. Polythene mulch increased the amount of soil-available water by restricting evaporation and elevating deepwater by capillarity and vapor transfer to the layer usable for roots under arid and semi-arid conditions (Qin *et al*., 2014).

Table 7. Single effect of mulching and planting bed on soil physical and chemical parameters in 2018

Treatments	Soil temperature (ºC)	Soil moisture content (%)	Soil $EC_{1:5}$ (dS/m)	Na content of soil (meq/100g soil)	Bicarbonate ion content (%)	Chloride ion content (%)
Mulching						
No mulch	33.3 b	6.2 c	3.67 a	7.63 a	0.550 a	0.183 a
Straw mulch	32.1 b	12.1 b	3.13 b	6.46 b	0.442 a	0.121 b
Polythene mulch	39.4 a	18.5 a	2.55 c	4.44 c	0.244 b	0.041 c
Significance level	***	***	***	***	**	***
Planting bed						
Convex bed	36.1	11.3	2.23 C	6.12	0.376	0.121
Flat bed	34.5	13.2	3.15 B	6.35	0.450	0.108
Concave bed	34.3	12.3	3.97 A	6.05	0.410	0.115
Significance level	NS	NS	***	NS	NS	NS
%CV	4.59	10.64	7.85	8.78	36.61	18.35

Means within each column are not significantly different

Table 8. Interaction effect of mulching and planting bed on soil physical and chemical parameters in 2018

Treatments	Convex bed	Flat bed	Concave bed
	Soil temperature (ºC)		
No mulch	33.5 bA	33.8 bA	32.8 bA
Straw mulch	32.5 bA	31.5 bA	32.3 bA
Polythene mulch	42.3 aA	38.3 aB	37.8 aB
Significance level	Significant at 5% level		
	Soil moisture content (%)		
No mulch	4.2 cB	5.7 cB	8.7 cA
Straw mulch	9.1 bB	14.3 bA	12.9 bA
Polythene mulch	20.5 aA	19.7 aA	15.2 aB
Significance level	Significant at 0.1% level		
	Soil $EC_{1:5}$ (dS/m)		
No mulch	2.67 aC	3.47 aB	4.88 aA
Straw mulch	2.11 bC	3.15 abB	4.12 bA
Polythene mulch	1.91 bB	2.84 bA	2.90 cA
Significance level	Significant at 1% level		
	Na content of soil (meq/100g soil)		
No mulch	7.88 aA	7.65 aA	7.35 aA
Straw mulch	6.57 bA	5.98 bA	6.82 aA
Polythene mulch	3.90 cB	5.43 bA	3.98 bB
Significance level	Significant at 5% level		
	Bicarbonate ion content (%)		
No mulch	0.551	0.575	0.525
Straw mulch	0.352	0.525	0.450
Polythene mulch	0.225	0.250	0.256
Significance level	Not significant		
	Chloride ion content (%)		
No mulch	0.183	0.174	0.192
Straw mulch	0.131	0.120	0.112
Polythene mulch	0.050	0.031	0.042
Significance level	Not significant		

Means showing similar small letter in a column and capital letter in a row is not statistically different

Electrical conductivity of soil is an important parameter that determines the level of salinity in soil which was extremely influenced by mulching and planting beds. It was observed that under the no mulch, straw mulch and polythene mulch methods $EC_{1:5}$ of 3.67, 3.13 and 2.55 dS m^{-1}, respectively was recorded (Table 7). The straw much and polythene mulch reduced $EC_{1:5}$ by 15 and 31 %, respectively over control. Similarly, from convex bed, flat bed and concave bed methods mean $EC_{1:5}$ of 2.23, 3.15 and 3.97 dS m^{-1}, respectively were recorded. Looking the interaction effects (Table 8), it was found that across the planting beds polythene much had always the lower EC, the least value (1.91 dS m^{-1}) being in the polythene mulch with convex bed planting system. Zheng *et al*., (2009) found a negative relation of EC with yield and identified as the key limiting factor for cotton growth under the drip irrigation system. Previously Haque *et al*. (2018) reported that use of polythene mulch significantly reduces electrical conductivity of soil which is in agreement with the present study.

Sodium content is another important parameter which determines the level of salt toxicity. When mulches were used the EC value was 7.63 meq $100g^{-1}$ soil, in rice straw mulch it was 6.46 meq $100g^{-1}$ soil and in polythene much treatment it was 4.44 meq $100g^{-1}$ soil, which indicates that polythene mulch was able to reduce Na content of soil by 42 % over no mulch (control) treatment. However, planting beds had no positive effect on Na content of soil. Similar to Na ion concentrations, the bicarbonate and chloride ion content was also significantly influenced by mulch treatments (Table 7). In both of the cases polythene much had several times lower amount compared to the control treatment. The straw mulch treatment also had lower bicarbonate and chloride ion content compared to the no mulch treatment.

Economic profitability analysis

The economic viability of using different mulch materials under different planting bed systems was determined through calculation of marginal benefit-cost ratio (MBCR) of the mulch treatments. The economic analysis was done using three year mean fruit yield data. The summary result is shown in Table 9. Marginal benefit-cost ratio (MBCR) is the ratio of marginal or added benefits and added costs. To compare different mulch treatments with no mulch control treatment under different planting bed system the following formula was used.

$$\text{MBCR(over no mulch control)} = \frac{\text{Gross return in mulch treatment-Gross return in no mulch treatment}}{\text{Variable cost in mulch treatment-Variable cost in no mulch treatment}}$$

$$\text{MBCR (over no mulch control)} = \frac{\text{Added benefit (over control)}}{\text{Added cost (over control)}}$$

$$\text{Gross return} = \text{Yield} \times \text{price}$$

Under convex bed planting system the straw mulch and polythene mulch had MBCR of 8.7 and 12.0, but in flat bed system these two mulch materials gave MBCR of 11.9 and 11.0, respectively (Table 9). If we consider the concave bed planting system the rice straw mulch and polythene mulch gave MBCR of 16.0 and 11.8, respectively. Under convex bed planting system polythene mulch treatment had 38% higher MBCR compared to rice straw mulch treatment. Therefore, based on the higher yield and economic profitability the polythene mulch and convex bed planting combination could be recommended for growing vine crops in the coastal saline soils of Bangladesh. Based on the present experiment flat bed and concave bed system is not recommended due to significantly lower yield, rather convex bed was recommended due to higher yield and the ability to reduce salinity.

Table 9. Economic profitability of using different mulch materials under different bed systems for growing bitter gourd in coastal saline soils

Treatments	Gross return (Tk)	Added benefit (Tk)	Added cost (Tk)	MBCR
	Convex bed planting system			
No mulch	595354	-	-	-
Straw mulch	768646	173292	20000	8.7
Polythene mulch	1316063	720709	60000	12.0
	Flat bed planting system			
No mulch	466260	-	-	-
Straw mulch	705146	238886	20000	11.9
Polythene mulch	1125594	659334	60000	11.0
	Concave bed planting system			
No mulch	325271	-	-	-
Straw mulch	645479	320208	20000	16.0
Polythene mulch	1035406	710135	60000	11.8

Values generated through calculation therefore, statistical analysis was not performed

Price: Bitter gourd- Tk 50000 t^{-1}, Rice straw- Tk 20000 ha^{-1}, Polythene mulch- Tk 60000 ha^{-1}

Conclusion

A suitable and profitable technology is far behind to manage saline soil as well as to improve crop production, as soil salinity seriously hampers the crop production in the coastal regions. Polythene mulch was found very much promising to manage saline soil because it improves crop yield through reducing soil salinity, and increasing soil temperature and moisture content. The convex bed planting could also be a potential tool to increase bitter gourd yield in the saline soils. The combination of the two techniques- polythene mulch and convex bed planting could produce the greatest benefit in bitter gourd cultivation under saline conditions with coastal areas.

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References

Ahmed, R., M. H. K. Howlader, A. Shila and M. A. Haque. 2017. Effect of salinity on germination and early seedling growth of maize. *Progressive Agriculture*, **28** (1): 18-25. DOI: https://doi.org/10.3329/pa.v28i1.32855

Almeida**,** D. M., M. M. Oliveira and N. J. M. Saibo**.** 2017. Regulation of Na^+ and K^+ homeostasis in plants: towards improved salt stress tolerance in crop plants. *Genet Mol Biol.* **40**(1 Suppl 1): 326–345. https://doi.org/10.1590/1678-4685-GMB-2016-0106**.**

Bates, L. S., R. P. Waldren and I. D. Tear. 1973. Rapid determination of free proline for water-stress studies. *Plant and Soil*. **39**: 205-7.

Brady, N. C., and R. R. Well. 2013. The Nature and Properties of Soils. Pearson Education in South Asia. Dorling Kindersley (India) Pvt. Ltd.

Chu, L., K. Yao-hu and W. A. N. Shu-qin. 2015. Effects of water application intensity of microsprinkler irrigation on water and salt environment and crop growth in coastal saline soils. *J. Integrative Agric*. **14**(10): 2077-2089. https://doi.org/10.1016/S2095-3119(15)61062-0.

Dar, M. I., M. Irfan, F. Rehman, F. Naushin and F. A. Khan. 2016. Proline Accumulation in Plants: Roles in Stress Tolerance and Plant Development. In book: Osmolytes and Plants Acclimation to Changing Environment: Emerging Omics Technologies. https://doi.org/10.1007/978-81-322-2616-1_9.

Devkota, M., 2011. Nitrogen management in irrigated cotton-based systems under conservation agriculture on salt-affected lands of Uzbkistan. ZEF/Rheinische Friedrich-Wilhelms-Universitat Bonn, Bonn, Germany, pp. 163.

Devkota, M., C. Martius, J. P. A. Lamers, K. D. Sayre, K. P. Devkota, R. K. Gupta, O. Egamberdiev and P. L. G. Vlek. 2013. Combining permanent beds and residue retention with nitrogen fertilization improves crop yields and water productivity in irrigated arid lands under cotton, wheat and maize. *Field Crops Res*. **149**: 105-114. https://doi.org/10.1016/j.fcr.2013.04.012

Dong, Q., Y. Yang, T. Zhang, L. Zhou, J. He, H. W. Chau, Y. Zou and H. Feng. 2018. Impacts of ridge with plastic mulch-furrow irrigation on soil salinity, spring maize yield and water use efficiency in an arid saline area. *Agricultural Water Management*, **201**: 268-277. https://doi.org/10.1016/j.agwat.2017.12.011.

Dubois, M. and K. A. Gilles. 1956. Colorimetric method for determination of sugars and related substances. *Annals of Chemistry*, **3**: 350-354.

FAO (Food and Agriculture Organization). 2008. Global network on integrated soil management for sustainable use of salt-effect soils. Rome: FAO Land and Plant Nutrition Management Service.

Haque, M. A., M. Jahiruddin and D. Clarke. 2018. Effect of plastic mulch on crop yield and land degradation in south coastal saline soils of Bangladesh. *In. Soil and Water Conservation Res*. 6(4): 317-324. https://doi.org/10.1016/j.iswcr.2018.07.001.

Haque, M. A., M. Jahiruddin, M. A. Hoque, M. Z. Rahman and D. Clarke. 2014. Temporal variability of soil and water salinity and its effect on crop at Kalapara upazila. *J. Environ. Sci. & Natural Resources*, **7**(2): 111-114. https://doi.org/10.3329/jesnr.v7i2.22218

Kienzler, K. M., J. P. A. Lamers, A. McDonald, A. Mirzabaev, N. Ibragimov, O. Egamberdiev, E. Ruzibaev and A. Akramkhanov. 2012. Conservation agriculture in Central Asia-what do we know and where do we go from here? *Field Crops Res*. **132**: 95-105. DOI: 10.1016/j.fcr.2011.12.008

Li, S., Y. Li, H. Lin, H. Feng, and M. Dyck. 2018. Effects of different mulching technologies on evapotranspiration and summer maize growth. *Agric. Water Manage*. **201**: 309-318. https://doi.org/10.1016/j.agwat.2017.10.025.

Li, X., Y. Kang, S. Wan, X. Chen, S. Liu and J. Xu. 2017. Effect of ridge planting on reclamation of coastal saline soil using drip-irrigation with saline water. *Catena*. **150**: 24-31. https://doi.org/10.1016/j.catena.2016.11.003.

Qi, Z., H. Feng, Y. Zhao, T. Zhang, A. Yang and Z. Zhang. 2018. Spatial distribution and simulation of soil moisture and salinity under mulched drip irrigation combined with tillage in an arid saline irrigation district, northwest China. *Agric. Water Manage*. **201**: 219-231. https://doi.org/10.1016/j.agwat.2017.12.032.

Qin, S. H., J. L. Zhang, H. L. Dai, D. M. Wang and D. Li. 2014. Effect of ridge—furrow and plastic-mulching planting patterns on yield formation and water movement of potato in a semi-arid area. *Agric Water Manage*. **131**: 87–94. DOI: 10.1016/j.agwat.2013.09.015

Richards, L. A., 1954. Diagnosis and improvement of saline and alkali soils. In: USDA(Ed.), Agriculture Handbook. USDA, Washington, DC, USA

Sayre, K. 2007. Conservation agriculture for irrigated agriculture in Asia. In: Lal, R,, Suleimenov, M., Stewart, B.A., Hansen, D.O., Doraiswamy, P. (Eds.), Climate Change and Terrestrial Carbon Sequestration in Central Aisia. Taylor and Francis, The Netherlands, pp. 211-242.

Sun, J., Y. Kang, S. Wan and W. Hu. 2017. Influence of drip irrigation level on salt leaching and vegetation growth during reclamation of coastal saline soil having an imbedded gravel–sand layer. *Ecological Engineering*. **108:** 59-69. https://doi.org/10.1016/j.ecoleng.2017.08.004.

Tan, S., Q. Wang, D. Xu, J. Zhang and Y. Shan. 2017. Evaluating effects of four controlling methods in bare strips on soil temperature, water, and salt accumulation under film-mulched drip irrigation. *Field Crops Res*. **214**: 350-358. https://doi.org/10.1016/j.fcr.2017.09.004

Yang, J., X. Mao, K. Wang and W. Yang. 2018. The coupled impact of plastic film mulching and deficit irrigation on soil water/heat transfer and water use efficiency of spring wheat in Northwest China. *Agric Water Manage*. **201**: 232-245. https://doi.org/10.1016/j.agwat.2017.12.030

Yoshida, S., A. D. Forno, J. A. Cock and, K. A. Gomez. 1976. Physiological Studies of Rice. 2nd Eds. Int. Rice Res. Inst., Manila, Philippines.

Zheng, Z., F. Zhang, F. Ma, X. Chai, Z. Zhu, J. Shi and S. Zhang. 2009. Spatiotemporal changes in soil salinity in a drip-irrigated field. *Geoderma*. **149**(3-4): 243-248. https://doi.org/10.1016/j.geoderma.2008.12.002.

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PERFORMANCE OF LEAFY VEGETABLES INTERCROPPED WITH BRINJAL

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Abstract

An experiment was conducted during rabi and kharif season of 2018 - 2019 and 2019-2020, respectively at Regional Agricultural Research Station (RARS), Cumilla to find out the suitable crop combination of leafy vegetables with brinjal for increasing productivity and economic return through intercropping system. Five treatments viz. Brinjal + Red amaranth (T_1), Brinjal + Leaf amaranth (T_2), Brinjal + Patshak (T_3), Brinjal + Spinach (T_4) and Sole crop of brinjal (T_5) were used in rabi season. In kharif season all the treatments were same except T_4 where Indian spinach was used with brinjal instead of spinach. Results showed that yield and yield contributing characters of brinjal did not differ significantly due to different intercropping systems. Yield of brinjal was comparatively low in intercropping but total productivity increased due to additional yield of leafy vegetables. Increase of total productivity in terms of brinjal equivalent yield (BEY) was 2.03 to 25.68% (Rabi) and 2.36 to 22.29% (Kharif) and in intercrop combination compared to sole crop. All the intercropping combinations showed higher brinjal equivalent yield (BEY), gross return and benefit cost ratio (BCR) over sole crop. Among the intercropping combinations, Brinjal + Spinach (rabi) and Brinjal + Indian spinach (kharif-1) was the most feasible and profitable in respect of BEY (48.94 and 27.62 t/ha, respectively), gross return (Tk. 1223400 and 1105000/ha, respectively), gross margin (Tk.908823 and 782487/ha, respectively) and benefit cost ratio (3.88 and 3.42, respectively).

Keywords: Intercropping, leafy vegetables, brinjal, B:C ratio.

Introduction

Brinjal (*Solanum melongena* L.) is one of the most popular and widely cultivated vegetable crops in Bangladesh. It is a wide spaced (100 cm × 75 cm) crop and life span ranges 240-280 days. Being relatively a long duration crop in first growth stage brinjal grows slowly and establishment of full canopy takes several weeks. This privilege can be taken for growing various short duration (30-40 days) crops (mostly leafy vegetable) in between the rows as intercrops. Most of the green leafy vegetables like red amaranth, leaf amaranth, patshak, spinach and Indian spinach are rich source of minerals including iron, calcium, potassium, magnesium and also provide important vitamins, including vitamins K, C, E, and many of the vitamins B (Natesh *et al.,* 2017). Those crops can easily be

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intercropped with brinjal at early growth stage for their short stature and quick growing habit. Intercropping has been considered advantageous in terms of economy of space, saving on tillage, as well as utilization of available nutrients and moisture in unused space. It could result in an increase in the productivity of vegetables per unit area, and could increase gross return. The practice of intercropping leafy vegetables with brinjal may provide higher yield and income (Islam *et al*., 2014). Intercropping is one of the increased production systems and it offers the possibility of yield advantage compare to sole cropping through yield stability and improved yield in tropical and sub-tropical areas (Nazir *et al*., 2002; Malik *et al.*, 2002; Bhatti, 2005). In Bangladesh small farmers constitute 79.4% of our farming community and their cultivated lands are decreasing day by day (MoA, 2014). Besides, multiple cropping may ensure proper utilization of resources towards increased production per unit area and time on a sustainable basis (Ahmad *et al*., 2007). However, various studies have been conducted in the past about vegetables intercropping system but results on brinjal-leafy vegetables intercropping are very scanty. Considering the scope of intercropping with brinjal, this trial was undertaken to find out the suitable crop combination for increasing total productivity, net return and maximization of land utilization.

Materials and Methods

This experiment was conducted at the experimental field of Regional Agriculture Research Station (RARS), Cumilla during the rabi and kharif season of 2018-2019 and 2019-2020, respectively. The study was set in RCB design with three replications. There were five treatments in kharif season viz. T_1: Brinjal + Red amaranth, T_2: Brinjal + Leaf amaranth, T_3: Brinjal + Jute as patshak, T_4: Brinjal + Indian spinach and T_5: sole crop of brinjal and for rabi season treatments were T_1: Brinjal + Red amaranth, T_2: Brinjal + Leaf amaranth, T_3: Brinjal +Jute as patshak, T_4: Brinjal + Spinach and T_5: sole crop of brinjal. Seeds of red amaranth, leaf amaranth, patshak, Indian spinach and spinach were sown in between brinjal rows at the rate of 2, 1.5 ,15, 35 and 35 kg seed/ha, respectively. Brinjal (thirty days old seedling), seeds of red amaranth, leaf amaranth, patshak and spinach were planted/sown on 5 and 9 November 2018 and 2019 in rabi season, respectively and in kharif season thirty days old seedling of brinjal and seeds of red amaranth, leaf amaranth, patshak and Indian spinach were planted/sown on 8 and 15 March 2019 and 2020, respectively. Unit plot size, spacing, fertilizer doses and intercultural operations were same for both the season. The unit plot size was 5.0 m × 2.25 m and the sole crop of brinjal was transplanted at 1.0 m × 0.75 m spacing. The sole crop of brinjal and intercropped treatments were fertilized with cowdung 10 t/ha and 170-50-125-18-4.3-1.70 kg/ha NPKSZnB ha^{-1} in the form of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively. One third of N, half of K and full amount of cowdung, P, S, B, Zn were applied during final land preparation. Remaining N and K were applied in three equal installments at 20, 40 and 60 days after transplants (DAT) as ring method around the brinjal. Brinjal (Var. BARI Begun-10) as base crop and red amaranth (var. BARI Lalshak-1), leaf amaranth (var. BARI Datashak-2), Jute (Binapatshak-1), Indian spinach (var. BARI Puishak-2) and spinach (var. BARI Palongshak-1) were used as intercrops in this study. Three irrigations were done in the experimental field. First irrigation was applied when transplanting brinjal/sowing the component crop. Second and third irrigation were applied at 80 and 160 days after transplanting (DAT) of brinjal. Weeding was done as per requirement. Spinosad (Tracer 45 SC) at the rate of 0.4 ml/litre water was sprayed on brinjal for controlling brinjal shoot and fruit borer at vegetative, fruit setting and fruit developing stage. Harvesting of crops for rabi season was started on 22 and 27 March and continued to 15 and 21 June in 2019 and 2020, respectively and for kharif season harvesting was started on 5 and 8 July and continued to 19 and 25 October in 2019 and 2020, respectively. Data on yield and yield contributing characters were recorded and analyzed using Statistics 10 software and the means were separated by LSD test at 5% level of significance. Brinjal equivalent yield (BEY) was converted by converting yield of intercrops on the basis of present market price of individual crop following the formula:

$$BEY = \text{Yield of intercrop brinjal} + \frac{Y_i \times P_i}{\text{Price of brinjal}}$$

Where, Y_i = yield of intercrop (leafy vegetables) and P_i = Price of intercrop (leafy vegetables). Land equivalent ratio (LER) values were determined from the yield data of the crops according to Mian (2008).

$$LER = RY_b + RY_i = \frac{E_{IY}}{E_{SY}} + \frac{BEY_{CC}}{E_{SY}}$$

Where,

RY_b= Relative yield of brinjal (main crop)

RY_i= Relative yield of intercrops (leafy vegetables)

B_{IY}= Intercrop yield of brinjal

B_{SY}= Sole crop yield of brinjal

B_{EYCC}= Brinjal equivalent yield of component crops {(component crop yield in intercrop × price of component crop)/price of brinjal}

Benefit cost analysis was also done

Results and Discussion

Rabi

Yield and Yield Contributing Characters of Brinjal

Growing of intercrops in interspaces between brinjal rows did not affect much the base crop (Table 1). The number of fruits/plant ranged from 26.91 to 34.24 where maximum number of fruits/plant was obtained in sole crop of brinjal (34.24) followed by Brinjal + Leaf amaranth (31.76) intercropping combination. The lowest number of fruits/plant (26.91) was recorded in Brinjal + Spinach intercropping combination. In case of fruit length, the longest fruit (32.07 cm) was found in Brinjal + Patshak and the smallest one (28.90 cm) was found from the combination of Brinjal + Red amaranth (Table 1).

Table 1. Yield and yield attributes of brinjal in brinjal- leafy vegetables intercropping system in rabi (pooled data of 2018-2019 and 2019-2020).

Treatments	Number of fruit/plant (no.)	Fruit length (cm)	Individual fruit weight (g)	Fruit yield/plant (kg)	Fruit yield (t/ha)
T_1 (Brinjal + Red amaranth)	28.40	28.90	94.18	2.67	35.89
T_2 (Brinjal + Leaf amaranth)	31.76	30.00	95.32	3.02	36.74
T_3 (Brinjal + Patshak)	30.16	32.07	99.90	3.01	37.68
T_4 (Brinjal + Spinach)	26.91	31.80	102.75	2.77	34.00
T_5 (sole crop of brinjal)	34.24	31.87	110.85	3.76	38.94
CV (%)	12.36	2.94	9.13	9.52	11.60
$LSD_{(0.05)}$	2.13	1.11	8.34	3.11	8.99

Individual fruit weight and fruit yield/plant was recorded maximum in sole crop of brinjal. The maximum fruit yield (38.94 t/ha) obtained from sole crop of brinjal. Islam *et al.* (2014) also reported that the maximum fruit yield (16.46 t/ha) was obtained from sole crop of brinjal crop than intercropping system. In intercropped combination, the fixed amounts of applied fertilizer were uptake both the base (brinjal) and component (leafy vegetables) crops. Additional nutrients were not added in these combinations. So, brinjal yields were comparatively higher in sole crop of brinjal than intercropping system. Among the intercropped combinations the maximum fruit yield was recorded (37.68 t/ha) when it was intercropped with patshak followed by Brinjal + Leaf amaranth (36.74 t/ha) and Brinjal + Red amaranth (35.89 t/ha) and minimum yield was recorded in Brinjal + Spinach intercropping combination (34.00 t/ha)).

On an average, the yield of red amaranth, leaf amaranth, patshak and spinach under intercropping were 10.56, 16.20, 3.41 and 18.67 t/ha, respectively (Table 2). Results showed that, among the leafy vegetables, spinach showed higher yield (18.67 t/ha) in intercropping followed by leaf amaranth (16.20 t/ha).

Table 2. Yield of companion crops and brinjal equivalent yield (BEY) under brinjal-leafy vegetables intercropping system in rabi (pooled data of 2018-2019 and 2019-2020).

Treatment	Yield of leafy Vegetables (t/ha)	BEY (t/ha)	% increase of BEY over sole crop of brinjal	LER
T_1 (Brinjal + Red amaranth)	10.56	40.11	3.00	1.03
T_2 (Brinjal + Leaf amaranth)	16.20	43.22	10.99	1.10
T_3 (Brinjal + Patshak)	3.41	39.73	2.03	1.02
T_4 (Brinjal + Spinach)	18.67	48.94	25.68	1.26
T_5 (sole crop of brinjal)	-	38.94	-	1

Brinjal Equivalent Yield (BEY)

Brinjal equivalent yields were higher in all the intercropping combination (39.73 to 48.94 t/ha) than the sole crop of brinjal (38.94 t/ha). The highest brinjal equivalent yield (48.94 t/ha) was recorded in Brinjal + Spinach intercropped combination which was followed by Brinjal + Leaf amaranth (43.22 t/ha) and Brinjal + Red amaranth (40.11 t/ha) (Table 2). Total productivity was also increased of 3.0, 10.99, 2.03 and 25.68 percent over sole crop of brinjal. The result revealed that Brinjal + Spinach led to higher total productivity than other intercropping combinations as well as sole crop. Islam *et al.* (2014) also reported the increases in total productivity in terms of brinjal equivalent yield (BEY) 8.80 to 26.67 t/ha in intercrop combination compared to base crop.

Land Equivalent Ratio (LER)

LER of different crop combinations ranged from 1.02 to 1.26. The highest land equivalent ratio (1.26) was recorded under Brinjal + Spinach intercropping system followed by Brinjal + Leaf amaranth (1.10) (Table 2). The lowest LER (1.02) was in Brinjal + Patshak intercropped combination. The mean values of LER (more than one) in all intercropping treatments revealed that land was more efficiently utilized under intercropping than sole crop of brinjal. The results are in agreement with the findings of Juskiw *et al.* (2000), Islam *et al*. (2012).

Table 3. Cost benefit analysis of brinjal-leafy vegetables intercropping system in rabi (pooled data of 2018-2019 and 2019-2020).

Treatments	Gross return (Tk/ha)	Total cost (Tk/ha)	Gross margin (Tk/ha)	BCR
T1 (Brinjal + Red amaranth)	1002850	280257	722593	3.57
T2 (Brinjal + Leaf amaranth)	1080500	294956	785544	3.66
T3 (Brinjal + Patshak)	993250	288070	705180	3.45
T4 (Brinjal + Spinach)	1223400	314577	908823	3.88
T5 (sole crop of brinjal)	973500	285150	688350	3.41

Price: Brinjal: Tk 25/kg, Red amaranth: Tk 10/kg, Leaf amaranth: Tk 10/kg, Patshak :Tk 15/kg, Spinach: Tk 20/kg

Cost benefit analysis

Intercropping combination of brinjal with leafy vegetables showed higher monetary return than sole crop (Table 3). The highest gross return (Tk.1223400/ha) was recorded from Brinjal + Spinach intercropping. This intercropping combination also gave the higher gross margin (Tk. 908823/ha) and benefit cost ratio (3.88) followed by Brinjal + Leaf amaranth as intercrop with BCR (3.66). Among the intercropping, the lowest gross return

(Tk.993250/ha), gross margin (Tk. 705180/ha) and BCR (3.45) were obtained from the combination of Brinjal + Patshak. The results of increased productivity and returns were consistent with the earlier reports of yield advantage of crop mixture compared to monoculture (Islam *et al*., 2012; Ahmed *et al*., 2013; Islam *et al*., 2014).

Kharif-1

Yield and Yield Contributing Characters of Brinjal

The number of fruits/plant ranged from 19.52 to 22.02 where maximum number of fruits/plant was obtained in sole crop of brinjal (22.02) followed by Brinjal + Red amaranth (21.14) intercropping combination and the minimum number of fruits/plant (19.52) was recorded in Brinjal + Patshak intercropping combination (Table 4). In case of fruit length, the longest fruit was found in sole crop of brinjal (16.56 cm) followed by Brinjal + Indian spinach (16.03 cm) and the shortest was found in Brinjal + Red amaranth (15.44 cm) intercropping combination. Individual fruit weight and fruit yield/plant was recorded maximum in sole crop of brinjal. The highest fruit yield (22.43 t/ha) was also obtained from sole crop of brinjal. Islam *et al.* (2014) also reported that the maximum fruit yield (16.46 t/ha) was obtained from sole crop of brinjal than intercropping system. In intercropped combination, the fixed amount of applied fertilizer was uptake both the base (Brinjal) and component (leafy vegetables) crops. Additional nutrients were not added in these combinations. So, brinjal yields were comparatively higher in sole crop of brinjal then intercropping system. Among the intercropped combinations the highest brinjal yield was recorded when it was intercropped with Patshak (19.89 t/ha) followed by Brinjal + Indian spinach (18.00 t/ha) and the lowest yield was recorded in Brinjal + Leaf amaranth (15.87 t/ha) intercropping combination.

Table 4. Yield and yield attributes of brinjal in brinjal-leafy vegetables intercropping system in kharif-1 (pooled data of 2018-2019 and 2019-2020).

Treatment	Fruits/plant (no.)	Fruit length (cm)	Individual fruit weight (g)	Fruit yield /plant (kg)	Fruit yield (t/ha)
T_1 (Brinjal + Red amaranth)	21.14	15.44	65.87	1.40	17.30
T_2 (Brinjal + Leaf amaranth)	20.36	15.87	65.61	1.33	15.87
T_3 (Brinjal + Patshak)	19.52	15.87	61.93	1.17	19.89
T_4 (Brinjal + Indian spinach)	20.74	16.03	67.00	1.33	18.00
T_5 (sole crop of brinjal)	22.02	16.56	77.5	1.69	22.43
CV (%)	10.03	1.11	8.62	8.51	5.39
LSD (0.05)	1.67	0.33	10.97	0.22	1.79

On an average, the yield of red amaranth, leaf amaranth, patshak and Indian spinach under intercropping were 13.83, 18.90, 6.99 and 15.40 t/ha, respectively (Table 5). Results showed that, among the leafy vegetables, leaf amaranth showed the highest yield (18.90 t/ha) in intercropping followed by Indian spinach (15.40 t/ha) where patshak was showed the lowest yield (6.99 t/ha).

Table 5. Yield of companion crops and brinjal equivalent yield (BEY) under brinjal-leaf vegetables intercropping system in kharif-1 (pooled data of 2018-2019 and 2019-2020).

Treatments	Yield of leafy vegetables (t/ha)	BEY (t/ha)	% increase of BEY over sole crop of brinjal	LER
T_1 (Brinjal + Red amaranth)	13.83	24.22	7.98	1.07
T_2 (Brinjal + Leaf amaranth)	18.90	22.96	2.36	1.02
T_3 (Brinjal + Patshak)	6.99	23.38	4.23	1.04
T_4 (Brinjal + Indian spinach)	15.40	27.62	22.29	1.23
T_5 (sole crop of brinjal)	-	22.43	-	1.00

Brinjal Equivalent Yield (BEY)

Brinjal equivalent yield was expressed in total productivity. Brinjal equivalent yield were higher in all the intercropping brinjal (22.96 to 27.62 t/ha) than the sole crop of brinjal (22.43 t/ha) (Table-5). The highest brinjal equivalent yield (27.62 t/ha) was recorded in Brinjal + Indian spinach intercropped combination which was followed by Brinjal + Red amaranth (24.22 t/ha) and Brinjal + Patshak (23.38 t/ha) (Table 5). The total BEY also increased 7.98, 2.36, 4.23 and 22.29 percent in red amaranth, leaf amaranth, patshak and Indian spinach intercropping, respectively over sole crop of brinjal. Islam *et al.* (2014) also reported the increases in total productivity in terms of brinjal equivalent yield (BEY) 8.80 to 26.67 t/ha in intercrop combination compared to base crop.

Land Equivalent Ratio (LER)

LER of different crop combinations ranged from 1.02 to 1.23 (Table 5). The highest land equivalent ratio (1.23) was recorded under Brinjal + Indian spinach intercropping system followed by Brinjal + Red amaranth (1.07) (Table 5). The lowest LER (1.02) was in Brinjal + Leaf amaranth intercropped combination. The mean values of LER (more than one) in all intercropping treatments revealed that land was more efficiently utilized under intercropping than under sole cropping of brinjal. The results are in agreement with the findings of Juskiw *et al*. (2000), Islam *et al*. (2012).

Table 6. Cost benefit analysis of Brinjal-leafy vegetables intercropping system in kharif-1 (pooled data of 2018-2019 and 2019-2020).

Treatments	Gross return (Tk/ha)	Total cost (Tk/ha)	Gross margin (Tk/ha)	BCR
T_1 (Brinjal + Red amaranth)	968600	317481	651119	3.05
T_2 (Brinjal + Leaf amaranth)	931700	319167	612533	2.92
T_3 (Brinjal + Patshak)	935400	313570	621830	2.98
T_4 (Brinjal + Indian spinach)	1105000	322513	782487	3.42
T_5 (sole crop of brinjal)	897200	308928	588272	2.90

Price: Brinjal: Tk 40/kg, Red amaranth: Tk 20/kg, Leaf amaranth: Tk 15/kg, Patshak: Tk 20/kg, Indian spinach: Tk 25/kg.

Cost Benefit Analysis

Intercropping combination of Brinjal with leafy vegetables showed higher monetary return than sole crop (Table 6). The highest gross return (Tk. 1105000/ha) was recorded from Brinjal + Indian spinach intercrop combination than sole crop of brinjal (Tk. 897200/ha) (Table 6). This intercropping combination also gave the higher gross margin (Tk.782487/ha) and benefit cost ratio (3.42) followed by Brinjal + Red amaranth with BCR (3.05). Among the intercropping, the lowest gross return (Tk. 897200/ha), gross margin (Tk. 588272/ha) and BCR (2.90) were obtained from the sole crop of brinjal followed by Brinjal + Leaf amaranth (2.92). The results of increased productivity and returns were consistent with the earlier reports of yield advantage of crop mixture compared to monoculture (Islam *et al*., 2012; Ahmed *et al*., 2013; Islam *et al*., 2014).

Conclusion

The results of two years study during *rabi* and kharif season showed that intercropping of leafy vegetables with Brinjal increased total productivity as well as economic return over sole crop of brinjal. Among the intercropped combinations, Brinjal + Indian Spinach in summer and Brinjal + Spinach in winter were more productive and profitable than all other combinations.

References

Ahmad, R., A. Jabbar, A. H. Ahmad, E. Ullah and I. H. Bhatti. 2007. Evaluation of direct seeded upland rice-based intercropping systems under strip planting geometry. *Pakistan J. Agric. Sci*, **44**(2), 189-193.

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

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

Islam, M. T., Rahman, M. F. Hossain and N. Ara. 2014. Feasibility of intercropping leafy vegetables and legumes with brinjal. *Bangladesh J. of Agril Res*. **39**(4): 685-692.

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

Juskiw, P. E., J. H. Helm and D. F. Salmon. 2000. Competitive ability in mixture of small grain cereals. *Crop Sci*. **40:**159-164.

Malik, M. A., M. F. Saleem, M. Sana and A. Aziz. 2002. Agro-economic expression of different relay crops after rice harvest under conventional and zero tillage. *International Journal of Agriculture and Biology*. **4**(2): 277-278.

Mian, M. A. K. 2008. *Performance of maize oriented cropping patterns under different nutrient management* (Doctoral dissertation, Ph. D. Dissertation. Dept. Agron. Bangladesh Agril. Univ., Mymensingh).

MOA (Ministry of Agriculture). 2014. Hand Book of Agricultural Statistics, December 2007. Government of the Peoples Republic of Bangladesh. http://www.moa.gov.bd/ statistics/ statistics.htm

Natesh HN, Abbey L, Asiedu SK (2017). An overview of nutritional and anti- nutritional factors in green leafy vegetables. *Horticult Int J*. **1**(2): 58-65.

Nazir, M. S., Jabbar, A., Ahmad, I., Nawaz, S. & Bhatti, I. H. (2002). Production potential and economics of intercropping in autumn-planted sugarcane. *Int. J. Agric. Biol*. **4**(1), 140-142.

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RELAYING OF MAIZE WITH POTATO UNDER MAIZE-FALLOW-T. AMAN CROPPING PATTERN IN CHARLAND

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Abstract

A field experiment was conducted in the charland of the Jamuna river under Sundargonj upazilla (AEZ 3) of Gaibandha during 2017-18 and 2018-19. Two cropping systems were compared: Potato/Maize-T. Aman (relay cropping of maize with potato) and Maize-Fallow-T. Aman. The experiment was laidout in six dispersed replications maintaining randomized complete block design (RCB) design. The results revealed that the improved cropping pattern (Potato/Maize-T. Aman) produced the higher system rice equivalent yield (21.58 t ha^{-1}) than the existing cropping pattern (11.61 t ha^{-1}), that is almost double than the existing cropping pattern. Similarly, the production efficiency (PE) was 44% higher in the improved cropping pattern with a value of 70 kg ha^{-1} day^{-1} than the existing ones (48.5 kg ha^{-1} day^{-1}). The land use efficiency (LUE) was also 29% more in the same cropping pattern (84.5%) compared to the farmers existing cropping pattern (65.5%). The profitability in terms of gross margin was almost double in the improved cropping pattern (Tk. 1,95,630) than the farmers' existing cropping pattern (Tk. 1,00,750). Inclusion of Potato relay with the existing cropping increase the system productivity and MBCR (1.91) of the farmers in the char areas.

Keyword: Relay cropping, Potato, Maize, Cropping system intensification, Profitability.

Introduction

Charland (Riverine Island) is a mid-channel island that periodically emerges from the riverbed as a result of erosion and deposition of sands . Charland areas irrespective of their geographic attachment to the mainland and distance from the growth centers are particularly vulnerable to flood, drought, and river erosion. There are about 1 Mha (million hectare) of char lands in Bangladesh, of which about 64 to 97% of the char areas are cultivable (Islam *et al.,* 2016). In Gaibandha, the char lands developed by the Brahmaputra and the Tista rivers is about 27,000 ha, mostly extended in Fulchari, Saghata and Sundargonj upazilla (Karim *et al.,* 2017). Generally, farmers in char land cultivate locally adapted crop varieties of different crops with inadequate production systems causes low yield. In recent years char land areas turn into major cash crop growing area such

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as hybrid maize, potato, sweet potato, lentil, mustard, grasspea, field pea, sweet gourd, etc. In this char land, Maize-fallow-T. Aman is the main cropping pattern commonly practices among the farmers.

Now a days, hybrid maize becomes popular in some char areas as monoculture during *rabi* season (November to April) due to its diversified uses and higher productivity. In Poultry feed formulation, producing starch, corn flour, corn oil, inositol, oral glucose high maltose syrup etc are producing from Maize. In addition, Maize plant is a good source of animal feed and source of household fuel.

Potato (*Solanum tuberosum* L.) is the main edible tubers in Bangladesh which are useed as a vegetable throughout the year.

Relay cropping is a multiple cropping system increases system productivity and can solve time contravene among sowing of different crops (Tanveer *et al.*, 2017). It also improve soil quality, farmers income, land equivalent ratio, and control weeds and pest infestation (Jabbar *et al.*, 2011; Bandyopadhyay *et al.*, 2016). Relay cropping is also a beneficial technology that results in better utilization of residual soil moisture of previous crops and reduces cost of production (Jabbar *et al.*, 2005). Potato and Maize can be grown in relay cropping as they have different canopy and growth duration (Zhang *et al.*, 2008). Potato-Maize relay cropping is a system or approach where maize is sown in potato after the reproductive stage but before the maturity of potato. The wider plant spacing of hybrid maize provides facility of other crops for growing as relay cropping. Hence, the study was undertaken with a view to cropping system intensification by relaying of maize with potato in charland of Sundargonj, Gaibandha.

Materials and Methods

A field experiment was conducted during 2017-18 and 2018-19 at Char Zigabari in Sundargonj upazilla of Gaibandha (25°3' N, 89°4' E and 18 m above sea level) with the AEZ-3 (Tista Meander Floodplain) under On-Farm Research Division (OFRD), Bangladesh Agricultural Research Institute, Gaibandha. The climate of the site is sub tropical monsoon with high rainfall during May to September. Annual average rainfall is 2086 mm, of which 93% occurs from May to October (Fig. 1). The soil of the experimental site is strongly acidic. Initial soil status was very low in soil organic matter, nitrogen and zinc; low in phosphorus and potassium; medium in sulphur and optimum in boron (Table 1).

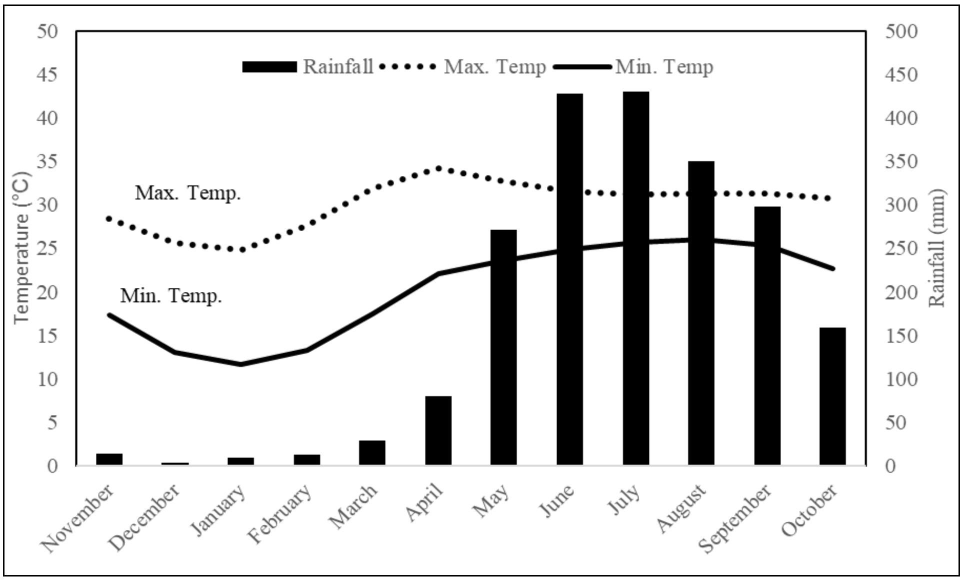

Fig. 1. Monthly rainfall (mm) and monthly mean maximum and minimum temperature of Sundargonj, Gaibandha.

Table 1. Initial soil status of Char Jigabari, Sundargonj, Gaibandha.

	pH	OM (%)	Total N (%)	K	P	S	Zn	B
				meq/100 g	µg/g soil			
Value	5.5	0.61	0.05	0.09	5.98	13.6	0.20	0.48
Interpretation	Strongly acidic	VL	VL	VL	L	L	VL	O

*VL=very low, L=low, O=optimum

The experiment was laid out in a randomized complete block design (RCBD) with 6 dispersed replications. Two cropping patterns were evaluated viz., Potato/Maize-T. Aman (improved pattern) and Maize-Fallow- T. Aman (farmers' existing pattern) for their comparative performance and economic return. The tested crop varieties were BARI Alu-25, BARI Hybrid Maize-9 and locally popular maize variety (NK 40). The unit plot size was 100 sq.m. (10 m x 10 m). Potato seeds were sown @ 1.5 t ha^{-1} and Maize @ 20 kg ha^{-1}. Twenty five-day old rice seedlings were uprooted carefully from the seedbed and transplanted into the main field, with 2-3 seedlings $hill^{-1}$ in both cropping patterns. In existing cropping pattern, fertilizers were applied as per farmer's practice. In improved pattern, Soil Test Based (STB) fertilizer doses were applied in all crops, while relay maize received 50% STB doses of sole maize. In potato, total phosphorous (P), sulphur (S), zinc (Zn) and boron (B) and half of nitrogen (N) and potassium (K) were applied during the final land preparation. Rest of nitrogen and potassium was applied at 30-35 days after planting during earthing up of soil. In case of maize, one third of N and all P, K, S and Zn were applied in the furrow of the potato field. Remaining N was applied in two equal splits as side dressing in maize rows at 8-10 leaf stage (30-35 DAS) and at taselling stage (50-60 DAS), and mixed thoroughly with the soil as soon as possible for better utilization. In aman rice, all P, K, S and Zn were broadcast on the soil surface immediately before transplanting. Nitrogen was applied into three equal splits at 10 days after transplanting (DAT), 30 DAT and 50 DAT.

Grain yield was determined by harvesting a 20 m^2 (4 m × 5 m) area in each plot. Fresh grain yield of maize and rice was dried to 12% and 14% moisture content. Straw moisture content (%) was determined on a subsample of the fresh straw which was weighed, dried at 70 °C for 3-5 days until a constant weight achieved.

Rice equivalent yield (REY) was calculated to compare pattern performance by converting the yield of each crop into equivalent rice yield on a price basis, using the formula: REY (of $crop_x$) = $Y_x (P_x / P_r)$, where, Y_x is the yield of crop 'x' (tons harvested product ha^{-1}), P_x *is* the price of crop, x and P_r is the price of rice (Biswas *et al.*, 2006). The price of rice, potato, maize rice straw and maize straw was Tk. 20, 12, 16.5, 1.0 and 0.5 kg^{-1}, respectively.

The production efficiency (PE) was calculated by dividing the total grain production ha^{-1} in a sequence with total duration of crops in a sequence (Tomar and Tiwari, 1990). Total field duration of a cropping pattern expressed in percentage of 365 days was taken as the land use efficiency (LUE) of the pattern (Tomar and Tiwari, 1990).

The cost and return analysis are included gross return, total variable cost (TVC), gross margin and marginal benefit cost ratio (MBCR). The output and inputs were valued depending on existing market prices. The gross return for each cropping pattern were calculated by multiplying the market price of the produce with crop yield while gross margin for each cropping pattern was calculated by subtracting the TVC from gross return. The MBCR of alternative cropping pattern over farmers existing pattern was computed as the marginal value product (MVP) over the marginal value cost (MVC). The Marginal of farmer's existing pattern (F) and alternative pattern (E) shown as follows:

$$\text{Marginal Benefit Cost Ratio (MBCR)} = \frac{\text{Gross return (E)} - \text{Gross return (F)}}{\text{TVC (E)} - \text{TVC (F)}} = \frac{MVP}{MVC}$$

Results and Discussion

System performance of the improved cropping pattern and existing pattern

Grain yields of maize in the existing cropping pattern were 11.00 and 9.85 t ha^{-1} in two years, respectively with an average of 10.4 t ha^{-1} and straw yields were

5.93 and 5.65 t ha^{-1} with an average of 5.80 t ha^{-1}. Grain yield of T. Aman rice was 2.82 and 2.48 t ha^{-1} with an average of 2.65 t ha^{-1} and straw yield was average 4.20 t ha^{-1} (4.38 t ha^{-1} in the first year and 4.02 t ha^{-1} in the second year). In the improved cropping pattern, potato tuber yields were 21.2 and 19.8 t ha^{-1} in 2017-18 and 2018-19, respectively with an average yield of 20.5 t ha^{-1} (Table 2). The grain yields of maize were 7.95 and 7.25 t ha^{-1} with an average of 7.60 t ha^{-1} and mean stover yield was 5.95 t ha^{-1} (6.15 t ha^{-1} in 2017-18 and 5.60 t ha^{-1}in 2018-19). In the improved cropping pattern, the grain yield of maize was 27% lower than the existing cropping pattern that compensate the higher tuber yield of potato. Grain yields of T. Aman rice were 2.80 and 2.50 t ha^{-1} with an average of 2.65 t ha^{-1}, like the existing cropping pattern and straw yields were 4.35 and 4.05 t ha^{-1} in two years, respectively.

The total field duration was 310 days in the improved cropping pattern, that was 29% more than the existing cropping pattern (total field duration 240 days). On the other hand, the turn around time was 125 day in the existing cropping pattern and 55 days in the improved cropping pattern, means 70 more days were required in the improved cropping pattern. The turn around time reduced by 56% (70 days) due to the introduction of an additional crop (relaying of maize with potato).

There was a trend for higher rice equivalent yield (REY) from Maize-Fallow-T. Aman cropping pattern than Potato/Maize- T. Aman cropping pattern on pooled data (Table 2). The average rice equivalent yield of the existing cropping pattern was 11.61 t ha^{-1}, whereas it was almost double in the improved cropping pattern (21.58 t ha^{-1}). The higher REY of the Potato/Maize -T. Aman cropping pattern than the Maize-Fallow -T. Aman cropping pattern might be due to the higher production of potato (average 20.5 t ha^{-1}) and good market price. Alam *et al.* (2017) similarly reported that cropping intensification increase rice equivalent yield (REY).

Production efficiency and land use efficiency

The average highest (PE) production efficiency (70 kg) was recorded in the improved cropping pattern, that was 44% higher than the existing cropping pattern. The lowest PE was recorded in the existing cropping pattern (48.5 kg). Similarly, Potato/Maize-T. Aman expressed maximum land-use efficiency (LUE) during both the years with an average of 84.5% (86% in 2017-18 and 83% in 2018-19) (Table 3). This pattern occupied land for more time in a year, thereby achieved higher LUE. Maize–Fallow–T. Aman expressed the lowest LUE (65 to 66% in both the year), as no summer crop was grown in this pattern. The results revealed that the improved cropping pattern increased land use efficience by 29% than that of exixting cropping pattern.

Table 3. Production efficiency, Land use efficiency of the cropping pattern

Cropping pattern	Production efficiency (kg $ha^{-1}day^{-1}$)			Land use efficiency (%)		
	2017-18	2018-19	Average	2017-18	2018-19	Average
Maize-Fallow-T. Aman (Existing pattern)	50	47	48.5	66	65	65.5
Potato/Maize-T. Aman (Improved pattern)	71	69	70	86	83	84.5

Crop and system economic performance

The highest gross return was calculated from the improved cropping pattern, Potato/Maize-T. Aman (Tk. 4,31,600), almost double than the existing cropping pattern (Tk. 2,32,200) (Table 4). The reason might be due to the higher tuber yield (20.5 t ha^{-1}) of potato as well as more price received in the improved cropping pattern. The total variable cost was Tk. 2,35,970 in the improved pattern and Tk. 1,31,450 in the existing pattern. Finally, the gross margin was almost double in the improved cropping pattern (Tk. 1,95,630) compared to existing pattern (Tk. 1,00,750). The MBCR was calculated 1.91 in improved cropping pattern over existing cropping pattern. Alam *et al.* (2017) reported that cropping system intensification increase the system profitability. Hoque *et al.* (2015) reported that potato hybrid maize relay cropping pattern is suitable for getting higher economic return at Comilla region.

Table 4. Cost benefit analysis of the two cropping patterns evaluated at Sundargonj, Gaibandha, 2017-18 and 2018-19 (average of two years)

Cropping pattern	REY (t $yr^{-1}ha^{-1}$)	Gross return (Tk. $yr^{-1}ha^{-1}$)	Total variable cost (Tk. $yr^{-1}ha^{-1}$)	Gross margin (Tk. $yr^{-1}ha^{-1}$)	MBCR (Whole pattern)
Maize-Fallow-T. Aman (Existing cropping pattern)	11.61	2,32,200	1,31,450	1,00,750	-
Potato/Maize-T. Aman (Improved cropping pattern)	21.58	4,31,600	2,35,970	1,95,630	1.91

* *Price (Tk. kg^{-1}): Urea- 16, TSP- 25, MP- 15, Gypsum- 9, Zinc Sulphate- 130, Boric acid- 140*

* *Rice grain- 20, Rice straw- 1.0, Maize grain-16.5, Maize straw=0.5 and Potato tuber-12*

* *REY: rice equivalent yield, MBCR: marginal benefit cost ratio.*

Conclusion

This study revealed that, Potato/Maize-T. Aman cropping pattern showed better performances in terms of pattern rice eqilevalent yield, production efficiency, land use efficiency and economics compared to the existing cropping pattern. Farmers' are keen interested to know about the relay cropping of maize with potato and convienced that this technology could increase their productivity as well as farm income. Due to practicing relay cropping of maize with potato in a land in a year, system productivity could be increased, and food security will be ascertained for the farmers. So, potato/maize-T. Aman cropping pattern should be disseminated on land suited to this cropping pattern in char areas of Gaibandha and other similar areas.

References

Alam, M. J., E. Humphreys, M. A. R. Sarkar and Sudhir Yadav. 2017. Intensification and diversification increase land and water productivity and profitability of rice-based cropping systems on the High Ganges River Floodplain of Bangladesh. *Field Crops Res.* **209**: 10-26.

Bandyopadhyay, P. K., K. C. Singh, K. Mondal, R. Nath, P. K. Ghosh, N. Kumar and S. S. Singh. 2016. Effects of stubble length of rice in mitigating soil moisture stress and on yield of lentil (*Lens culinaris* Medik) in rice-lentil relay crop. *Agril. Water Management*. **173**: 91–102

Biswas, B., D. C. Ghosh, M. K. Dasgupta, N. Trivedi, J. Timsina and A. Dobermann. 2006. Integrated assessment of cropping systems in the Eastern Indo-Gangetic plain. *Field Crops Res.* **99**: 35-47.

Hoque, A., M. Islam, M. Hossain and M. Khan. 2015. Productivity of potato-hybrid maize relay cropping system as influenced by fertilizer dose. *Bangladesh Agron. J.* **17**(2), 9-13.

Islam, M. N., M. A. Hossain, M. Mohiuddin, M. A. K. Mian and M. Biswas. 2016. A survey on crops and cropping of char areas in Bangladesh. *In*: Unfavorable Eco-System: Crop Production Under Char land Eco-System. Agronomy Division Bangladesh Agricultural Research Institute Joydebpur, Gazipur-1701. pp. 55.

Jabbar, A., R. Ahmad, E. Ullah and M. S. Nazir. 2005. Agro-economic performance of diversified rice-based relay cropping systems at zero and conventional tillage under strip plantation. *Pakistan J. Agril. Sci.* **12**:18–21.

Jabbar, A., R. Ahmad, I. H. Bhatti, T. Aziz, M. Nadeem and R. A. Wasi-u-Din. 2011. Residual soil fertility as influenced by diverse rice-based inter/relay cropping systems. *International J. Agri. Bio.* **13**: 477–483.

Karim, M. A., M. A. Quayyum, S. Samsuzzaman, H. Higuchi and E. Nawata. 2017. Challenges and Opportunities in Crop Production in Different Types of Char Lands of Bangladesh: Diversity in Crops and Cropping. *Tropical Agri. Develop.* **61**(2): 77-93.

Tanveer, M., S. A. Anjum, S. Hussain, A. Cerdà and U. Ashraf. 2017. Relay cropping as a sustainable approach: problems and opportunities for sustainable crop production. *Environ. Sci. Pollu. Res.* **24:** 6973–6988.

Tomar, S. S. and A. S. Tiwari. 1990. Production potential and economics of different cropping sequences. *Indian J. Agron.* **35**(1,2): 30-35.

Zhang, L. Z., W. Van der Werf, L. Bastiaans, S. Zhang, B. Li and J. H. J. Spiertz. 2008. Light interception and utilization in relay intercrops of wheat and cotton. *Field Crops Res.* **107**: 29–42.

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HEDONIC PRICE ANALYSIS FOR HOG PLUM PURCHASE DECISION IN SOUTHERN PART OF BANGLADESH

A. HOSSAIN[1], M. S. HOQ[2] AND A. K. MANDAL[3]

Abstract

The hog plum (*Spondias mombin*) is locally known as *Amra* is very popular fruit in Bangladesh. It is very delicious fruit and sources of Vitamin C. The purpose of this study is to identify the importance of the attributes of hog plum on its price. A total of 121 respondents were interviewed to identify the attributes of hog plum purchase decision using both OLS and robust regression models. Results show that quantity, whole fresh and blemish free are important attributes for hog plum purchase decision. Quantity, blemish free and traceability are significantly important attributes for low income consumer groups whereas quantity and whole fresh are significantly important attributes for high income consumer groups. The implication of the study is that proper hog plum farming system and its marketing activities design are necessary for making it a profitable business.

Keywords: Hog Plum, Quality attributes, hedonic price, robust regression.

Introduciton

Consumption of fruit is highly recognized in human diet. The daily per capita fruit requirement is between 250-300gm (Bhuiyan, 2012). Most of the people do not consume fruit daily becuase of its high cost, one of the several reasons. Hog plum is one of the less expensive and mentionable fruit for its promising profit percentage and nutritional values. According to Department of Agricultural Extension (DAE), approximately 7,200 tons hog plum is grown around 650 hectares of land in only three southern districts of Bangladesh namely Pirojpur, Jhalokathi and Barishal (Islam and Sujan, 2016).

Hog plum (*Spondias mombin*) is edible, delicious and sources of Vitamin C (Siddiqu *et al.*, 2015). It is also a valuable health food which are low in calories, high in vegetable proteins, zinc, chitin, fiber, vitamins and minerals. The fruit is found in Bangladesh and especially available in the period of March-September. It is also found in Assam and Bombay and it can be used to prepare different value added product (Akter *et al.*, 2012). The fruit is also known as *"Amra"* in Bangladesh. The people of all ages are fond of this fruit during the summer season. The fruit is usually consumed in green stage but it can be used to prepare pickle or chutney, jam and other processed food. The fruit is normally sold in

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open markets or in the busy streets like bus station, train station, launch station and even in the ferry ghat.

The purpose of this study is to identify the importance of attributes for hog plum purchase decision and its impact. The hedonic price model was used to identify the importance of each of the attributes of hog plum. The price that finalized by bargaining from both the buyer and seller is hedonic price. According to hedonic price model, consumers do not purchase product rather they purchase the product for its attributes which maximizes the utility of the product (Lancaster, 1966).

The earliest study of hedonic prices for food was firstly carried out by Waugh in 1927 who studied how quality determined the price of vegetables, asparagus (Waugh, 1928). A number of literatures on the hedonic prices of agricultural commodities are available including tomatoes (Bierlen and Grunewald, 1995), milk (Gillmeister *et al.*, 1996), chicken (Ahmad and Anders, 2012) and eggs (Karipidis *et al.*, 2005).

The hedonic prices are also available on fruits including apples (Kajikawa, 1998; Ricks *et al.*, 2002; Endrizzi *et al.*, 2015; Sarder *et al.*, 2020), mango (Yaseen et al., 2016), grapes (Golan and Shlit, 1993), guava and hog plum (Hossain and Badiuzzaman, 2020) and fruit juices (Weemaes and Riethmuller, 2001). The hedonic price study on fruit especially on hog plum in Bangladesh is very scarce. The reason is that the awareness of the consumers regarding the fruit attributes is not well known. Therefore, the study is used to achieve the following specific objectives.

(1) To identify the influential hog plum characteristics for consumer purchase decision, and
(2) To quantify the role of each of the hog plum characteristics in explaining the fruit price variation as well.

The next section of this study details the methodology of the study followed by data description and sampling in section 3, results and discussion in section 4. Conclusion of the study in the last section.

Methodology

The hedonic price models were highly applied in food industry. A hedonic price function is used to determine the relative importance of product attributes since the consumers do not purchase product rather they pruchase the product for its attributes. A consumer utility is expressed in the following equation:

$$U = f\,(S_1, S_2, \ldots \ldots \ldots S_n) \qquad (1)$$

Where, S_1 is the service provided by the product *í*. Ladd and Zober (1977) identified that each of the service or attribute can contribute positively or negatively to the consumption of product *í*. According to Ladd and Zober (1977), *"The price paid for the proudct equals the sum of the marginal yields of the* *characteristics provided by the product, multiplied by the marginal implicit prices of the product's characteristics".*

The following regression model was therefore, used to identify the marginal implicit prices:

$$\text{logprice} = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2 \dots \dots \dots + \beta_n\chi_n \quad (2)$$

Where, logprice is the logarithm of price, β_i are the parameters to be estimated for χ_i exogenous variables and β_o is the constant for no error terms. All the exogenous variables are binary variables except quantity purcahse of hog plum. The quantity of hog plum purchase is measured in continuous variable. Halvorsen and Palmquist (1980) explained the binary variables in such a way that the percentage changes of the dependent variable-in this case the price of hog plum will be measured in terms of indepdent variables say, its form (1 if the hog plum is whole fresh, and 0, otherwise), *ceteris paribus*. It indicates the percentage changes in price over the baseline level for certain attributes (whole fresh, big size, hard texture, blemish free etc.). On the other hand, the coefficient of the continuous variable indicates that holding other factors fixed, the percentage changes in price is explained in relation to a unit changes in quantity. Both the OLS and robust regression models were estimated with the help of log-linear model. The robust regression models were estimated due to heteroskedasticity problem. The models were tested with the help of Breusch-Pagan/ Cook-Weisberg test.

Data description and sampling

A questionnaire is primarily produces with the help of available literatures and then a pilot study was conducted among 30 consumers of the hog plum in Barishal Sadar, Dumki and Patuakhali. The pilot study shows that all the factors included in the model were influential for hog plum purchase decision. An interview schedule was then finalized to collect the data from the respondents and 6 field workers were appointed for conducting the survey. The study used stratified sampling technique where the four coastal districts were selected as strata at first, and then the random sampling technique were used to interview the respondents. A total of 121 samples were collected from the Barishal division, located in the southern part of Bangladesh. The four districts of Barishal division namely Barishal, Pirojpur, Jhalokathi, and Patuakhali were selected for the hog plum purchase decision. The highest number of samples were taken from Barishal district by 45% followed by Pirojpur, Jhalokathi and Patuakhali by 31%, 14% and 10% respectively (Table 1) according to the hog plum production volume (BBS, 2018). Table 1 represents the descriptive statistics of both the dependent and independent variables including area, monthly income and expenditure on fruits.

Table 1. Descriptive statistics of dependent and independent variables

Variable	Description	f	$\overline{\chi}$	Min	Max	S
Price	Per kg price in Bangladeshi Taka (BDT)	121	73.34	25.00	120.00	22.16
logprice	Logarithm of price	121	1.84	1.40	2.08	0.15
Quantity	Total purchase at a time in kg	121	1.14	0.10	6.00	1.15
Fresh	1 if hog plum is whole fresh and 0, otherwise	121	0.64	0.00	1.00	0.48
Size	1 if hog plum is big in size and 0, otherwise	121	0.52	0.00	1.00	0.50
Texture	1 if the texture of hog plum is hard and 0, otherwise	121	0.76	0.00	1.00	0.43
Blemish	1 if the hog plum is free from blemish and 0, otherwise	121	0.45	0.00	1.00	0.50
Chemical	1 if the hog plum is free from chemical and 0, otherwise	121	0.53	0.00	1.00	0.50
Traceability	1 if the hog plum has no traceability and 0, otherwise	121	0.48	0.00	1.00	0.50
Area	Barishal	55	0.45			
	Pirojpur	37	0.31			
	Jhalokathi	17	0.14			
	Patuakhali	12	0.10			
Income	Low if monthly income is less than BDT 20,000	67	55.37			
	High if monthly income is BDT 20,000 or more	54	44.63			
Expenditure	Monthly Expenditure on fruit:					
	Less than BDT 2,000	81	66.94			
	BDT 2,000-4,000	35	28.93			
	Above BDT 4,000	5	4.13			

Note: f, s and $\overline{\chi}$ refers to the number of frequency, standard deviation and the average value. Min and Max refers to the minimum and maximum response of the consumers. Source: Author's own estimations, Field Survey (August-December, 2019).

Table 2. Hog Plum purchase decision in the study area

Dependent Variable: logprice	*All*			*Low Income Group*			*High Income Group*		
	β	$S_{\bar{\chi}}$	*p*	β	$S_{\bar{\chi}}$	*p*	β	$S_{\bar{\chi}}$	*p*
Quantity	-0.219	0.022	0.000	-0.166	0.038	0.000	-0.217	0.031	0.000
Fresh	-0.037	0.015	0.018	-0.048	0.020	0.022	-0.036	0.024	0.141
Size	0.003	0.008	0.715	-0.006	0.012	0.641	-0.007	0.012	0.568
Texture	0.011	0.016	0.496	-0.009	0.022	0.671	0.013	0.026	0.630
Blemish	0.031	0.017	0.067	0.001	0.023	0.979	0.069	0.025	0.008
Chemical	0.002	0.017	0.902	-0.031	0.037	0.402	0.011	0.025	0.663
Traceability	-0.005	0.017	0.775	0.028	0.029	0.353	-0.045	0.026	0.096
Constant	1.997	0.018	0.000	2.020	0.022	0.000	1.982	0.029	0.000
	n=121, R-squared=0.589, F-statistic=25.18***			n=54, R-squared=0.683, F-statistic=14.16***			n=67, R-squared=0.590, F-statistic=12.13***		

Note: *, **, *** denote the statistical significance at 10%, 5% and 1% levels under their p-values. β, $S_{\bar{\chi}}$ and p refer to coefficients, standard error and the p-value. Source: Author's own estimations, Field Survey (August-December, 2019).

The results show that most of the respondents spend less than BDT 2,000 on fruits per month since the maximum interviewed respondents were under low income group having income has less than BDT 20,000 and they are 67% of the toal respondents. The average price of per kg hog plum is BDT 73 which denote that the price of the hog plum is somewhat high because on average, a respondent purchase only one kg hog plum. The highest variation (C.V = $\frac{S}{\bar{\chi}} \times 100$) are observed in blemish free and in having no traceability of the hog plum by 111% and 104% respectively. The results indicate that the price highly varied due to blemish free and having no traceability.

Results and Discussion

The purchase decision of hog plum is estimated in two ways using two different regression models. The first model is estimated for the full sample using robust regression model due to have heteroskedasticity problem (see appendix 1). Moreover, the full sample was divided in two groups considring income of the respondents. The following Table 2 shows the estimated parameters of the three different hedonic price models.

The results show that all models are fit since F statistics are significant at 1% level. The R-squared values are reasonable. For example, the value of R squared for all consumers model is 0.589 which indicates that the price of hog plum is varied by 59% for each of the independent variables included in the all consumers model.

All consumers' model: All the estimated parameters of the exogeneous variables are expected and found that quantity, whole fresh and blemish free are significantly important for hog plum purchase decision. Varela *et al.* (2009) studied consumer preference in the fruits markets of Taiwan and Udegbe (2019) studied consumer preferences in Nigeria. Both of the study revealed that traditioanl fruits are preferred due to fresh fruits but they didn't identify the willingness to pay for this attribute. The results also show that hog plum is discounted at approximately 22% for every one extra kg purchased. At the same time, the price per kg of hog plum is decreased by approximately 4% if the hog plum is whole fresh compared to sliced, *ceteris paribus*. It indicates that the consumers want to purchase the ready hog plum which is directly consumed in the form of sliced or the pickle of hog plum. On the other hand, the price per kg of hog plum is increased by approximately 3% if the hog plum is blemish free which is in line with the study of Hossain and Badiuzzaman (2020) for guava purchase decision. Ricks *et al.* (2002) also found the similar result for apple purchase decision. They stated that the fruit skin with flaws or blemish were considered as low quality fruit. Yaseen *et al.* (2016) inferred that Pakistani consumers are mostly considered blemish free, size and colour for mango purchase decision.

When we subgroup the consumers, the OLS regression model is considered for low income group consumers becuase of having no heteroskedasticity (see also appendix 1) whereas in case of high income group consumers, robust regression is used due to have heteroskedasticity problem (see appendix 1). The value of R squared for low income group consumers are higher than the high income group. The results of the subgroups of the consumers show that high income group consumers considere more fruit quality characteristics than the low income group (Huang and Lin, 2007). Quantity and whole fresh are significantly important for low income consumers whereas quantity, blemish free and traceability are important characteristics for high income consumers. The results show a different purchase decision of hog plum in southern part of Bangladesh.

Low income consumer group: The low income consumers are willing to pay less both for whole and purchase more than one kg of hog plum. The per kg price of hog plum is decreased by 17% if one extra kg is purchased, on the other hand, they will pay 5% less if the hog plum is whole fresh rather than sliced, if other things remain constant. It indicates that the more the price of hog plum, the less they desire to purchase. At the same time, the consumers are highly interested to buy the other forms of hog plum rather than whole fresh like sliced, pickle of hog plum etc.

High income consumer group: The high income consumers are willing to pay more for blemish free and traceability whereas they are willing to pay less for more quantity purchase. The hog plum is discounted at approximately 22% for every one extra kg of hog plum purchase; on the other hand, the consumers will pay 5% more if there is a traceability of the hog plum, *ceteris paribus* which is in line with the study of Sarder *et al.* (2020). They found that consumers pay more for traceable apple and less for more quantity purchase. Mabiso *et al.* (2005) also stated that consumers prefer and willing to pay more the labelled apple over non-labelled one. Endrizzi *et al.* (2015) stated that information can be important for certain group of consumers which is almost related with the usage of traceability. The consumers will pay 7% more if the hog plum is blemish free.

The results indicate the different purchase decision by income group of the consumers. The high income group consumers differ by blemish free and traceability whereas the low income group consumers differ by whole fresh of the hog plum. Quantity is the only factor considered by both of the consumer groups. The implication of the study is that the producer of the hog plum should care about the blemish of the hog plum. The intermediaries involved in the hog plum supply chain should care about the traceability, and blemish free of the hog plum and ultimately the pricing strategy of hog plum. The intermediaries may introduce private labelling for the identification of the quality fruits. The reason is that the consumers in this study are found to pay more for the fruits having traceability over the non-traceability ones. Otherwise, the hog plum consumers may seek the available alternatives such as guava (*Psidium Guajava*), pummelo (*Citrus Maxima*), ceylon olive (*Elaeocarpus Serratus*) etc. which may hinder the sales and farming of hog plum in near future.

Conclusion

The trading of hog plum may be a profitable venture to different intermediaries meeting the consumer need and demand. The farming system of hog plum and its pricing system are the barriers of its business success. The purpose of the study was to identify the attributes of hog plum to its purchase decision and its relative importance. The results of this study show that low income consumers group have different purchase decision than the high income consumers group. The results also show that high income consumers consider more attributes than the low income consumers. In the full sample regression model, it is seen that quantity, whole fresh and blemish free are the important attributes for hog plum purchase decision. Quantity, blemish free and traceability are important attributes for high income consumers purchase decision whereas quantity and whole fresh are important attributes for low income consumers purchase decision.

The implication of this study is that the farmers should care about the farming system of hog plum. To have the consumer required hog plum, the farmer should produce the hog plum blemish free. The intermediaries, on the other hand, should care about the form of hog plum and its traceability. The form of the hog plum indicates the raw hog plum into slice, pickle, chutney, and jam etc. The traceability of hog plum indicates the packaging of the hog plum under different grading. The hog plum would be a profitable business if the seller consider these issues as the consumers need and demand.

The following recommendations may be considered for the better production and marketing activities of the hog plum venture:

- ✓ The proper transportation, preservation and marketing facilities should be developed for reducing a large number of damage and spoil of hog plum.
- ✓ The utility may be increased through the processing and value addition of hog plum by preparing jam, pickle, chutney etc.

The study may be altered for the larger sample size collected from the whole country. The study may be different if the consumption pattern is identified in relation to the gender of the respondents. The contingent vlauation method may be applied for finding the consumer’s willingness to pay if a number of characteristics and a larger sample size would be available. Conjoint analysis may be applied to rank the characteristics of hog plum as well, the scope of the future research.

References

Ahmad, W. and Anders, S. 2012. The value of brand and convenience attributes in highly processed food products. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*. **60**(1):113-133.

Akter, S., S. M. S. Shahriar, F. Akter, S. Morshed, and M. N. Islam.2012. Study on chemical composition of fresh Mymensingh and Barishal Hog-Plum (Spondius Mangifera) and developed leather and jelly and sensory evaluation. *Journal of Environmental Science and Natural Resources*. **5**(2): 29-36.

BBS 2018. Yearbook of Agricultural Statistics, Statistics and Informatics Division, 29th Series, Ministry of Planning, Government of the People's Republic of Bangladesh.

Bierlen, R. and O. Grunewald. 1995. Price Incentives for Commercial Fresh Tomatoes. *Journal of Agricultural and Applied Economics*. **27**(1): 138-148.

Bhuiyan, M. H. R. 2012. Pickle and chutney development from fresh hog plum (Spondias dulcis). *Journal of Environmental Science and Natural Resources*. **5**(2):67-72.

Endrizzi, I., L. Torri, M. L. Corollaro, M. L. Demattè, E. Aprea, M.Charles and F. Gasperi. 2015. A conjoint study on apple acceptability: Sensory characteristics and nutritional information. *Food quality and preference.* **40:** 39-48.

Gillmeister, W. J., R. D. Yonkers, and J.W. Dunn. 1996. Hedonic pricing of milk components at the farm level. *Review of Agricultural Economics*. 181-192.

Golan, A., and H. Shalit. 1993. Wine quality differentials in hedonic grape pricing. *Journal of Agricultural Economics.* **44**(2):311-321.

Halvorsen, R., and R. Palmquist. 1980. The interpretation of dummy variables in semilogarithmic equations. *American economic review*. **70**(3):474-475.

Hossain, A., and Badiuzzaman. 2020. Hedonic prices for fruits market in Bangladesh: lessons from guava and hog plum purchase decision. Resubmitted to *Journal of Retailing and Consumer Services*.

Huang, C. L., and B. H. Lin. 2007. A hedonic analysis of fresh tomato prices among regional markets. *Review of agricultural economics*. **29**(4):783-800.

Islam, F., and M. H. K. Sujan. 2016. Rationality of hog plum cultivation in Jhalokathi district, an empirical analysis in the socio-economic context of Bangladesh. *Journal of Advances in Social Science and Humanities*. **2**(1), 8-18.

Kajikawa, C. 1998. Quality level and price in Japanese apple market. *Agribusiness: An International Journal.* **14**(3):227-234.

Karipidis, P. I., E.Tsakiridou, N. M. Tabakis, and K. Mattas. 2005. Hedonic analysis of retail egg prices. *Journal of Food Distribution Research*, 36(856-2016-56442):68.

Ladd, G.W and M. Zober. 1977. Model of Consumer Reaction to Product Characteristics. *Journal of Consumer Research*. **4:**89-100.

Lancaster, K. J., 1966. A New Approach to Consumer Theory. *Journal of political economy*. **74**(2):132-157.

Mabiso, A., J. A. Sterns, L. House, and A. F. Wysocki, 2005. Estimating consumers' willingness-to-pay for country-of-origin labels in fresh apples and tomatoes: A double-hurdle probit analysis of American data using factor scores (No. 378-2016-21263).

Ricks, D. J., J. A. Sterns and T. A. Woods. 2002. Customer preferences for Michigan apples: a case example of a market research program for a commodity industry. *Journal of Food Distribution Research*, 33(856-2016-56586):125-135.

Sarder, M.M., A. Hossain and K. Tripura. 2020. Retail strategies of apple in a developing country: a hedonic price analysis. Accepted for publication in the Journal of the Patuakhali Science and Technology University, JPSTU/297/20.

Siddiqu, A., S. Nasrin, M. Moonmoon, M. A. Islam, and M. M. Khatun. 2015. Bacterial assessment of street-vended Hog Plum (Spondias Mombin) and its public health importance. *Bangladesh Veterinarian*. **32**(1):19-26.

Udegbe, S. E. 2019. Consumer preference on purchase decision—case study of fruits and vegetables in Nigeria. *Economics and Social Sciences Academic Journal,* 1(2):54-61.

Varela, O., W. C. Huang, and S. E. Sanyang. 2009. Consumer behavior and preference in the fruit markets of Taiwan. *Agric. Econ. Mark. J*. **2:**19-28.

Waugh, F. V. 1928. Quality factors influencing vegetable prices. Journal of Farm Economics. **10**(2):185-196.

Weemaes, H., and P. Riethmuller. 2001. What Australian consumers like about fruit juice: results from a hedonic analysis. In World Food and Agribusiness Symposium of the International Food and Agribusiness Management Association.

Yaseen, A., M. Mehdi, S. Somogyi and B. Ahmad. 2016. Consumer preferences to pay a price premium for quality attributes in Pakistani grown mangoes. *Pakistan Journal of Commerce and Social Sciences (PJCSS)*. **10**(3): 615-637.

Appendix 1

Heteroskedasticity Test by Breusch-Pagan/ Cook-Weisberg test

Heteroskedasticity Test	Full Sample	Low Income Group	High Income Group
Chi-square	21.580	0.370	15.090
p-value	0.000	0.543	0.000

Note: The null hypothesis is rejected for both full sample and low income group consumer purchase decision since the values of chi-square are significant at 1% level of significance. It indicates that there are heteroskedasticity in both of the model. On the other hand, the null hypothesis is accepted for high income group consumers since the value of chi-square is not significant at 1%, 5% or even 10% level of significance. It indicates that there is no heteroskedasticity.

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PREVAILING INSECTS AND MITE PESTS OF BRINJAL AND THEIR NATURAL ENEMIES AT JASHORE IN BANGLADESH

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Brinjal (*Solanum melongena* L.) is one of the important vegetable crops grown in all parts of Bangladesh. It has a positive role in both summer and winter to fulfill the market demand of vegetables in Bangladesh. It contains high content of vitamins, minerals and bioactive compounds those are remunerative to human health. In this respect, brinjal is ranked among the top 10 vegetables in terms of oxygen radical absorbance capacity (Cao *et al.*1996). Asia has the largest eggplant production, which comprises more than 90% of the world production area and 87% of the world production (Choudhary and Gaur 2009). One of the major constraints to the successful brinjal production in Bangladesh is the damage caused by insect and mite pests. Studies reveal that 20-30% of the total brinjal production is lost directly or indirectly by the attack of insect and mite pests every year (Dutta et al., 2017; Amin et al. 2018). In order to develop economically feasible, ecologically sound and socially acceptable pest management strategies, detail information of a pest complex, the status and the sequence of appearance of the pest during the crop period, the losses and type of damages of the crop are of great importance (Bijjur and Verma, 1995). In Bangladesh insect pests of brinjal and their damage severity and natural enemies in different location of this country are insufficient. Therefore, the present study was undertaken to record the insect pest complex of brinjal with natural enemies, pest status, nature of damages, and the time of appearance of the pests in relation to the phenology of the crop.

The research was conducted in the Regional Agricultural Research Station (RARS), Jashore, during November 2018 to April 2019 (rabi season). The brinjal variety Jashore local (Chega) was used. Seeds were sown in seedbed on 20th October 2018. The total area of the experimental field was 30m X 20m (600m2) consisting of 21 plots. Each plot was 5 m length and 3 m breadth. The spacing was 1.0m X 0.75m. The land was fertilized with cow dung, urea, TSP, MoP and gypsum @ 10000, 550, 450, 250 and 111 kg/ha, respectively. Healthy and uniform brinjal seedlings were transplanted in the experimental plots on 20th November, 2018. Irrigation, weeding and other intercultural operations were done when necessary. But no insecticide or plant protection measures were used during the study.

Observations on the population of different insect pests were recorded from seedling to maturity stages of the crop. Data on different species of insects were recorded from randomly selected 10 plants in each plot. The shoot infestation was judged by counting healthy and infested shoot from 10 randomly selected plants per plot. Similarly, fruit infestation was recorded by counting the number of total healthy fruits and damaged fruits. Number of damaged leaves/five plants

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were observed to record data for sucking pests were counted on six leaves (each from 2 upper, middle and lower leaves per plant) by examining each leaf carefully during early morning hours, when the pest was less active. Mite population was counted by hand lens and magnifying glass. Natural enemies were also counted following similar method carefully. Relative population of insect was counted. The insects were identified following Nayar et al. (1995) and Biswas et al. (1998). The insect were graded as major and minor on the basis of their population density per plant, feeding behavior, nature and extent of crop damage.

Ten species of insect pests belonging to 4 orders and 9 families were found to infest at different growth stages of brinjal during the study. Among the recorded insects, only three (3) namely, Brinjal shoot and fruit borer (Leucinodes orbonalis), epilachna beetle (Epilachna dodecastigma), and jassid (Amrasca biguttula biguttula), were considered as the major pests. Four species of natural enemies namely coccinellid beetles, Coccinella septempunctata, Coccinella transversalis, Menochilus sexmaculatus and spider, Argiope luzona were recorded from the brinjal crop (Table 1).

The population density per plant of major and minor insects and their feeding behavior on brinjal crop is presented in table 2. Among the pests, 6 insect species were grouped as sap sucker, one as fruit borer, two as leaf eater and one as leaf roller. The population density per plant of major insects namely, brinjal shoot and fruit borer, epilachna beetle and jassid was 5.75, 7.65 and 22.55, respectively. Similarly, the population density per plant of the minor insects namely, aphid, whitefly, mealy bug, green leafhopper, leaf roller, leaf beetle and mite was 18.35, 35.45, 45.25, 35.45 3.25, 9.45 and 48.75, respectively. Population density perplant of natural enemies namely, C. septempunctatam, C. transversalis, M. sexmaculatus and A. luzona was 4.96, 4.24, 5.85 and 4.45, respectively (Table 2.). Four species of natural enemies were found in the experimental field, Jashore. They were found to prey different insect pests

Brinjal shoot and fruit borer, epilachna beetle, aphid, mealy bug, leaf roller were found to infest the brinjal crop at the vegetative stage and continued their infestation during maturity stage. The other insects namely, jassid, whitefly, green leafhopper, leaf beetle were noticed from seedling to maturity stage of the crop. Mite Tetranychus sp. was present in the crop at the flowering to maturity stages. The natural enemies, coccinellid beetles present at the late vegetative stage and continued their predation up to maturity stage of the crop. Spider was recorded from the brinjal crop at late vegetative stage to stages of the crop.

In Bangladesh, the insect pests of brinjal were recorded by several scientists. Ali et al. (2012), Latif et al. (2009), Rashid et al. (2013) recorded five (5) major insect pests found in brinjal crop viz. brinjal shoot and fruit borer (BSFB), aphid, white fly, jassid and thrips which were also recorded in the present observation. Latif et al. (2009) recorded 12 species of insect pests attacking brinjal crop in

Bangladesh which were also included in the present study. Amin *et al.* (2018) recorded 8 species of natural enemies in brinjal in BSMRAU, Gazipur. which were recorded in the present observation.

The appearances and succession of the insect pests on brinjal crop showed that different pest species occurred in an overlapping manner and the crop was under the continuous attack of one or more pests. Most of the major and minor pests appeared in the crop during the vegetative, flowering and fruiting stages and the maximum infestation occurred during flowering and fruiting stages of the crop. The research results gives information on the insect pests of brinjal crop over the previous reports in Bangladesh.

Table 1. Insect and mite pests and their natural enemies of brinjal during November 2018 to April 2019 in the experimental field of the Regional Agricultural Research Station, Jashore

Name of the insect	Scientific name	Family	Order	Status
Brinjal shoot and fruit borer	*Leucinodes orbonalis* (Guen.)	Pyralidae	Lepidoptera	Major
Whitefly	*Bemisia tabaci* (Genn.)	Aleyrodidae	Hemiptera	Minor
Epilachna beetle	*Epilachna dodecastigma* (Wied.)	Coccinellidae	Coleoptera	Major
Aphid	*Aphis gossypii* (Glover)	Aphidae	Hemiptera	Minor
Jassid	*Amrasca biguttula biguttula* (Ishida)	Cicadellidae	Hemiptera	Major
Mealy bug	*Centrococcus insolious* (Green)	Pseudococcidae	Hemiptera	Minor
Green leaf hopper	*Nephotettix virescens*	Cicadellidae	Hemiptera	Minor
Leaf roller	*Antoba olevacea*	Noctuidae	Lepidoptera	Minor
Leaf beetle	*Monolepta signata* Oliv.	Chrysomelidae	Coleoptera	Minor
Mite	*Tetranychus* sp.	Tetranychidae	Acarina	Minor
Lady bird beetle	*Coccinela septempunctata*	Coccinelidae	Coleoptera	Predator
Lady bird beetle	*Coccinela transversalis*	Coccinelidae	Coleoptera	Predator
Lady bird beetle	*Menochilus sexmaculatus*	Coccinelidae	Coleoptera	Predator
Spider	*Argiope luzona*	Argiopidae	Acarina	Predator

Table 2. Population density (number per plant) and prevalence of different insect and mite pests and their natural enemies of brinjal in the Regional Agricultural Research Station, Jashore.

Name of insect	Sc. Name	Population/ plant/leaf	Nature of damage	Prevalence of the pests
Brinjal shoot and fruit borer	*L. orbonalis*	5.75	Shoot and fruit borer	V-Fr
Whitefly	*B. tabaci*	22.55	Sap sucker	S-Fr
Epilachna beetle	*E. dodecastigma*	7.65	Leaf eater	V-Fr
Aphid	*A. gossypii*	18.35	Sap sucker	V-Fr
Jassid	*A. biguttula biguttula*	35.45	Sap sucker	S-Fr
Mealy bug	*C. insolious*	45.25	Sap sucker	V-Fr
Green leaf hopper	*N. virescens*	35.45	Sap sucker	S-Fr
Leaf roller	*A. olevacea*	3.25	leaf roller	V-Fr
Leaf beetle	*M. signata*	9.45	leaf eater	V-Fr
Mite	*Tetranychus* sp.	48.75	Sap sucker	F-Fr
Lady bird beetle	*C. septempunctata*	4.96	Predation	V-Fr
Lady bird beetle	*C. transversalis*	4.24	Predation	V-Fr
Lady bird beetle	*M. sexmaculatus*	5.85	Predation	V-Fr
Spider	*Argiope luzona*	4.45	Predation	V-Fr

S= Seedling Stage, V= Vegetative Stage, F=Flowering Stage, Fr= Fruiting Stage

References

Ali, M., M., Ashfaq, W., Akram, S.T. Sahi, and A. Ali. 2012. The physio-morphic characters of the brinjal (Solanum melongena L.) plant and their relationship with the jassid (Amrasca biguttula biguttula (Ishida)) population fluctuation. *Pakistan J. Agric. Sci.* **49**(1): 67-71.

Amin, M.R., M.S. Miah, H. Rahnan, N.P. Nancy and M.K.A. Bhuiyan. 2018. Functional and group abundance of insects on eggplant at *Bangladesh J. Agril. Res.* **43**(4): 647-653.

Bijjur, S. and S. Verma. 1995. Sequential appearance of insect pests and natural enemy complex of on Pea crop. *Indian J. Ent.* **57**(4): 373-377.

Biswas, G.C., M.Y., Mian, M.C., Shaha, A. Ahmed, and S. Islam. 1998. Brinjal shoot and fruit borer infestation and damage estimation of fruits of four brinjal varieties in Khagrachari of Bangladesh. *Bangladesh J. Agril. Res.* **23**(1): 15-23.

Cao, G., E. Sofic, and R.L. Prior. 1996. Antioxidant capacity of tea and common vegetables. *J. Agric. Food Chem.* **44:** 3426–3431.

Choudhary, B. and K. Gaur. 2009. The development and regulation of Bt brinjal in India (Eggplant/Aubergine). International Service for the Acquisition of Agri-biotech Applications (ISAAA) Brief No. 38. ISAAA, Ithaca, NY, USA. Pp. 15.

Dutta, N.K, S.N. Alam, M.Nahmudunnabi, M.R.Amin and Y.J.Kwon. 2017. Effect of insecticides on population reduction of sucking insects and lady bird beetle in eggplant field. *Bangladesh J. Agril. Res.* **42**(1): 35-42.

Latif, M. A., M.M., Rahman, M.R. Islam, and M.M. Nuruddin. 2009. Survey of arthropod biodiversity in the Brinjal field. *Bangladesh J. Entomol.* **6**(1): 28-34.

Nayar, K.K., T.N.A. Krishnan, and B.V. David. 1995. General and Applied Entomology. (11th edn.). Tata McGraw- Hill pub. Co. Ltd. 4/12, New Delhi- 110002. Pp. 557.

Rashid, M.H., M.J., Khatun, M.S., Mahfuz, C.K. Dash, and M.A. Hussain. 2013 Seasonal fluctuation of insect pests of brinjal at Agricultural Research Station, Burirhat, Rangpur. *Int. J. Expt. Agric.* **3**(1): 4-8.

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

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

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

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

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

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