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MORPHOPHYSIOLOGICAL CHANGES OF MUNGBEAN UNDER DIFFERENT WATER REGIMES

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Abstract

Drought stress can severely affect crop growth and productivity by altering several physiological processes. This experiment was carried out to explore the drought tolerance ability of four mungbean varieties based on their water relation and performance of some growth parameters. The experiment was conducted in pot at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur from 27th March to 15th May 2017, under a semi-controlled (vinylhouse) condition. Three different water regimes 50 to 60% field capacity (FC), 70 to 80% FC, 90 to100% FC and four mungbean varieties namely BARI Mung-5, BARI Mung-6, BU mug 2, BU mug 4 were used as treatment variable. Among the three water regimes, 50%-60% FC was considered as the severe drought stress. Results indicated significant variations in different traits of both water and growth parameters of the varieties under severe drought stress (50%-60% FC). Among the four mungbean varieties BARI Mung-6 showed superior performance with higher xylem exudation, chlorophyll content, shoot dry matter and lower water uptake capacity at 50%-60% FC (severe drought stress) whereas BU mug 2 showed the lowest performance. Results of this experiment conclude that BARI Mung-6 can be considered as a more water stress tolerant variety than the other three and recommended for cultivation under water limited conditions.

Keywords: Mungbean, xylem exudation, water uptake capacity, chlorophyll and drought stress.

Introduction

Mung bean (*Vigna radiata* L.) is an important pulse consumed all over the world, particularly in the Asian countries like Bangladesh, India, Pakistan, Myanmar, Indonesia, etc. and has been known to be a promising source of protein as high as 19.5 to 28.5%. (Nair and Schreinemachers, 2020). Mungbean covers 11.66% of total pulse cultivated areas in Bangladesh and secures 4th position (BBS, 2019). In Bangladesh, mungbean cultivated area is 41339.68 hectare and average yield is 0.821 ton/ha (BBS, 2019). Mungbean fits easily in the existing cropping pattern due to its short duration, low input needs, minimum care requirement and also it

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increases cropping intensity (Ahmed *et al*., 2019). It also fixes atmospheric nitrogen in soil and improves overall soil health and the system productivity (Khan *et al*., 2018). However, the production of mungbean is greatly hampered due to various abiotic and biotic stresses. Among them drought is the major environmental barrier, which can cause moderate to severe yield loss depending on stress duration and severity, and growth stage of mungbean plant as well (Bangar *et al*, 2019). Different morphophysiological processes of mungbean are greatly hampered due to drought stress, which ultimately reduces the grain yield (Baroowa 2016). Drought stress can reduce munbean yield upto 51% to 85.50% (Zare *et al*., 2013). In Bangladesh, drought stress has become a major concern of for limiting mungbean production to a great extent, especially in the northwestern region. However, it is well known that varietal difference is often found in the response to abiotic stresses. In Bangladesh there are several high yielding mungbean varieties available that are popularly grown by the farmers. Hence, it is utmost needed to analyze the extend of altered morphophysiological processes of the popular varieties due to water stress in order to recommend the suitable one for growing in the drought prone area of the country. This study was therefore conducted under a semi-controlled condition to select a suitable variety under water limiting conditions considering the extent of changes of water relation traits and some growth parameters by the stress.

Materials and Method

The experiment was conducted in pot at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur from 27th March to 15th May 2017, under semi-controlled (vinylhouse) condition. Treatment variables were soil moisture levels of 50%-60%, 70%-80%, 90%-100% field capacity (FC) and four mungbean varieties, namely BARI Mung-5, BARI Mung-6, BUmug 2, BUmug 4. The experiment was conducted by following Completely Randomized Design (CRD) with two factors and four replications. Plastic pots of 25 cm length and 20 cm diameter were filled with 9.5 kg silty clay loam soil with 4:1 ratio of soil and cowdung. Soil was fertilized with 0.11 g N, 0.08 g P, 0.10 g K, 0.05 g S, 0.002 g Zn, and 0.001 g B in terms of 50, 80, 40, 59.37,1.25, and 1.38 kg urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid per hectare, respectively. Ten healthy seeds were sown maintaining uniform spacing in each pot on 27th March 2017 and after emergence six healthy plants were kept. Pesticide application and weeding were done according to the requirement.

After full expansion of first trifoliate leaf (12 DAS), irrigation water was maintained for drought imposition up to harvest and to keep three soil moisture status (50%-60%, 70%-80%, 90%-100% field capacity). According to Giriappa, 1988, irrigation requirement was determined by calculating soil moisture (%) at field capacity (MFC), soil moisture (%) before irrigation (MBI) with soil moisture meter, soil bulk density (A) in gcm^{-3}, rooting depth (D) in cm using the following equation: IR= {(MFC - MBI) ÷ 100} × A× D. The method described by Karim *et.al,* (1988). Used in calculating soil bulk density and soil moisture (%) at field capacity.

Xylem exudation rate (XER) was measured at 5 cm above from the base of plant at flowering stage. At first dry cotton, polyethylene piece and thread were weighed. A slanting cut on stem was made with a sharp knife. The weighed cotton was placed on the cut surface, covered and tied with polyethylene piece and thread. The exudation of sap was collected from the stem for 1 hour at normal temperature. The final weight of the cotton with sap was taken. The exudation rate was expressed per hour basis as follows:

XER = {(Weight of cotton+ polyethylene piece+ thread+ Sap) - (Weight of cotton+ polyethylene piece+ thread)} / Time (h)

Water uptake capacity (WUC) was determined from fully expanded uppermost leaves using 30 leaf disks (4.5 mm wide). The leaf disks were soaked in distilled water (100 ml) and kept in the dark for 24 hours after recording the fresh weight. After 24 hr turgid weight were measured. After that leaf disks were oven dried at 70°C for 72 hours and dry weights were recorded. According to Schonfeld *et.al,* (1988) water uptake capacity (WUC) was determined using following formula: WUC = (TW-FW)/ DW. Here, FW = Fresh weight of the leaf disks, DW = Dry weight of the leaf disks and TW = Turgid weight of the leaf disks.

Chlorophyll content was estimated from the fully expanded uppermost leaf samples using the method described by Porra *et.al,* (1989). The fresh leaf sample of 100 mg were taken in small glass vials containing 5 ml of 80% acetone preserved in the dark for 24 hours. Then the absorbance was measured at 663 nm and 646 nm wave length. 80% acetone was used as blank and the result was expressed as mg g^{-1} fresh weight. The formula for computing chlorophyll a, b and total chlorophyll were-

Chlorophyll a (mg g^{-1} fresh weight) = [12.21 (A663) – 2.81 (A646)] × [V/1000 × W]

Chlorophyll b (mg g^{-1} fresh weight) = [20.13 (A646) – 5.03 (A663)] × [V/1000 × W]

Total Chlorophyll (mg g^{-1} fresh weight) = [20.2 (D646) + 8.02 (D663)] × [V/1000 × W]

Where, V = Volume of acetone used (ml), W = Weight of fresh leaf sample in (g).

The data regarding to the water uptake and chlorophyll content were recorded after the appearance of visual symptom of drought stress (30 DAS) and harvested at 50 days after sowing. Then the pods were separated and shoot (stem and leaf) dry weights were recorded by drying for 72 hours at 70°C in drying oven. The relative performance was calculated using the following formula (Asana and Williams 1965):

Relative performance = Variable measured under stressed condition / Variable measured under normal condition.

Height of individual plant was measured using meter scale from the base at the ground level to the tip of all sampled plants at 20 DAS and 50 DAS. Then change of plant height was measured by deducting the height at 20 DAS from the height gained at 50 DAS.

Statisticx 10 program was utilized for analyzing the collected data with Least Significant Difference (LSD) at 5% level of significance for comparing the treatment means.

Results and Discussion

Xylem Exudation Rate

Xylem exudation rate is known as the flow of sap through the cut end of a stem against the gravitational force. It depends on the available water in soil to be up taken by plant. Xylem exudation rate was greatly interrupted due to water deficit stress in all the four mungbean varieties (Fig 1). Xylem exudation rate was found the highest (1.32 to 2.33 g/hr) at 90% -100% field capacity and it decreased (1.01 to 1.97 g/hr) at 70%-80% field capacity and became lowest (0.76 to 1.58 g/hr) at 50%-60% field capacity. With reducing field capacity, the soil water potential was reduced and as a result the difference of water potential between the soil and the plant root was reduced. This in turn affects to reduce flow rate of xylem exudation. Among the varieties BARI Mug 6 was found to maintain the maximum xylem exudation rate (1.58 g/hr) at the lowest field capacity (50%-60%), while BUmug 2 had the minimum xylem exudation rate (0.76 g/hr) (Fig 1). It indicates that, BARI Mung-6 was able to maintain comparatively better transpiration flow, which might be for its ability to keep higher difference in water potential of soil and leaf. This result is consistent with the report of Islam *et.al,* (2021 and 2022) in mungbean.

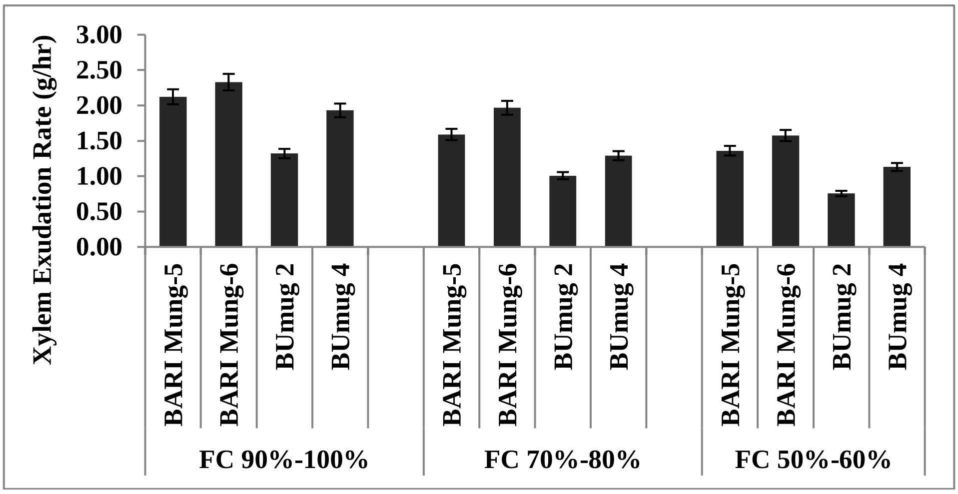

Fig. 1. Xylem Exudation Rate (g/hr) of four mungbean varieties at different levels of field capacity (FC). Bars represent mean ± SE.

Water Uptake Capacity

Water uptake capacity (WUC) quantifies the capacity of plants to reach turgid condition by absorbing water per unit of dry weight. Lower value of WUC indicates better water uptake capacity of a plant. Water uptake capacity (WUC) was recorded 2.43to 3.44% at 50%-60% field capacity, 1.70 to 2.33% at 70% - 80% field capacity and 1.15 to 1.63% at 90%-100% field capacity (Table 1). A higher WUC indicated that plants were subjected to a greater degree of moisture stress as these plants would absorb a greater amount of water to reach turgid weight, which is consistent with the report by Sangakkara *et.al,* (1996). The level of WUC was found to differ among the varieties of mungbean (Table 1). At the lowest field capacity (50%-60%), BARI Mug 6 was found to maintain the minimum WUC (2.43%) while BU mug 2 had the maximum WUC (3.44%) (Table 1). At drought stress condition (50%-60% FC), it indicated that BARI Mung-6 was able to maintain water level very close to the turgid level among the four mungbean varieties. Results were also reported that the tolerant varieties possessed the lowest WUC under drought stress compared to other varieties. (Islam *et.al,* 2022).

Table 1. Water uptake capacity (WUC) of four mungbean varieties under three variable water regimes

Variety	Water Uptake Capacity		
	FC of 90%-100%	FC of 70%-80%	FC of 50%-60%
BARI Mung-5	1.32 i	1.99 f	2.75 c
BARI Mung-6	1.15 j	1.70 g	2.43 d
BUmug 2	1.63 g	2.33 d	3.44 a
BUmug 4	1.47 h	2.16 e	3.24 b
CV%		4.48	

Means along both rows and columns followed by the same letter (s) did not differ significantly at 5% level of probability.

Chlorophyll Content

Chlorophyll content was reduced significantly under water deficit condition, imposed in terms of variable field capacity (Table 2). The chlorophyll-a content in the treatments with the lowest field capacity (50% - 60%) was 1.30 mg/g FW in BARI Mung-6 whereas in high field capacity (90 % - 100%) it was 1.40 mg/g FW. Chlorophyll-b content in BARI Mung-6 was 1.10 mg/g FW at 90 % - 100% field capacity and that was reduced to 1.01 mg/g FW at 50% - 60% field capacity in BARI Mung-6. At both the field capacity (90%-100% & 50%-60%), BUmug 2 showed lower amount of chlorophyll-a (1.27 to 1.10 mg/g FW) and chlorophyll-b content (1.01 to 0.97 mg/g FW). It might be due to genetic variation of varieties. On the other hand the decrease of chlorophyll content under water deficit condition can be attributed to the sensitivity of this pigment to increasing environmental stresses, especially to drought and salinity (Sing *et.al,* 2021).

Table 2. Chlorophyll content of four mungbean varieties under three variable water regimes

Variety	Chlorophyll a (mg/g fresh weight)			Chlorophyll b (mg/g fresh weight)			Total Chlorophyll (mg/g fresh weight)		
	FC of 90%-100%	FC of 70%-80%	FC of 50%-60%	FC of 90%-100%	FC of 70%-80%	FC of 50%-60%	FC of 90%-100%	FC of 70%-80%	FC of 50%-60%
BARI Mung-5	1.38 a	1.24 d	1.21 de	1.05 b	1.01 cde	0.99 ef	1.71 b	1.60 d	1.52 e
BARI Mung-6	1.40 a	1.35 b	1.30 c	1.10 a	1.03 bc	1.01 cde	1.75 a	1.68 bc	1.65 c
BUmug 2	1.27 c	1.16 f	1.10 g	1.01 cde	0.99 ef	0.97 f	1.60 d	1.49 e	1.39 f
BUmug 4	1.37 ab	1.22 de	1.19 e	1.03 bcd	1.00 de	0.98 ef	1.68 bc	1.57 d	1.48 e
CV		1.87			2.18			1.60	

Means along both rows and columns followed by the same letter (s) did not differ significantly at 5% level of probability.

As such, in treatment with the lower field capacity (50%-60%), BARI Mug 6 was found to maintain the higher level of chlorophyll-a, chlorophyll-b and total chlorophyll content (1.30, 1.01 and 1.65 mg/g FW respectively) while BUmug 2 had the lower level of chlorophyll a, chlorophyll b and total chlorophyll content (1.10, 0.97 and 1.39 mg/g FW respectively). Similar result is also recorded by Islam *et.al*, (2022). This result indicates that at water deficit condition, BARI Mung-6 was able to reduce chlorophyll degradation most efficiently among all the four mungbean varieties.

Shoot Dry Weight

Field capacity with different soil water status had a profound effect on total shoot dry weight. Shoot weight was found higher at 100%-90% field capacity (7.98 to 13.82 g/plant), which decreased to 5.19 to 10.86 g/plant at 70%-80% field capacity and lowest at 50%-60% field capacity 2.38 to 5.76 g/plant (Fig 2.a) in all the mungbean varieties. The highest shoot dry weight was recorded in BARI Mung-6 i.e. 5.76 g/plant under drought stress condition (50%-60% field capacity) while BUmug 2 was recorded with lowest shoot weight 1.93 g/plant. Imtiaz *et.al*, (2020) and Prakash *et.al*, (2017) also found dry weight reduction in water stress condition. Relative shoot dry weight at 50%-60% and 70%-80% field capacity was also higher in BARI Mung-6 (0.42 and 0.79 respectively) compare to that of BUmug 2 (0.30 and 0.65 respectively) (Fig. 2.b). This result indicated that among all the four mungbean varieties BARI Mung-6 was most competent to accumulate dry matter under drought stress condition.

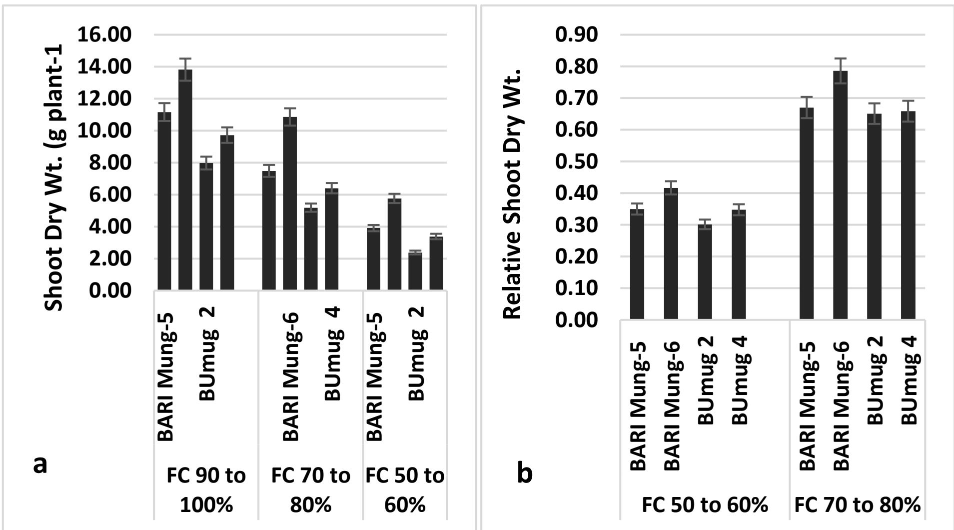

Fig 2. Shoot dry weight (g/plant) (a) at three different levels of water regime and relative shoot dry weight (b) at 50-60% and 70%-80% field capacity compared to 90-100% FC of four mungbean varieties. Bars represent mean ±SE.

Plant Height Change

Plant height was affected adversely by the water deficit stress, imposed in term of variable field capacity. Irrespective of mungbean varieties, increasing rate of plant height was found higher at 90%-100% field capacity with a range of 5.10 to 5.96 (cm/month). Increasing rate of plant height was decreased (3.52 to 5.46 cm/month) when field capacity at 70%-80%. Then at 50%-60% field capacity increasing rate of plant height was found the lowest (2.67 to 4.47 cm/month) (Fig. 3). According to Bangar *et.al,* (2019), drought reduced plant height of mungbean in both vegetative and reproductive stage. Among the four mungbean varieties BARI Mung-6 was recorded with maximum Increase of plant height (4.47 cm/month) compare to that of BUmug 2 (2.67 cm/month) under drought stress condition (50%-60% field capacity) (Fig 3). The result indicated that BARI Mung-6 was able to maintain higher turgidity due to its higher water uptake capacity and xylem exudation rate, which ultimately helped it to had higher plant height among all the four mungbean varieties.

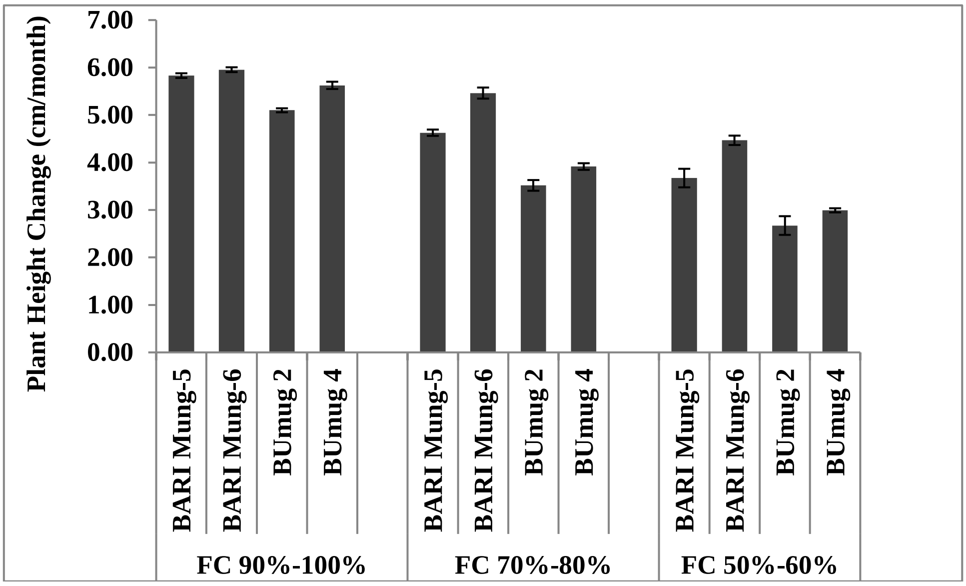

Fig 3. Increase of plant height from 20 DAS to 50 DAS at different level of water regime in four mungbean varieties. Bars represent mean ±SE.

Number of pods per plant

Drought stress adversely affected the pod number per plant, as treated with different level of field capacity (Table 3). Pod number was found higher in all the four mungbean varieties at 90%-100% field capacity (17.00 to 23.00 pod/plant) which decreased in 12.00 to 16.00 pod/plant with field capacity (70%-80%) and the lowest pod number (7.00 to 11.00 pod/plant) was recorded at 50%-60% field capacity. The reduction in number of pod/plant was might be due to water shortage at flowering phase that increased pollen abortion which is consistent with the report of Prakash *et.al*, (2017). It seems that shortage of water in the reproductive phages led to the reduction in photosynthesis and increased in ABA catalyst (Bangar *et.al,* 2019) that ultimately caused the abscission of flowers and young pods. Under water deficit condition (60%-50% field capacity) BARI Mung-6 had the highest pod number (11.00 pod/plant), while BUmug 2 had the lowest pod number (7.00 pod/plant). It indicated that water status of BARI Mung-6 at flowering stage was comparatively higher in drought stress condition among all the for mungbean varieties, which resulted in less abscission of flower or young pod.

Table 3. Number of pod per plant of four mungbean varieties under three variable water regime

Variety	Number of Pod/Plant		
	FC of 90%-100%	FC of 70%-80%	FC of 50%-60%
BARI Mung-5	20.00 b	14.00 d	10.00 g
BARI Mung-6	23.00 a	16.00 c	11.00 fg
BUmug 2	17.00 c	12.00 ef	7.00 h
BUmug 4	19.00 b	13.00 de	8.00 h
CV%		8.90	

Means along both rows and columns followed by the same letter (s) did not differ significantly at 5% level of probability.

Conclusion

Drought stress effect on different morpho-physiological parameters was found minimum in BARI Mung-6, followed by BARI Mung-5 and BUmug 4. The effect of drought stress was maximum in BUmug 2. Based on the findings it was concluded that BARI Mung-6 is relatively tolerant to water shortage effect and can be recommended for cultivation in the drought prone area of Bangladesh.

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INTERCROPPING OF JUTE AS LEAFY VEGETABLE WITH HYBRID MAIZE UNDER DIFFERENT PLANTING SYSTEMS

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J. RAHMAN[5] AND J. CHOWDHURY[6]

Abstract

An experiments were conducted at Agronomy research field, Gazipur and Regional Agricultural Research Station, Jamalpur of Bangladesh Agricultural Research Institute during *kharif-1* season of 2018 and 2019 to find out the suitable combination of maize and jute (leafy vegetable) intercropping system for higher productivity and monetary advantage. Treatments included in the experiment were: T_1= Hybrid maize normal row (MNR) (60cm × 20cm) + 1 row jute (33%), T_2= MNR (60cm × 20cm) + 2 row jute (66%), T_3= MNR (60cm × 20cm) + 3 row jute (100%), T_4= MNR (60cm × 20cm) + jute broadcast (100%) and T_5= Sole maize (60 cm × 20 cm). The experiment was laid out in a randomized complete block design with three replications. At Gazipur, Light availability on jute decreased with the increase of shade produced by maize canopy over the time up to 40 DAS (at harvest of jute) under intercrop situation and the highest light availability was observed on jute in T_4 treatment. The maximum grain yield of maize was in sole crop and it was decreased by 1-6 % at Gazipur and 2-9 % at Jamalpur due to intercropping. Maize equivalent yield (MEY) of intercropping treatments showed better performance than sole maize. The highest MEY (19.28 t/ha at Gazipur and 17.41 t/ha at Jamalpur), gross margin (Tk. 252040/ha at Gazipur and Tk. 313380/ha at Jamalpur) and benefit cost ratio (3.65 and 3.33 at Gazipur and Jamalpur, respectively) were observed in T_4 treatment among the intercropping treatments. The results revealed that T_4 = MNR (60cm × 20cm) + jute broadcast (100%) could be agronomically feasible and economically profitable for maize and jute (leafy vegetable) intercropping system at Gazipur and Jamalpur.

Keywords**:** Planting system, Light availability, BCR; Maize, Jute (leafy vegetable)

Introduction

Intercropping is advanced agro technique of cultivating two or more crops in the same piece of land at the same time have been practiced in past decades and achieved the goal of agriculture.

It increases in productivity per unit of land via better utilization of resources, minimizes the risks, reduces weed competition and stabilizes the yield (Seran and Brintha, 2010). Higher productivity from intercropping depends on judicious

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choice of component crops, suitable planting system or proportion of component crops (Islam *et al*., 2006). Maize based intercropping is found profitable and suitable in many countries (Misra *et al*., 2021) as well as in Bangladesh. Maize is ideal for intercropping, especially with legumes, potato, onion, groundnuts and vegetables. Maize- legumes cropping system is a sustainable diversification for productivity, profitability and resource use efficiency (Islam *et al*., 2020). Besides, maize is C_4 plant which has higher yield potential (Ahmed, 2001) and greater land use efficiency (Bhuiyan, 2001). It has high potential for carbohydrate accumulation per unit area per day (Javier *et al*., 2020). Due to huge demand of maize, particularly in poultry feed industry; it is getting the special importance by the government of Bangladesh (Farid and Shil, 2006). Maize is an unbranched and erect cereal crop grown with wide spacing. Several short duration and short stature vegetable like jute (*patshak*) may be grown in association with hybrid maize. On the other hand, jute or *patsahak* is a very popular leafy vegetable. The jute leaf contains over 17 active nutrient compounds including protein, fat, carbohydrate, fiber, ash, calcium, potassium, iron, sodium, phosphorous, beta-carotene, thiamine, riboflavin, niacin, ascorbic acid, food energy, Vit. A etc. Therefore jute leaf has a great importance in terms of human nutrition, health and beauty care. So, this experiment was conducted to find out the suitable planting systems of hybrid maize and jute (*patshak*) intercropping for higher productivity and monetary advantage.

Materials and Methods

The field experiment was conducted at Agronomy research field, Gazipur (AEZ-28) and Regional Agricultural Research Station, Jamalpur (AEZ-9) of Bangladesh Agricultural Research Institute during *kharif* season of 2018 and 2019. The physical and chemical properties of initial soil of the experimental plot has been presented in Table 1 and rainfall data (average of 2018 and 2019) for both sites during cropping period has been presented in Fig. 1. Treatments included in the experiment were: T_1= Hybrid maize normal row (MNR) (60cm × 20cm) + 1 row jute (33%), T_2= MNR (60cm × 20cm) + 2 row jute (66%), T_3= MNR (60cm × 20cm) + 3 row jute (100%), T_4= MNR (60cm × 20cm) + jute broadcast (100%) and T_5= Sole maize (60 cm × 20 cm). The experiment was laid out in a randomized complete block design with three replications and the unit plot size was 6m × 5m. Hybrid maize (var. BARI Hybrid maize-9) and jute (var. Binapatshak-1) were used in both locations. Seeds of both crops were sown on 10 March, 2018 and 12 March, 2019 at Gazipur and on 5 March, 2018 and 10 March, 2019 at Jamalpur. The seeds of both crops were treated with provex @ 3 g/ kg seed in both locations and both years. Fertilizers were applied at the rate of 250-76-121-72-5-1 kg/ ha of N, P, K, S, Zn, B (FRG, 2012) as urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum, zinc sulphate and boric acid for sole maize and intercrop. One third of N, whole amount of TSP, MoP, gypsum, zinc sulphate and boric acid were applied as basal. Remaining 2/3 N was top dressed at 20 and 40 days after sowing (DAS) of maize. In intercrop, extra N (40 kg/ha) was applied at 20 DAS as side dress to jute. Sole jute was fertilized at the rate of 30- 5-20 kg/ha of N, P, K.Two third of N and all other fertilizers were applied as basal. Rest N was applied at 20 DAS in both locations. Light availability or Photo synthetically active radiation (PAR) was measured only at Gazipur location by PAR Ceptometer (Model – LP-80, Accu PAR, Decagon, USA). The PAR was measured at 5-day intervals from 25 to 40 DAS at around 11:30 am to 13:00 pm. Four readings each of PAR inc and PAR t were recorded at different spots of each plot. PARt indicated the light availability above underneath crop (jute). The transmitted PAR (PAR t) was expressed in percentage (Ahmed *et al.*, 2010):

$$\text{Light availability, PARt (\%)} = \frac{\text{PAR t}}{\text{PAR inc}} \times 100$$

where, PARinc= Incident PAR,

PARt= Transmitted PAR

Data on yield contributing characters of maize were taken from randomly selected 5 plants from each plot. Yield of both crops were taken from whole plot area in both locations. Maize was harvested on 28 and 30 June in 2018 and 2019, respectively, and jute (*patshak*) was harvested on 20 April in both years at Gazipur. On the other hand, maize was harvested on 3 and 6 July 2018 and 2019, respectively) and *patshak* was harvested on 15 and 19 April in 2018 and 2019, respectively, at Jamalpur. In both locations, maize equivalent yield was computed by converting yield of intercrops on the basis of prevailing market price of individual crop following the formula of Bandyopadhyay (1984) as given below:

Maize equivalent yield = Yim + (Yij × Pj)/ Pm

Where, Yim = Yield of intercropped maize, Yij = Yield of intercropped jute, Pm = Market price of maize and Pj = Market price of jute.

Collected data of both the crops were analyzed statistically and the means were adjudged by using LSD at 5% level of significance. Economic analysis was also done considering local market price of harvested crops. Monetary advantage was evaluated according to Shah *et al*. (1991) as follows:

$$\text{BCR} = \frac{\text{Gross return}}{\text{Cost of production}}$$

The physical and chemical properties of the soil of experimental field is given below:

Table 1. Soil analytical data of the experimental site at Gazipur and Jamalpur

Loacation	pH	OM (%)	Total N (%)	Exchangeable K (meq/ 100g soil)	P	S	Zn	B
					(µg/g)			
Gazipur	6.23	1.29	0.112	0.098	15.23	24.94	0.654	0.168
		VL	VL	VL	O	O	L	VL
Jamalpur	7.20	0.89	0.045	0.23	7.73	5.74	0.40	0.37
				L	O	VL	VL	L
Critical levels			0.12	0.12	7.0	10.00	0.60	0.20

L= Low, VL = Very low, O = Optimum

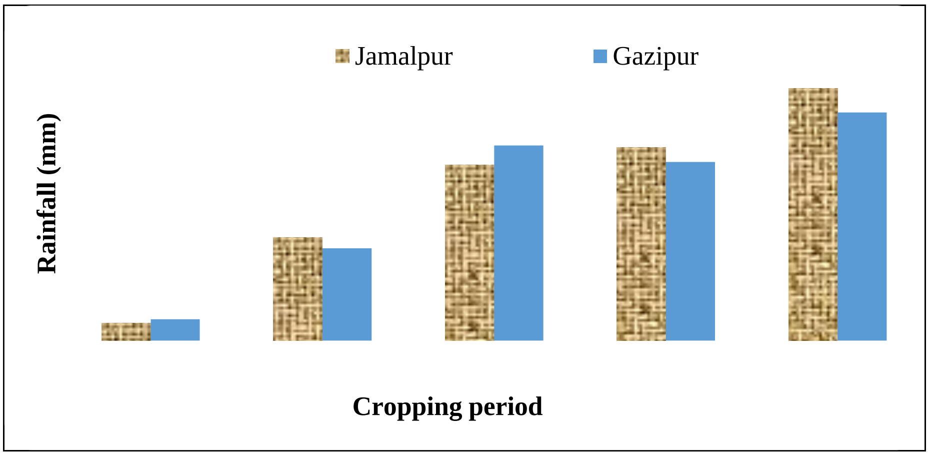


Fig.1 Rainfall data (average) for both sites during cropping period (*Kharif* 2018 and 2019)

Results and Discussion

Light availability

At Gazipur, Light availability on jute was measured from 25 to 40 DAS (Days After Seeding) . Jute was not affected by the shading of maize canopy. Because, jute was harvested at 40 DAS and in this time maize canopy did not produce much shade which affected jute plant. Under intercrop situation, availability of light on jute canopy was almost 100% at earlier growth stage (25 DAS) of jute and it was decreased with the increase of shade produced by maize canopy over the time up to 40 DAS (at harvest of jute). Light availability or transmitted PAR (PARt) on jute was more or less similar in all intercropping treatments. However, the lowest light availability on jute was observed at 40 DAS in T_1 (MNR + 1 row jute) followed by T_2 treatment and the highest light availability on jute was observed in T_4 treatment (MNR + jute broadcast) followed by T_3 treatment (Fig.2). It might be due to number of jute population was higher in T_4 than that of in T_1. Maize plant received more nutrients having comparatively bigger canopy in T_1 than that of in T_4 and that is why light availability on underneath jute crop was higher under smaller maize canopy (T_4) and light availability on underneath jute crop was lower under bigger maize canopy (T_1).

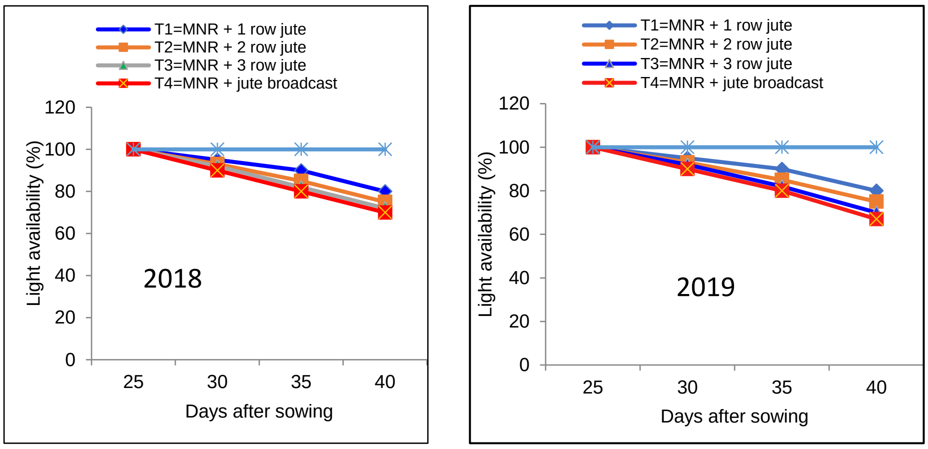


Fig.2. Light availability on jute (leafy vegetable) canopy in maize + jute intercropping systems at Gazipur (2018 and 2019)

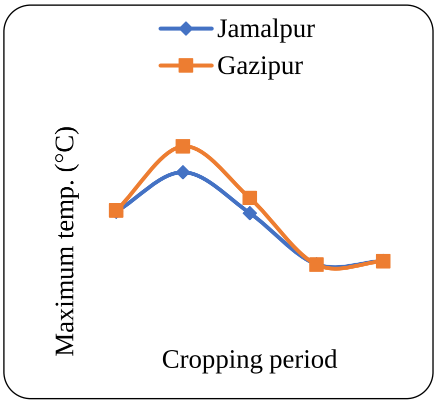
Growth and yield performance of maize

Plant height, yield and yield contributing characters of maize at both locations during *kharif-1* of 2018 and 2019 (pooled) are presented in Table 2. Plant height, yield contributing characters (number of grains /cob and 1000- grain weight) and grain yield of maize were not significantly differed in both locations. Although the highest grain yield (8.98 and 9.19 t/ha at Gazipur and Jamalpur, respectively) were recorded in sole maize due to no intercrop competition for growth resources like light, nutrients, moisture and space in sole cropping. This result corroborates with the findings of Begum *et al*. (2016 and 2020). The lowest grain yield (8.41 and 8.40 t/ha at Gazipur and Jamalpur, respectively) were recorded in MNR + jute broadcast.

Table 2. Plant height, yield and yield components of maize in maize- jute (as leafy vegetable) intercropping under different planting system during *kharif* season (Pooled of 2018 and 2019)

Treatment	Plant height (cm)	Number of grains/cob	1000-grain wt. (g)	Grain yield (t/ha)	Yield decreased over sole (%)
Gazipur					
T_1= MNR + 1 row jute (33%)	233	589	283	8.85	1.4
T_2= MNR + 2 row jute (66%)	235	581	278	8.65	3.7
T_3= MNR + 3 row jute (100%)	234	575	279	8.50	5.3
T_4= MNR + jute broadcast (100%)	235	548	278	8.41	6.3
T_5= Sole maize (60 cm × 20 cm)	233	611	290	8.98	-
LSD $_{(0.05)}$	NS	NS	NS	NS	
CV (%)	7.37	7.88	8.39	8.81	
Jamalpur					
T_1= MNR + 1 row jute (33%)	219	584	289	9.03	1.7
T_2= MNR + 2 row jute (66%)	222	580	281	8.83	3.9
T_3= MNR + 3 row jute (100%)	217	544	280	8.56	6.9
T_4= MNR + jute broadcast (100%)	218	539	275	8.40	8.6
T_5= Sole maize (60 cm × 20 cm)	220	611	292	9.19	-
LSD $_{(0.05)}$	NS	NS	NS	NS	-
CV (%)	7.90	7.52	8.08	8.00	-

Grain yield level at Gazipur was lower than Jamalpur. It might be due to comparatively lower temperature prevailed in cropping period at Jamalpur than Gazipur (Fig. 3). Similar trend was observed in case of relative humidity during cropping period (Fig. 4). However, grain yield in different treatments were attributed to the cumulative effect of yield components.



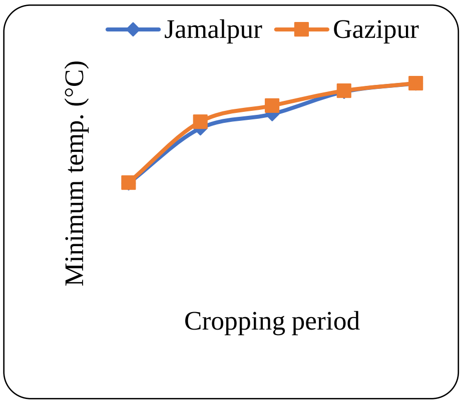


Fig.3. Maximum and minimum air temperature (average) for both sites during cropping period (*Kharif* -1, 2018 and 2019)

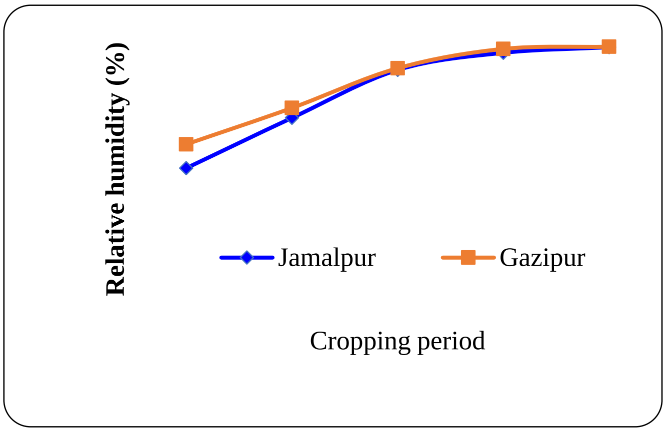


Fig.4. Relative humidity (average) for both sites during cropping period (Kharif -1, 2018 and 2019)

Effect on yield of jute (leafy vegetable)

Plant population, leafy vegetable yield of jute and MEY (Maize equivalent yield) in maize + jute (vegetable) intercropping is presented in (Table 3). Leafy vegetable yield and plant population of jute were significantly influenced by different planting systems. The highest plant population of jute (420 and 438 t/ha at Gazipur and Jamalpur, respectively) was found in MNR + jute broadcast treatment due to jute plant got higher space in broadcast treatment. Among the intercrop treatments, the highest vegetable yield (9.79 and 10.82 t/ha at Gazipur and Jamalpur, respectively) was observed in MNR + jute broadcast treatment due to the highest number of plant population per unit area. The lowest vegetable yield was observed in MNR + 1 row jute treatment in both locations due to the lowest number of plant population per unit area

Evaluation of intercrop productivity

Maize- jute intercrop productivity was evaluated on the basis of maize equivalent yield (MEY). MEY of maize- jute intercropping in both locations are presented in Table 3. MEY of all the intercropping systems was higher than sole maize in both locations indicating higher productivity of intercropping than sole maize. In intercropping, the highest maize equivalent yield (19.28 t/ha at Gazipur and 17.41 t/ha at Jamalpur) was observed in T_4 treatment (MNR + jute broadcast) which was 114.7 and 89.4% higher over sole maize at Gazipur and Jamalpur, respectively, followed by T_3 treatment. The lowest was observed in T_5 (sole maize) in both locations.

Table 3. Vegetable yield, jute population and MEY of maize- jute (as leafy vegetable) intercropping under different planting system during *kharif-1f*season (Pooled of 2018 and 2019)

Treatment	Number of jute plant//m^2 (no.)	Vegetable yield (t/ha)	MEY (t/ha)	% increased of MEY over sole maize
Gazipur				
T_1= MNR + 1 row jute (33%)	136	3.41	12.63	40.6
T_2= MNR + 2 row jute (66%)	266	6.29	15.64	74.2
T_3= MNR + 3 row jute (100%)	396	9.39	18.93	110.8
T_4= MNR + jute broadcast (100%)	420	9.79	19.28	114.7
T_5= Sole maize (60 cm × 20 cm)	-	-	8.98	-
LSD $_{(0.05)}$	56.58	1.45	-	-
CV (%)	9.29	13.96	-	-
Jamalpur				
T_1= MNR + 1 row jute (33%)	142	3.53	11.97	30.3
T_2= MNR + 2 row jute (66%)	272	6.41	14.17	54.2
T_3= MNR + 3 row jute (100%)	397	10.16	17.02	85.2
T_4= MNR + jute	438	10.82	17.41	89.4
T_5= Sole maize (60 cm × 20 cm)	-	-	9.19	-
LSD $_{(0.05)}$	45.49	1.50	-	-
CV (%)	7.18	9.17	-	-

Market price (Tk. /kg): Maize = Tk. 18 (in both locations), jute (leafy vegetable) = Tk. 20 at Gazipur and 15 at Jamalpur

Economic performance

Economic analysis is an important tool to evaluate the economic feasibility of intercropping systems and monetary advantage. Benefit cost analysis of maize + jute intercropping systems in both locations are presented in Table 4. Among intercropping treatments, the highest gross return (Tk. 347040/ha and Tk. 313380/ha at Gazipur and Jamalpur, respectively) was observed in T_4 treatment (MNR + jute broadcast) followed by treatment T_3 owing to higher MEY in both locations but the lowest cost of cultivation was found in T_4 treatment due to lower number of labours engaged in broadcast sowing. The highest cost of production was recorded in T_3 treatment followed by T_2 due to higher number of labours engaged in line sowing in both locations. The gross margin was followed the similar trend of gross return. Cost of production differed among the treatments. Among intercropping treatments, the highest benefit cost ratio (3.65 and 3.33 at Gazipur and Jamalpur, respectively) was obtained from T_4 (MNR + jute broadcast) followed by T_3 treatment. This result has been supported by the findings of Islam *et al.* (2013) and Begum *et al*. (2020).

Table 4. Cost- benefit analysis of hybrid maize- jute (leafy vegetable) intercropping during *kharif-1* season of 2018 and 2019 (Gazipur and Jamalpur)

Treatment	Gross return (Tk./ha)	Cost of cultivation (Tk./ha)	Gross margin (Tk./ha)	BCR
Location : Gazipur				
T_1= MNR + 1 row jute (33%)	227340	104000	123340	2.19
T_2= MNR + 2 row jute (66%)	281520	108000	173520	2.61
T_3= MNR + 3 row jute (100%)	340740	112000	228740	3.04
T_4= MNR + jute broadcast (100%)	347040	95000	252040	3.65
T_5= Sole maize (60 cm × 20 cm)	161640	96000	65640	1.68
Location : Jamalpur				
T_1= MNR + 1 row jute (33%)	215460	103000	120460	2.09
T_2= MNR + 2 row jute (66%)	255060	107000	210060	2.38
T_3= MNR + 3 row jute (100%)	306360	111000	306360	2.76
T_4= MNR + jute broadcast (100%)	313380	94000	313380	3.33
T_5= Sole maize (60 cm × 20 cm)	165420	95000	70420	1.74

Market price (Tk./ kg): Maize = Tk. 18 (in both locations), jute (leafy vegetable) = Tk. 20 at Gazipur and 15 at Jamalpur

Conclusion

Result revealed that all the intercropping systems showed better productivity than growing sole maize and sole jute as vegetables. Farmers can get diversified food while benefiting financially by intercropping jute + maize instead of sole maize. Hybrid maize normal row (60cm ×20cm) + jute broadcast (100%) intercropping might be agronomically feasible and economically profitable in Gazipur and Jamalpur.

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PERFORMANCE OF BARI TOMATO VARIETIES UNDER LATE WINTER PLANTING IN DINAJPUR REGION

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M. S. HUDA[4] AND M. AKTER[5]

Abstract

An experiment was carried out at Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Dinajpur during the *rabi* seasons of 2020 and 2021 to find the suitable tomato variety for late planting, when tomato demand and price remain higher on the market. A split- plot design with three replications was used where four planting dates viz., 15 January, 30 January, 15 February and 28 February in main plot and four varieties viz., BARI Tomato-15, BARI Tomato-16, Local (Rani) in sub-plot. . The result showed that both variety and planting dates were a significant effect on tomato fruit yield and yield contributing traits.In case of variety, BARI Tomato-16 gave the maximum fruit yield (51.31 t ha^{-1}) compared to other varieties. Regarding of planting date, 15 January was found suitable time for getting the highest tomato fruit yield (56.79 t ha^{-1}). The interaction effect showed that var. BARI Tomato-16, which was planted on 15 January yielded the higher fruit yield (66.16 t ha^{-1}) followed by BARI Tomato-15 (54.40 t ha^{-1}). Local (Rani) cultivar planted on 28 February produced the lowest yield (25.10 t ha^{-1}). The results of the economic analyses showed that the var. BARI Tomato-16 planted on 15 February had the highest gross return (Tk. 2255000 ha^{-1}), gross margin (Tk. 2057100 ha^{-1}) and benefit cost ratio (11.39) followed by BARI Tomato-16 planted on 28 February.

Keywords: Tomato, Off- season, Fruit yield, Cost-benefit ratio

Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most popular and nutrient rich vegetables in the globe as well as in Bangladesh. It is a good source of calcium, iron, vitamin C, and vitamin A. Due to its adaptability to a wide range of soil and climate, it is grown all across the Bangladesh. Due to its superior nutritive and processing features, demand for it on both the domestic and international markets have multiplied. BARI has taken the initiative to develop off-season tomatoes in light of the rising demand and significance of the tomato. Although there is a high demand for tomatoes throughout the year but country's output is centered in the winter months. Fruit setting and subsequent

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development are inhibited by high temperatures before and after the brief winter season. The predominant high summer temperatures are primarily to blame for tomato being unavailable throughout the summer and rainy seasons (Abdalla and Verkerk, 1968). Around 30°C is the recommended temperature for tomato flower setting. Up to 35°C, they can still maintain their blooms, but after that point, they will start to fade. The petals drop off before they can form a tomato after 30°C for any period of time, and fruit yield declines quickly (www.early-tomato.com. 2009). Under high temperature circumstances (over 30°C), there are significant differences across cultivars in terms of flowering and fruiting. Bangladesh's off-season tomato farming is severely hampered by high temperatures and extremely high rainfall.

Farmers in the Dinajpur areas are growing tomatoes that produce late. The farmers are getting more interested in growing late tomatoes than any other crop since they are more profitable in the Dinajpur region. About 1200 hectares of land were used to grow late tomatoes in 2020-2021. (DAE, 2021). However, the majority of farmers use native or Indian varieties, which are particularly sensitive to pests and disease and provide low yields. Some tomato cultivars that can produce a higher yield than the native ones have been developed by Bangladesh Agricultural Research Institute (BARI). Therefore, by picking the right variety and timing for planting, it is still possible to harvest tomatoes until the late season. During the pick season, tomatoes are very cheap. However, following that, the cost of the tomato continuously increases. By growing tomatoes in the late season, the supply of tomatoes can be increased. The potential of the tomato cultivars that BARI released in the Dinajpur region's agro-ecology has yet to be determined. Therefore, the study was conducted to find out tomato varieties responded to the region's agro-climatic conditions during the late *rabi* season.

Materials and Method

Experimental site description

The experiment was carried out at the Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Dinajpur, during two consecutives late rabi season of 2020 and 2021. The experimental site was located at Latitude: $25^{0}38'6.09''$ N and Longitude: $88^{0}39'3.17''$E at an elevation of 38 m above mean sea level and it belongs to the Agro-ecological Zone-1 (Old Himalayan piedmont plain) in Bangladesh (FRG, 2018). The initial soil sample (0-15 cm) was tested at the Soil Resources Development Institute (SRDI), Dinajpur, Bangladesh. The soil at the experimental area was medium-high and clay loam texture having 2.11% organic matter, pH 6.11, 0.09% total nitrogen (N), 0.11 meq 100 g^{-1} soil potassium (K), 45.20 μg/g phosphorus (P), 7.12 μg/g sulfur (S), 0.90 μg/g zinc (Zn) and 0.30 μg/g boron (B).

Experimental design and treatments

The experiment was laid out in a split plot design with 3 replications. The experiment was consisted of four planting dates viz. 15 January, 30 January, 15 February and 28 February and three varieties viz. BARI Tomato-15, BARI Tomato-16 and one Local (Rani) as treatments. Planting dates were assigned in the main plot and varieties in the sub-plot. The unit plot size was 2.4 m×2 m.

Crop husbandry

Tomato var. BARI Tomato-15, BARI Tomato-16 along with one local cultivar was used in this experiment. Seeds of BARI variety was collected from Olericulture Division, HRC, Bangladesh Agricultural Research Institute, Bangladesh. The crop was fertilized with 10 tons of cowdung and 100-34-104-27-1.5-1.3 $kgha^{-1}$ N-P-K-S-Zn-B through urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively (FRG'20). Total amount of cow dung, one third of MOP and full dose of P, S, Zn and B were applied during final land preparation. Urea and rest of MOP were applied in two equal installments at 21 and 35 Days After Transplanting (DAT) followed by light irrigation. Thirty days old seedling were planted as per treatment maintaining 60cm × 40cm spacing between and within rows. Leaf curl is a viral disease and is spread by white flies. Since the virus is spread by whitefly infestation to control white fly spray Admire/ Tido plus or Emitaf 0.5ml/L of water at least twice in 15 consecutive days from one week after planting to flowering.

Data collection

Data on the yield components were taken from 5 randomly selected plants from each plot. At harvest, the yield was recorded from the whole plot and then calculated per hectare basis. Data on number of clusters per plant, number of flowers per cluster, number of fruits per cluster, fruit length, fruit diameter, average fruit weight, number of fruits per plant and yield were taken and analyzed statistically by using R software packages and mean differences for each character were compared by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez. 1984).

Assessment of economic indices

The economic analysis took total variable costs (TVC) and gross returns (GR) into account. The variable costs included human labour, machinery rent and production inputs (seed, fertilizer, pesticides). Gross returns were determined by multiplying crop economic yield by price at harvesting time. The difference between GR and TVC was used to determine the gross margin (GM) (GM=GR -TVC). Benefit-cost ratio was calculated to determine the benefit and effect of competition among the treatments.

Weekly maximum and minimum air temperature and total rainfall

The detailed meteorological data in respect of air temperature and total rainfall recorded by meteorological Department, Dinajpur during the period of study have been presented in Figure 1. The highest maximum air temperature was observed in 1^{st} week of April (34.89^0C) and the lowest (21.72^0C) in 1^{st} week of January in 2020. The highest maximum air temperature was observed in 1^{st} week of April (35.12^0C) and the lowest (20.15^0C) in last week of January in 2021. On the other hand, the highest minimum air temperature (23.64^0C) was observed in 3^{rd} week of May and the lowest minimum air temperature (8.34^0C)in 1^{st} week of February in 2020. The highest minimum air temperature (25.29^0C) was observed in 3^{rd} week of May and the lowest 8.34^0C in 1^{st} week of February and the lowest minimum air temperature (8.53^0C) in 1^{st} week of February in 2021. Maximum rainfall 120 mm occurred in 3^{rd} week of May in 2020 and 642mm rainfall in 2^{nd} week of May in 2021 during the growing periods.

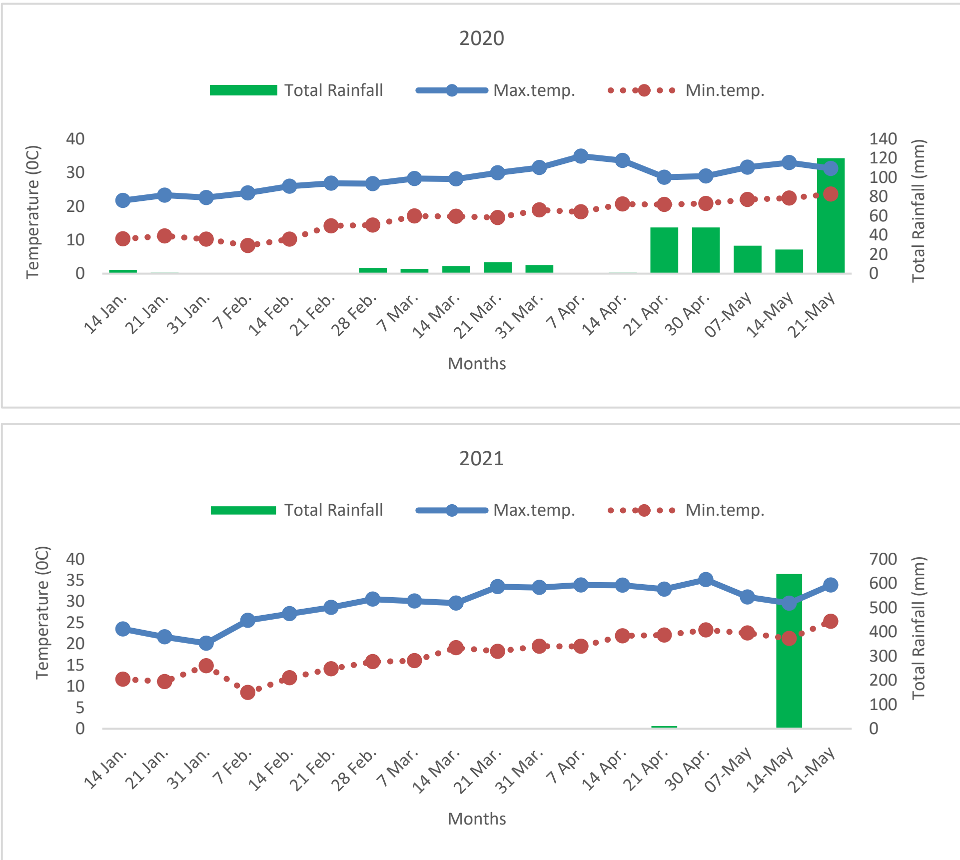

Fig. 1. Weekly average maximum and minimum temperature and total rainfall during the cropping period from 2020 and 2021 at ARS, BARI, Dinajpur

Results and discussion

Effect of planting date

The late winter planting period has a significant impact on tomato growth, yield and yield-related factors. The quantity, weight and production of tomatoes were steadily reduced by delayed planting. Regarding yield and yield qualities, there was a considerable variations between the planting dates (Table 1). Planting dates had a substantial effect on tomato clusters per plant. Early planting (January 15) followed by January 30 planting produced the largest number of clusters per plant (16.78). Planting on January 15 generated the most flowers per cluster (11.24) whereas February 28 produced the fewer flowers per cluster (6.10) in both years. This outcome was consistent with Hossain et al., 1986 and Ahammad et al., 2009's results that early planting increased the overall quantity of blossoms per plant. A nearly same pattern was discovered for fruit setting per cluster (Table 1). Early planting produced fruits that were larger than those planted in two subsequent years (5.92 cm×5.32 cm).

The January 15 planting produced the maximum average fruit weight (61.30 g), which was followed by the January 30 planting (59.86 g) in two consecutive years. The planting on January 15 produced the most fruits per plant (18.19), while the planting done later produced the fewer fruits per plant (12.70). This outcome was in agreement with those of Taha et al., 1984 and Yasmin et al., 2019. Because high temperatures and heavy rains reduced flower formation and/or caused bud and blossom drop, the crop grew from January 15 planting generated the highest marketable fruit yield (56.79 tha^{-1}) and the lowest (32.53 tha^{-1}) were from February 28 planting dates in both years. This might be as a result of enhanced photosynthesis accumulation in the fruits and improved photosynthesis translocation from source to sink. Levy et al., 1978; Dane et al., 1991; Sato et al., 2006 and Bhattarai et al., 2016 reported that high temperature between 15°C and 20°C is optimum for fruit setting of tomato. In January and February, the flower and fruit production were hampered by the average daytime temperature of 23.30°C to 27.5°C. According to Abdul and Harris, 1978; Sasaki et al., 2005; Beppu et al., 2001; Leonard and Kinet, 1982 temperature has an impact on the concentration of endogenous hormones. They discovered that immature leaves with low temperatures had lower levels of several gibberellins, which was linked to more blooms. This could be the reason for the increased fruit and blossom production after the 15 January planting.

Table 1. Effect of planting date on the fruit yield and yield contributing character of tomato (pooled of two years)

Planting date	No. of clusters/ plant	No. of flowers/ cluster	No. of fruits/ cluster	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	No. of fruits/ plant	Fruit Yield (t ha^{-1})
Jan.15	16.78	11.24	5.61	5.92	5.32	61.295	18.19	56.79
Jan.30	10.97	9.25	4.78	5.42	5.02	59.865	16.77	48.87
Feb.15	10.48	7.44	3.77	5.24	4.82	59.085	14.00	40.34
Feb.28	9.90	6.10	3.04	4.58	4.50	58.565	12.70	32.53
LSD $_{(0.05)}$	2.07	1.28	1.31	7.58	7.78	1.51	3.55	2.00
CV (%)	3.62	6.33	12.14	4.24	2.37	2.48	2.43	4.17

Effect of Variety

The varieties sown in the late rabi season had a substantialeffect on tomato yield and yield components (Table 2). In two consecutive years, var. BARI Tomato-16 generated the most clusters per plant (13.62) while Local variety produced the fewer clusters per plant (11.11). In both years, BARI Tomato-16 had the most blooms per cluster (9.66), whereas Local variety had the fewer (7.95). In both years, the local variety had the lowest number of fruits per cluster (3.97) while the BARI Tomato-16 had the highest number of fruits per cluster (5.00). The variety BARI Tomato-16 followed by BARI Tomato-15 (5.34 cm) had the longest fruits (5.91 cm), whereas the Local variety had the shortest fruits (4.62 cm) in both years. However, BARI Tomato-16 and BARI Tomato-15 at par with largest fruit diameter (5.15 cm), while the smallest fruit diameter (4.65 cm) was measured in a local variety. BARI Tomato-16 had the maximum average fruit weight (66.38 g), followed by BARI Tomato-15 (61.83 g), and local variety had the lowest average fruit weight (50.90 g) in both years. In two consecutive years, the variety BARI Tomato-16 had the largest amount of fruits (19.94), while a local variety had the fewer fruits (11.99). Mohammed (1995) and Mahmoud (1995) both reported comparable outcomes (2005). The BARI Tomato-16 gave the highest marketable fruit yield (51.31 t ha^{-1}), whereas the local variety produced the lowest fruit yield (38.75 t ha^{-1}) in both years. This might be as a result of its maximum fruit size, average fruit weight and no. of fruits per plant.

Table 2. Effect of variety on the yield and yield contributing character of tomato (pooled of two years)

Variety	No. of clusters/ plant	No. of flowers/ cluster	No. of fruits/ cluster	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	No. of fruits/ plant	Fruit Yield (t ha^{-1})
BARI Tomato-15	11.37	7.91	3.94	5.34	4.95	61.83	14.32	43.85
BARI Tomato-16	13.62	9.66	5.00	5.91	5.15	66.38	19.94	51.31
Local	11.11	7.95	3.97	4.62	4.65	50.90	11.99	38.75
$LSD_{(0.05)}$	0.57	0.64	0.57	1.62	1.29	2.79	0.67	1.15
CV (%)	4.24	7.76	11.69	4.52	2.38	2.85	4.59	2.77

Combined effect of planting date and varieties on the performance of tomato

Different yield characteristics were impacted by the combined effect of planting time and variety (Table 3). BARI Tomato-16 with January 15 planting showed greater performance than other combinations in terms of cluster size (19.92), flowers per cluster (13.91) and quantity of fruits per cluster (6.96). However, compared to other planting dates in both years, the fruit size of the BARI Tomato-16 with January 15 planting was greater (6.64 cm×5.62 cm). The BARI Tomato-16 with a planting date of January 15 produced the most average fruit weight (67.91g). On the other hand, BARI Tomato-16, planted on January 15, produced the most fruits per plant (22.40), followed by January 30 of same variety (22.37) in both years. BARI Tomato-16, planted on January 15, produced the highest marketable fruit output (66.16 t ha^{-1}) followed by BARI Tomato-15 (54.40 t ha^{-1}) and BARI Tomato- 16 (53.87 ha^{-1}) while the local variety, planted on February 28 produced the lowest yield (25.10 t ha^{-1})for two consecutive years.

Cost benefit analysis

Cost-benefit study was conducted in two years' value of tomato fruit yield shown in table 4. The variety BARI Tomato-16 planted on February 15 had the highest gross return (Tk. 2255000 ha^{-1}), net return (Tk. 2057100 ha^{-1}), and benefit cost ratio (11.39), followed by BARI Tomato-16 planted on February 28. The BCR showed that every treatment combination between variety and planting date was profitable and practical economically viable. However, because of the late sowing situation, a good tomato harvest can be generated if the farmers adopt all essential management practices. Low tomato prices are expected to persist on the market through the middle of the rabi season. When tomato output and supply fell but consumer demand remained high, the price started to rise in late March and early April. Because of this situation late planting conditions were found more advantageous to farmers in terms of high economic return, even though tomato yield was found to be lower in 15 February and 30 February planting of tomato seedling compared to 15 January and 30 January planting of tomato seedling.

Table 3. Interaction effect of planting date and variety on the yield and yield contributing character of late planting tomato (pooled of two years)

Treatment combination	No. of clusters/ plant	No. of flowers/ cluster	No. of fruits/ cluster	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	No. of fruits/ plant	Fruit Yield (t ha^{-1})
P_1V_1	14.23	10.91	3.95	5.61	5.43	62.89	17.75	54.40
P_1V_2	19.92	13.91	6.96	6.64	5.62	67.91	22.40	66.16
P_1V_3	16.19	8.88	5.90	5.50	4.9	53.09	14.41	49.81
P_2V_1	10.31	8.92	4.90	5.62	4.89	60.70	15.08	48.61
P_2V_2	12.25	9.92	4.92	5.99	5.37	67.40	22.37	53.87
P_2V_3	10.75	8.90	4.50	4.63	4.78	51.49	12.83	44.14
P_3V_1	9.81	6.88	3.50	5.32	4.75	62.04	13.01	39.95
P_3V_2	11.33	8.89	4.91	5.88	5.09	64.85	18.41	45.10
P_3V_3	10.29	6.53	2.92	4.49	4.61	50.36	10.58	35.97
P_4V_1	10.12	5.91	3.03	4.77	4.52	61.70	11.42	32.41
P_4V_2	10.95	6.48	3.17	5.10	4.72	65.33	16.53	40.08
P_4V_3	8.63	5.80	2.91	3.84	4.27	48.66	10.14	25.10
LSD $_{(0.05)}$	1.14	1.27	1.14	3.24	2.59	2.79	1.33	2.29
CV (%)	4.24	7.76	11.69	4.52	2.38	2.85	4.59	2.77

P_1=15 January, P_2=30 January, P_3=15 February, P_4=28 February, V_1=BARI Tomato-15, V_2=BARI Tomato-16, V_3=Local (Rani)

Table 4. Benefit-cost analysis of late planting tomato in respect to different treatments

Treatment combination	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
P_1V_1	1632000	197900	1434100	8.25
P_1V_2	1984800	197900	1786900	10.03
P_1V_3	1494300	197900	1296400	7.55
P_2V_1	1458300	197900	1260400	7.36
P_2V_2	1616100	197900	1418200	8.17
P_2V_3	1324200	197900	1126300	6.69
P_3V_1	1997500	197900	1799600	10.09
P_3V_2	2255000	197900	2057100	11.39
P_3V_3	1798500	197900	1600600	9.08
P_4V_1	1620500	197900	1422600	8.19
P_4V_2	2004000	197900	1806100	10.13
P_4V_3	1255000	197900	1057100	6.34

Average market price: Tomato 30 $Tk.kg^{-1}$ (Treat. Comb.1-6) and 50 $Tk.kg^{-1}$ (Treat. Comb.7-12)

P_1=15 January, P_2=30 January, P_3=15 February, P_4=28 February, V_1=BARI Tomato-15, V_2=BARI Tomato-16, V_3=Local (Rani)

Conclusion

Tomato var. BARI Tomato-16, which was planted on January 15 produced the maximum fruit yield, followed by BARI Tomato -15 in both the years. However, the variety BARI Tomato-16 planted on February 15 gave the highest benefit-cost ratio (11.39), followed by BARI Tomato-16 planted on February 28 BCR (10.13). Since the market price of tomato during the winter season often remains low and declined until the end of February, it then increased in March and beyond. Because of this, it's possible that the tomato varieties BARI Tomato-15 and BARI Tomato-16 planted on 15 February and 28 February (during the late rabi season) could be more profitable and economically feasible for tomato producers in the Dinajpur region.

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EVALUATION OF BETEL NUT GERMPLASM IN BARISHAL REGION

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Abstract

The field evaluation of betel nut germplasm was conducted at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barishal all the year round during three consecutive years of 2019-22 to select suitable entry (ies) for releasing as new variety (ies) for Barishal region. Seven entries of betel nut viz., E_1 (AC Rah-01), E_2 (AC Rah-02), E_3 (AC Rah-03), E_4 (AC Rah-04), E_5 (AC Rah-05), E_6 (AC Rah-06) and E_7 (AC Rah-07) were used as testing materials. The germplasm had been collected from different regions of Bangladesh since 1973. Three years average results showed that significant variations were observed among the evaluated betel nut germplasm. The maximum fresh and dry nut yield with husk (34.48 and 12.07 t/ha, respectively) was obtained from AC Rah-02 that was identical to AC Rah-01 (28.24 and 10.57 t/ha, respectively). Results revealed that the three years average yield performances of AC Rah-02 and AC Rah-01 were higher compared to that of other tested entries. Maturing condition of AC Rah-01 was late but early maturity was observed in AC Rah-02 and other tested entries. Nut shapes of AC Rah-01 and AC Rah-02 were oblong and oval, respectively. The laboratory analyses results revealed that alkaloids that caused oral cancer was less (3.95 mg/g) and the Ferric Reducing Antioxidant Power that cures the disease was higher (10.20 mgAAE/g) in AC Rah-01. The amount of total alkaloids (1.35%) and Arecoline content (4.69 mg/g) that cause cancer in the mouth were lower in AC Rah-02. Considering yield potentiality, maturity condition (late and early), lower incidences of insect-pest and diseases, and biochemical properties (higher Antioxidant power and lower contents of Alkaloids or Arecoline), AC Rah-01 and AC Rah-02 have been selected as promising entries of betel nut towards releasing new varieties for Barishal region of Bangladesh.

Keywords: Betel nut, germplasm, yield, arecoline and Barishal region.

Introduction

Betel nut is commonly referred to as areca palm, areca nut palm, betel palm, betel nut palm, Indian nut, Pinang palm and catechu. It grows well in warm and humid tropical climates and at an altitude of 1000 m above sea level. Betel nut is one of the cash crops of Bangladesh of which 90% of the betel nuts produced in Bangladesh are grown in the southern districts. Annual production of betel nut

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in Bangladesh is about 3.17 lac ton with an area 38.94 hectare. The major growing districts are Laksmipur, Cox's Bazar, Chattogram, Bhola, Sylhet, Pirojpur, Bagerhat Gaibandha, Noakhali, Narail, Barisha, Jhallokati and Khulna (BBS, 2020). Betel nut trees are usually planted around the house or by the side of the pond, canal banks, highlands and orchards. Betel nut is consumed both as a raw or ripe nut, as dried ripe nut and as semi-mature, cut and processed varieties. Each 100 grams of betel has the ability to provide 269 calories of energy.

The alkaloids in betel nut are the main active ingredients in research currently, while arecoline (methyl 1-methyl-3,6-dihydro-2H-pyridine-5-carboxylate) is considered the most important alkaloid in betel nut. The total alkaloid content of betel nut is estimated between 0.3% and 0.7%.

Many germplasm of betel nut had been collected from different regions of Bangladesh by the then Coconut Research Station (presently established as Regional Agricultural Research Station), Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barishal. The collected germplasm were conserved and evaluated at this station for selecting the superior/promising entry (ies) towards releasing as new variety (ies) for Barishal region of Bangladesh.

Materials and Methods

The evaluation of the betel nut germplasm was conducted at Regional Agricultural Research Station, BARI, Rahmatpur, Barishal during three consecutive years of 2019-20, 2020-21 and 2021-22 to select the suitable line/entries for releasing new variety (ies) for Barishal region. The experimental site under the agro-ecological zone (AEZ-13) of 'Ganges Tidal Floodplain'. The experimental sites are situated in the latitudes and longitudes of $22^{o}47^{/}23.06872^{//}$N and $90^{o}17^{/}37.65059^{//}$E; and $22^{o}47^{/}22.93429^{//}$N and $90^{o}17^{/}39.44634^{//}$E. The soil type is medium high land with loamy soil texture. The experiment was laid out in randomized complete block design with three replications. Seven entries of betel nut viz., E_1 = AC Rah-01, E_2 = AC Rah-02, E_3 = AC Rah-03, E_4 = AC Rah-04, E_5 = AC Rah-05, E_6 = AC Rah-06, and E_7 = AC Rah-07 were used as testing materials t. The germplasm had been collected from different regions of Bangladesh since 1973 (Table 3). It can be mentioned that the entries E_1 and E_2 were collected from Rangpur and Bagerhat (Mongla) districts, respectively. On the other hand, E_3, E_4, E_5, E_6 and E_7 had been collected from Barishal region. The collected germplasm had been conserved and seedlings planted with spacing row to row distance was 2.5 m and plant to plant distance was 2.5 m. The balanced dose of fertilizers had been applied for proper growth of the plant after planting as follows (Table 1).

Table 1. Rate of compost and chemical fertilizers of betel nut by age of tree

Age of tree (year)	Rate of fertilizers/tree					
	Compost (kg)	Urea (g)	TSP (g)	MP (g)	Gypsum (g)	Zinc sulphate (g)
0-2	10	100	100	120	15	10
3-4	12	130	120	160	25	20
5-6	14	160	140	200	35	30
6-7	17	190	160	240	45	40
9-10	18	230	160	260	55	50
> 10	20	250	200	300	60	50

Chemical fertilizers had been divided into two parts and applied twice a year at the base of the tree, the first time in September and the second time in February. The first stage of application of fertilizer was to make a ditch 50-65 cm apart, 15-25 cm deep and keeping 20-30 cm free from the base of the tree in a circle around the tree. Compost and chemical fertilizers were applied in the ditch and mixed well with the soil of the ditch. Fertilizers were applied in the same way in the second phase. Organic fertilizer (compost) was applied one month before application of chemical fertilizers. Different intercultural operations (irrigation, weeding, mulching, plant protection etc.) were done as and when necessary. Mulching was done by providing irrigation after application of fertilizer. Ten plants were selected randomly from each germplasm for recording the yield parameters and yields of betel nut. After planting betel seedlings with proper care, the yield starts coming within 4-5 years. Then, the yield gradually increases with advancement of years. From the age of ten years the tree begins to bear full fruit. It took 9-10 months for the fruit to ripen after flowering. Betel nuts were collected in the fully ripe stage. At the time of fruit collection, betel nuts were tied with rope and taken down. The fresh matured betel nut samples of four entries (AC Rah-0, AC Rah-02, AC Rah-03 and AC Rah-04) were collected randomly and were sent to the Central Laboratory, Research Wing, BARI, Gazipur for determining their biochemical compositions in 2021-22. Data were collected both on quantitative (yield contributing parameters and yields) and qualitative (source of collection, flowering season, harvesting season, maturing condition, nut shape, incidences of insect-pest and diseases and yield potentiality) traits of the tested betel nut germplasm during all the three studied years . The evaluations of the germplasm were made based on different parameters such as yield and yield contributing characters, maturity time, adaptability, size and shape of betel nut, quality, amount of Alkaloids causing carcinogenesis, attractiveness, disease and insect tolerance, bio-chemical compositions (like 50% insulation concentration, ferric reducing antioxidant power, antioxidant ability to cure disease, total phenolic content, total flavonoid content, ascorbic acid equivalent, gallic acid equivalent, tannic acid equivalent and chatacin) etc. Data were analyzed statistically by using computer software of

Statistics 10 version and then the mean differences were adjudged with Duncan's Multiple Range Test (DMRT).

Results and Discussion

Plant characters of betel nut as influenced by different germplasm

Statistically significant variations were observed among the evaluated betel nut germplasm in terms of stem diameter of middle portion, number of compound leaf/tree, nut/bunch, nut/tree, nut length with husk, nut diameter with husk, nut length without husk, nut diameter without husk, single fresh nut weight with husk, single dry nut weight with husk, single fresh nut weight without husk, single dry nut weight without husk, and fresh and dry nut yields with husk (Table 2). Stem diameter of middle portion became the maximum (39.22 cm) in AC Rah-02, which was at par to that of AC Rah-06 (36.20 cm), AC Rah-01 (36.12 cm) and AC Rah-03 (35.77 cm). The entry AC Rah-07 showed the lowest diameter (34.45 cm). The entry AC Rah-02 showed the maximum number of compound leaf/tree (10.00) which was identical to that of AC Rah-01 (9.00) and AC Rah-04 (8.33). The lowest number of leaf/tree was recorded in AC Rah-07 (6.00). Similarly, AC Rah-02 produced the maximum number of nut/bunch (195) followed by AC Rah-01 (176). The lowest number of nut/bunch was found in AC Rah-05 (137). The entry AC Rah-02 exhibited the higher number of nut/tree (741) but at par to AC Rah-01 (656). The lowest number of nut/tree was recorded in AC Rah-05 (376). The highest nut length with husk (54.69 mm) was recorded in AC Rah-01 followed by AC Rah-02 (48.58 mm). The entry AC Rah-07 gave the lowest nut length with husk (44.85 mm). On the other hand, AC Rah-02 showed the highest nut diameter with husk (44.99 mm) but breadths for AC Rah-04 and AC Rah-01 were 40.12 and 37.51 mm, respectively. Nut length without husk was the highest (13.87 mm) in AC Rah-01 followed by AC Rah-02 (12.50 mm). The entry AC Rah-07 gave the lowest length of nut without husk (9.67 mm). Nevertheless, AC Rah-02 showed the maximum t diameter of nut without husk (8.33 mm), which was similar to that of AC Rah-01 and AC Rah-04 (7.00 mm). The lowest diameter of nut without husk (5.67 mm) was recorded in AC Rah-07. The results indicated that the nut shape of AC Rah-01 was elongated in nature as compared to other evaluated germplasm. The entry AC Rah-02 produced the highest weight of single fresh nut with husk (40.00 g) followed by AC Rah-01 (35.67 g). The lowest single fresh nut weight was 26.67 g in AC Rah-07. The highest single dry nut weight with husk was recorded in AC Rah-02 (14.07 g) followed by AC Rah-01 (13.54 g) and AC Rah-04 (13.13 g) but it was the lowest (11.57 g) in AC Rah-05. AC Rah-02 exhibited the maximum ratio (2.84) of fresh and dry nut with husk closely followed by AC Rah-01 (2.63) and the lowest value (2.21) in AC Rah-04. Percentage of moisture content of nut with husk was found the highest (64.83%) in AC Rah-02 followed by AC ACRah-01 (62.04%) but the lowest (54.71%) in AC Rah-04. The entry AC Rah-02 also provided the maximum weight of single fresh nut without husk (13.87 g) followed by AC Rah-01 (12.50 g) and the lowest weight (9.67 g) from AC Rah-07. Likewise, the maximum single dry nut weight without husk (7.25g) was found in AC Rah-02 which was statistically identical to AC Rah-01 (6.94 g) and the lowest weight (5.53 g) in AC Rah-07. Results also showed that fresh and dry nut ratio without husk of the betel nut germplasm were ranged from 1.68 to 1.91. Moisture content of nut without husk was the highest (47.72%) in AC Rah-02 while AC Rah-01 exhibited the moisture content of 44.51%. The lowest moisture content (40.61%) of nut without husk was found in AC Rah-03. It was observed that all the tested plant characters of betel nut like number of compound leaf/tree, nut/bunch, nut/tree, nut length, nut diameter, single fresh and dry nut weights of AC Rah-01 and AC Rah-02 showed more values as compared to that of other tested germplasm that contributed to achieve higher yields of the promising entries (AC Rah-01 and AC Rah-02).

Table 2. Plant characters of betel nut as influenced by different germplasm at RARS, Rahmatpur, Barishal (Pooled of 3 years)

Entry	Tree height at 50 years age (m)	Stem diameter of different portions (cm)			Compound leaf/ tree (no.)	Nut bunch/ tree (no.)	Nut/ bunch (no.)
		Top	Middle	Bottom			
AC Rah-01	10.77	32.23	36.12ab	50.83	9.00ab	3.77	176b
AC Rah-02	10.83	36.27	39.22a	55.60	10.00a	3.83	195a
AC Rah-03	11.13	33.23	35.77ab	55.40	8.00b	3.17	149cd
AC Rah-04	10.13	32.12	35.43b	56.32	8.33ab	3.53	155c
AC Rah-05	9.65	31.45	35.58b	55.18	7.33bc	3.00	137d
AC Rah-06	9.83	32.21	36.20ab	54.43	8.00b	2.83	142cd
AC Rah-07	10.33	30.36	34.45b	54.72	6.00c	2.67	140d
CV (%)	9.70	6.49	5.54	7.55	11.95	19.78	12.16

Table 2. Contd.

Entry	Nut/ tree (no.)	Nut length with husk (mm)	Nut diameter with husk (mm)	Nut length without husk (mm)	Nut diameter without husk (mm)	Single fresh nut weight with husk (g)	Single dry nut weight with husk (g)
AC Rah-01	656ab	54.69a	37.51b	13.87a	7.00ab	35.67b	13.54ab
AC Rah-02	741a	48.58b	44.99a	12.50b	8.33a	40.00a	14.07a
AC Rah-03	466cd	47.06b	39.76b	11.00b	6.33b	28.67c	12.07bc
AC Rah-04	547bc	48.28b	40.12b	11.33b	7.00ab	29.00c	13.13a-c
AC Rah-05	414cd	45.71b	36.36b	10.33c	6.00b	27.33c	11.57c
AC Rah-06	408cd	45.67b	39.58b	10.00c	6.00b	28.00c	12.16bc
AC Rah-07	376d	44.85b	38.53b	9.67d	5.67c	26.67c	11.77bc
CV (%)	16.94	6.75	5.97	11.71	15.93	7.32	8.03

In a column, mean values with the same letter (s) or without letter do not differ significantly whereas mean values with dissimilar letter differ significantly as per DMRT.

Table 2. Contd.

Entry	Fresh and dry nut wt. ratio with husk	Moisture content of nut with husk (%)	Single fresh nut weight without husk (g)	Single dry nut weight without husk (g)	Fresh and dry nut wt. ratio without husk	Moisture content of nut without husk (%)
AC Rah-01	2.63	62.04	12.50ab	6.94a	1.80	44.51
AC Rah-02	2.84	64.83	13.87a	7.25a	1.91	47.72
AC Rah-03	2.38	57.91	11.00bc	6.53ab	1.68	40.61
AC Rah-04	2.21	54.71	11.33bc	6.60ab	1.72	41.76
AC Rah-05	2.36	57.68	10.33bc	6.05ab	1.71	41.45
AC Rah-06	2.30	56.57	10.00c	5.57b	1.80	44.33
AC Rah-07	2.27	55.88	9.67c	5.53b	1.75	42.76
CV (%)	-	-	11.67	10.91	-	-

In a column, mean values with the same letter (s) or without letter do not differ significantly whereas mean values with dissimilar letter differ significantly as per DMRT.

Fresh and dry nut yields of betel nut as influenced by different germplasm

In all the three years, entry AC Rah-02 gave the highest yields of fresh and dry nut (Table 3). However, AC Rah-01 gave slightly lower yields (fresh and dry nut) than that of AC Rah-02 in all the years. The highest fresh nut yield with husk (34.48 t/ha) was obtained from AC Rah-02 that was at par to AC Rah-01 (28.24 t/ha) and the lowest yield in AC Rah-07 (12.09 t/ha). Fresh nut yields were obtained from AC Rah-04, AC Rah-03, AC Rah-06 and AC Rah-05 were 19.18, 16.14, 13.87 and 13.78 t/ha, respectively. Similarly, the maximum yield of dry nut with husk (12.07 t/ha) was found in AC Rah-02 followed by AC Rah-01 (10.57 t/ha). Besides, dry nut yields of AC Rah-04, AC Rah-03, AC Rah-05 and AC Rah-06 were 7.44, 6.55, 5.68 and 5.38 t/ha, respectively while it was the lowest in AC Rah-07 (5.10 t/ha). Results further revealed that the average yield performances of AC Rah-02 and AC Rah-01 were higher as compared to that of other tested entries of betel nut. The higher values of yield contributing characters (number of nut/bunch, nut/tree, nut length, nut diameter, single fresh and dry nut weights) of the promising entries of betel nut germplasm (AC Rah-02 and AC Rah-01) led to produce higher yields. It can be noted that after planting betel seedlings, if taken care of properly, the yield starts coming within 4-5 years. Then, with age, the yield gradually increases. From the age of ten years the tree begins to bear full fruit and continues till the age of 60 years. Then the yield gradually decreases. It takes 8-10 months for the fruit to ripen after flowering. Trees can continue fruiting for 30-60 years (www.pfaf.org). Betel nuts are collected in fully ripe, semi-ripe or raw state. The collecting betel nut depends on how it is used and how it is processed.

Table 3. Year-wise fresh and dry nut yields with husk of the evaluated germplasm of betel nut at RARS, Rahmatpur, Barishal

Entry	Fresh nut yield with husk (t/ha)				Dry nut yield with husk (t/ha)			
	2019-20	2020-21	2021-22	Pooled	2019-20	2020-21	2021-22	Pooled
AC Rah-01	26.86b	29.28b	28.58b	28.24ab	9.87a	10.62b	11.22a	10.57ab
AC Rah-02	31.37a	37.25a	34.82a	34.48a	11.37a	12.86a	11.98a	12.07a
AC Rah-03	14.36d	17.71c	16.34cd	16.14c	5.74c	7.15c	6.76bc	6.55bc
AC Rah-04	19.53c	17.81c	20.21c	19.18b	7.75b	6.79c	7.77b	7.44b
AC Rah-05	12.12d	15.16cd	14.06de	13.78cd	4.81c	6.82c	5.41cd	5.68cd
AC Rah-06	13.35d	15.21cd	13.05de	13.87cd	5.30c	5.81c	5.02d	5.38e
AC Rah-07	13.14d	12.06d	11.06e	12.09d	5.21c	5.83c	4.25d	5.10e
Mean	18.68	20.64	19.73	19.68	7.15	7.98	7.49	7.54
CV (%)	10.42	10.61	12.94	12.39	15.65	11.59	12.83	10.55

In a column, mean values with the same letter (s) or without letter do not differ significantly whereas mean values with dissimilar letter differ significantly as per DMRT.

Climatic condition for betel nut cultivation

The previous five years annual total rainfalls at RARS, Rahmatpur, Barishal were 2425, 1475, 1677 and 1756 mm in the years of 2017, 2018, 2019, 2020 and 2021, respectively (Fig. 1). It was noted that the annual rainfall requirement for betel nut cultivation above 1250 mm. As the rainfall per annum at the experimental area remained above the critical level during the previous five years (2017-2021) was ranged from 1475 to 2425 mm, which helped in achieving the higher yield of nut. On the other hand, the existing monthly average air temperatures (average of previous five years) were ranged from 18.33 to 33.61^{o}C in the study area (Fig. 2). It was also reported that ideal temperature for betel nut cultivation is 18-35^{o}C (Banglapedia, 2021). At lower or higher temperatures the yield decreases. The results further revealed that the experimental region is quite suitable for betel nut cultivation in terms of climatic condition.

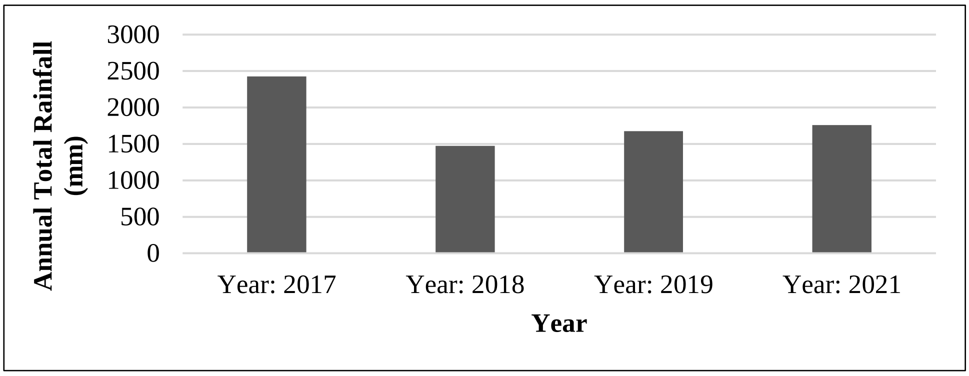

Fig. 1. Annual total rainfall by year at RARS, Rahmatpur, Barishal.

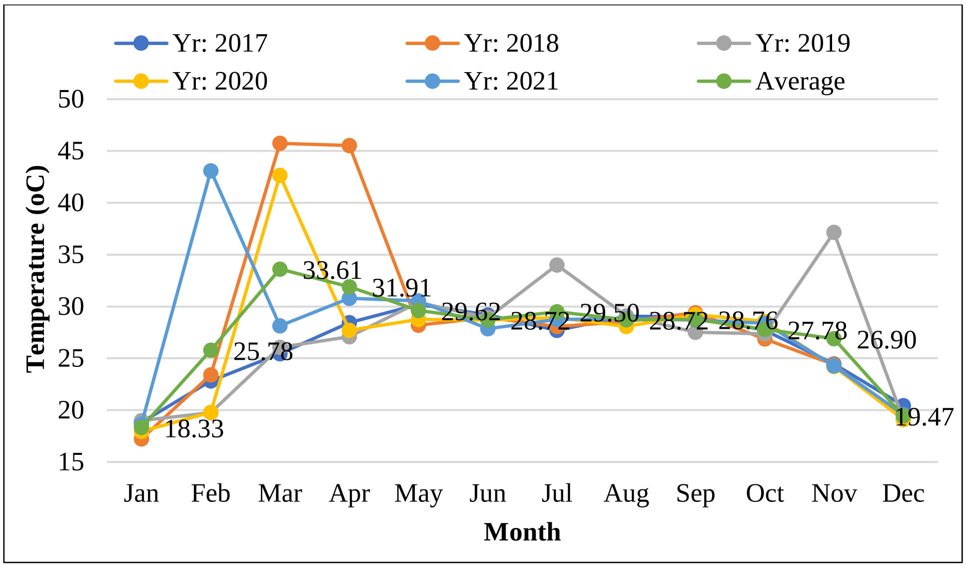

Fig. 2. Monthly temperature of by year at RARS, Rahmatpur, Barishal.

Qualitative traits of the betel nut germplasm (2021-22)

Actually all the evaluated germplasm of betel nut had been collected from different parts of Bangladesh since 1973. The entry AC Rah-01 attained at the flowering stage comparatively in late condition (March-April) than that of other entries (AC Rah-02, AC Rah-03, AC Rah-04, AC Rah-05, AC Rah-06 and AC Rah-07). In AC Rah-01, the harvesting stage was also appeared in January-February. However, other entries flowered earlier (October-November). Maturity of AC Rah-01 was late but early maturity was observed in other entries. Nut shapes of AC Rah-01 and AC Rah-02 were oblong and oval, respectively. Nut shapes of other tested entries (AC Rah-03, AC Rah-04, AC Rah-05, AC Rah-06 and AC Rah-07) were almost round. Incidences of insect-pest and diseases in AC Rah-01 and AC Rah-02 were comparatively low as compared to other entries. Yield potentiality of AC Rah-01 and AC Rah-02 were higher as compared to other entries. However, moderate to low yield potentialities were observed in AC Rah-03, AC Rah-04, AC Rah-05, AC Rah-06 and AC Rah-07.

Biochemical compositions of selected betel nut germplasm (2021-22)

The results of the laboratory analyses tested samples of betel nut germplasm revealed that total fat was the highest (14.80%) in AC Rah-03 but it was the lowest (11.30%) in AC Rah-02 (Table 5). Besides, the entry AC Rah-01 showed moderate value of total fat (13.15%). The maximum total alkaloid 1.82% was found in AC Rah-03 followed by AC Rah-02 and AC Rah-01 with 1.35 and 1.51%, respectively. The entry AC Rah-04 showed the lowest alkaloid (1.13%)

content. Free radical scavenging activity (DPPH-RSA) and 50% inhibitory concentration (IC50) was recorded the highest (14.11 µg/ml) in AC Rah-03 but lower in AC Rah-01 and AC Rah-02 (10.49 and 12.15 µg/ml, respectively). AC Rah-01 showed the highest values (10.20 mg AAE/g and 4.03 mg GAE/g, respectively) of Ferric Reducing Antioxidant Power (FRAP) and AC Rah-02 exhibited the FRAP values of 9.08 mg AAE/g and 3.62 mg GAE/g. The lowest FRAP (8.93 mgAAE/) was recorded in AC Rah-04. The maximum total Antioxidant Capacity (TAC) (34.54 mgAAE/g) was found in AC Rah-04 followed by AC Rah-01 and AC Rah-02 of 30.95 and 28.75 mg AAE/g, respectively. The highest total Phenolic Content (TPC) (101.18 mg GAE/g) was found in AC Rah-01 followed by AC Rah-02 of 90.36 mg GAE/g. The lowest TPC (81.13 mgGAE/g) was obtained from AC Rah-03. Tanin content of AC Rah-01 was the highest (91.86 mgTAE/g) followed by AC Rah-02 (82.28 mg TAE/g). The lowest content of Tanin (73.79 mg TAE/g) was found in AC Rah-03. Total Flavonoid Content (TFC) was comparatively higher in AC Rah-01 (237.98 mg CE/g) than AC Rah-02 (217.53 mg CE/g). The TFC were lower in AC Rah-03 (199.62 mg CE/g) and AC Rah-04 (203.21 mg CE/g). Arecoline Contents were higher in AC Rah-03 (5.90 mg/g) followed by AC Rah-04 (5.31 mg/g) while it was lower in AC Rah-01 (3.95 mg/g) and AC Rah-02 (4.79 mg/g). Results revealed that alkaloids that caused oral cancer was less (3.95 mg/g) and the Ferric Reducing Antioxidant Power that cures the disease was higher (10.20 mg AAE/g) in AC Rah-01. The content of total alkaloids (1.35%) and Arecoline content (4.69 mg/g) that cause cancer in mouth were lower in AC Rah-02. Considering the biochemical compositions of the selected betel nut germplasm, AC Rah-01 and AC Rah-02 were selected as promising entries of betel vine. Arecoline is an important ingredient in betel nut, has been regarded as a possible carcinogen for human beings by the International Cancer Research Institute (Dave *et al*., 1992). It is speculated that betel nut contains arecoline, which acts as cholinergic alkaloids that stimulates the dose-related bronchocontraction (Taylor *et al*. 1992). As chewing of betel nut can induce oral submucosal fibrosis and oral cancer due to the presence of alkaloids, therefore, lower content of Alkaloids or Arecoline in the promising entries (AC Rah-01 and AC Rah-02) may reduce the risk of oral cancer in human body. On the other hand, the higher ferric reducing antioxidant power may protect the human body from different diseases like malaria, ascariasis, arthritis, enterozoic abdominalgia, stagnation of food, diarrhea, edema, and beriberi (Peng, 2017). The betel nut plant, mainly cultivated for nut or seed production, which is an essential part of betel pepper has important medicinal values as well (Nath and Karmakar 2001; Staples and Bevacqua, 2006). Researchers reported that important and useful chemical ingredients present in the areca nut which made it a basic element of betel quid and enhanced its commercialization (Gupta and Warnakulasuriya 2002).

Table 4. Qualitative traits of the evaluated betel nut germplasm at RARS, Rahmatpur, Barishal

Entry	Source of collection	Flowering season	Harvesting season	Maturing condition	Nut shape	Incidences of insect-pest and diseases	Yield potentiality
AC Rah-01	Rangpur	Mar-Apr	Jan-Feb	Late	Oblong	Low	Higher
AC Rah-02	Mongla (Bagerhat)	Feb-Mar	Nov-Dec	Early	Oval	Low	Higher
AC Rah-03	Barishal region	Feb-Mar	Oct-Nov	Early	Round	Moderate	Moderate
AC Rah-04	Barishal region	Feb-Mar	Oct-Nov	Early	Round	Moderate	Moderate
AC Rah-05	Barishal region	Feb-Mar	Oct-Nov	Early	Round	Moderate	Moderate
AC Rah-06	Barishal region	Feb-Mar	Oct-Nov	Early	Round	Moderate	Low
AC Rah-07	Barishal region	Feb-Mar	Oct-Nov	Early	Round	Moderate	Low

Table 5. Biochemical compositions of selected betel nut germplasm (2021-22)

Betel nut germplasm	Dry weight basis				
	Total fat (%)	Total alkaloid (%)	DPPH-RSA IC50 (µg/ml)	FRAP (mgAAE/g)	FRAP (mgGAE/g)
AC Rah-01 (Proposed)	13.15	1.51	10.49	10.20	4.03
AC Rah-02 (Proposed)	11.30	1.35	12.15	9.08	3.62
AC Rah-03 (Local)	14.80	1.82	14.11	9.54	3.78
AC Rah-04 (Local)	13.10	1.13	12.63	8.93	3.56

Table 5. Contd.

Betel nut germplasm	Dry weight basis				
	TAC (mgAAE/g)	TPC (mgGAE/g)	Tanin (mgTAE/g)	TFC (mgCE/g)	Arecoline Content (mg/g)
AC Rah-01 (Proposed)	30.95	101.18	91.86	237.98	3.95
AC Rah-02 (Proposed)	28.75	90.36	82.28	217.53	4.79
AC Rah-03 (Local)	29.46	81.13	73.79	199.62	5.90
AC Rah-04 (Local)	34.54	86.98	79.17	203.21	5.31

Source: Central Laboratory, Research Wing, BARI, Gazipur

Note: DPPH-RSA = 2,2-diphenyl-1-picrylhydrazyl Free Radical Scavenging Activity; IC50 = 50% Inhibitory Concentration; FRAP = Ferric Reducing Antioxidant Power; TAC = Total Antioxidant Capacity; TPC = Total Phenolic Content; TFC = Total Flavonoid Content; AAE = Ascorbic Acid Equivalent; GAE = Gallic Acid Equivalent; TAE = Tannic Acid Equivalent; CE = Chatechin Equivalent.

Conclusion

Considering higher yield potentiality, maturity condition (late and early), lower incidences of insect-pest and diseases, and biochemical properties (higher Antioxidant power and lower contents of Alkaloids or Arecoline), AC Rah-01 and AC Rah-02 have been selected as promising entries of betel nut towards releasing as new varieties for Barishal region of Bangladesh.

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EFFECTS OF DIFFERENT CHEMICAL TREATMENTS OF MURTA CANE (*Schumannianthus dichotomus* L.) ON THE QUALITY OF *SHITALPATI* (MAT) IN BANGLADESH

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M. M. RAHMAN[4] AND M. Z. RAHMAN[5]

Abstract

The experiment was conducted during two consecutive seasons of 2019-2020 and 2020-2021 at Farmers' home of Kamdebpur village of Nalchity upazila under Jhalakati district (2019-2020) and Bangladesh Agricultural Research Institute, Regional Agricultural Research Station, Rahmatpur, Barishal (2020-2021) to develop suitable protocol of chemical treatment of murta cane for improving the quality of *shitalpati* (cooling mat) in Bangladesh. There were nine treatments in the experiment viz., T_1 = Boiled with Tamarind leaf + Cowa leaf (50g leaf/liter water), T_2 = Soaking and boiled with fermented rice starch (250ml/liter water), T_3 = Boiled with white vinegar (100ml/liter water), T_4 = Boiled with cowa leaf + Vinegar (25g cowa leaf/liter water and 50ml vinegar/liter water), T_5 = Boiled with Detergent powder (10g/liter water), T_6 = Boiled with Fermented rice starch + Arrowroot (fermented rice starch 250ml/liter water and arrowroot 5g/liter water), T_7 = Boiled with Tamarind leaf + Cowa leaf + Rice starch (50g leaf/liter water and fermented rice starch 250ml/liter water), T_8 = Boiled with Rice starch + Fermented milk (fermented rice starch: milk = 10: 1), and T_9 = Control (no treatment). The experiment was conducted in a Completely Randomized Design (CRD) with three replications. The chemical treatment had significant effect on the quantitative and qualitative traits of murta cane. In terms of qualitative traits, the lowest average value (2.58) was recorded in treatment T_7 that denoted from very good to good quality of *shitalpati* followed by T_4 treatment (rating 2.67). The rating from good to moderate qualities of *shitalpati* were found in T_6 (3.33), closely followed by T_2 (3.42) and T_1 (3.42) treatment. Considering the average value of the qualitative traits (brightness, surface glossiness, surface smoothness and comfort), the treatments T_7, followed by T_4 and T_8 could be applied for the treatment of murta cane towards weaving very good to good qualities of *shitalpati*.

Keywords: *Shitalpati*, murta cane, chemical treatment, quality.

Introduction

Shitalpati (cooling mat) is made from the stripe of the murta plant (*Schumannianthus dichotomus* L.) which is collected from culm of the murta plant (Chowdhury *et al*., 2007). The cultivation and processing of murta has great potential for the rural economy of the *shitalpati* weaving areas of Bangladesh (Ahmed *et al*., 2007). The upper shell of the murta cane, locally known as *pit bet*,

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used for weaving cool mat, the next part (called as *buka bet*) is taken out and used to make *buka* mat and the remaining part (called as *chhota bet*) is used for making thin rope. Depending on the growing region, the murta plant is also called as *paitra, mustaq, patibet, patipata, muktagach, patigacha, murtha, ratagacha, patijong, shitalpati* plant etc. The murta plant grows around water bodies in northeastern and southern districts of Bangladesh. *Shitalpati* is very soft, cool and beautiful which is traditionally used in summer and human body feels natural comfort. The mat is used by people all over Bangladesh and some parts of India as sitting mat, bedspread or prayer mat. Mats with decorative designs are also called *nakshipati* (Banu, 2012). *Shitalpati* is also weaved with herbs, animals and surrounding designs and motifs. It has red, blue, green, black and purple colors (Banglapedia, 2014). Both men and women participate in collecting and processing murta but weaving process involved by women. *Shitalpati* is a traditional handicraft product that is about 350 years old. *Shitalpati* is weaved traditionally in the districts of Sylhet, Moulvibazar, Habiganj, Jhalokati, Barishal, Pirojpur, Jashore, Faridpur, Sunamganj, Netrokona, Nilphamari, Kurigram, Tangail, Mymensingh, Narsingdi, Munshiganj, Sirajganj, Cumilla, Chandpur, Feni, Lakshmipur and Noakhali. However, Rajnagar, Balaganj, Baralekha and Molla Bazar of Sylhet region, Sonagazi and Raipur of Noakhali, Swarupkathi and Nilgati of Barishal and Satche of Faridpur produced high quality of *shitalpati* (Banglapedia, 2014). The Forestry Master Plan (1992) claimed that about eight thousand people in the country are involved in making *shitalpati* (GoB, 1992) and the annual value of the murta and hogla plants used for making *shitalpati* in 1992 was about USD 0.11 million (Basit, 1995). The traditional art of *shitalpati* weaving of Sylhet has been included in the United Nations Educational, Scientific and Cultural Organization (UNESCO)'s as Intangible Cultural Heritage (ICH) of Humanity (Anonymous, 2017a).

The *shitalpati* is made through different indigenous chemical treatments or processes of murta cane in the country. It was reported that cane is picked up from the culm of murta plant. Then rice starch and water are mixed and boiled the murta cane for making it smooth and white (Anonymous, 2017b). Cane is made where one bunch is tied in the form of a *bira* followed by boiled by mixing rice starch and hog plum (*Spondias mombin*), jarul (*Lagerstroemia speciosa*) and geowa (*Excoecaria agallocha*) leaves with water. This results in soft, smooth and shiny cane (*Annonymous*, 2019). The indigenous ingredients like tamarind leaf (*Tamarindus indica*), cowa leaf (*Garcinia cowa*) etc. are also used for murta cane processing. Quality of *shitalpati* is judged by its glossiness, smoothness and fineness of texture. Most of the *shitalpati* available are of poor quality and sold at low price in the local market. However, formal research has yet to be conducted for the improvement of *shitalpati* handicraft in Bangladesh. Development of suitable chemical treatment would improve the quality of *shitalpati* as well as its market demand, which ultimately will increase the net income of the respective stakeholders. In these circumstances, the experiment was designed to develop suitable protocol of chemical treatment of murta cane in Bangladesh.

Materials and Methods

The experiment was conducted during 2019-2020 and 2020-2021 seasons at Farmers' home of Kamdebpur village under Nalchity upazila of Jhalakati district (2019-2020) and Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Rahmatpur, Barishal (2020-2021) to develop suitable protocol of chemical treatment/process of murta cane for improving the quality of *shitalpati* in Bangladesh. There were nine treatments in the experiment viz., T_1 = Boiled with Tamarind leaf + Cowa leaf (50g leaf/liter water), T_2 = Soaking and boiled with fermented rice starch (250ml/liter water), T_3 = Boiled with white vinegar (100ml/liter water), T_4 = Boiled with cowa leaf + Vinegar (25g cowa leaf/liter water and 50ml vinegar/liter water), T_5 = Boiled with Detergent powder (10g/liter water), T_6 = Boiled with Fermented rice starch + Arrowroot (fermented rice starch 250ml/liter water and arrowroot 5g/liter water), T_7 = Boiled with Tamarind leaf + Cowa leaf + Rice starch (50g leaf/liter water and fermented rice starch 250ml/liter water), T_8 = Boiled with Rice starch + Fermented milk (fermented rice starch: milk = 10: 1), and T_9 = Control (no treatment). The design of the experiment was Completely Randomized Design (CRD) with three replications. The stem (*doga*) of mutra plant was harvested and then the green top layer was separated from the stem for making cane (locally known as *Atibeti*). The murta cane was treated or processed following the chemical treatment specifications as designed under this experiment. At fast, murta cane was kept in the treatment solution for 7 days towards fermentation and then it was boiled with the same solution for about 15 minutes until appearing the desired yellowish colour of the cane. The boiled cane was dried in the sun for 2-3 days until getting ready for making *shitalpati*.

Data were recorded on different quantitative traits viz., p^H (before and after boiling of murta cane with treatment solution) and temperatures (before and after dipping of cane in hot treatment solution). However, data on surface temperature and four qualitative traits (surface glossy, bright, smooth and comfortable) were taken after weaving of shitalpati using the respective murta cane treated as per treatment specifications. The p^H value of hot treatment solution was measured using water pH meter. Temperatures of hot treatment solution were measured with the help of mercury based water thermometer before and after boiling of murta cane. *Shitalpati* was weaved with the treated murta cane under different treatment specifications. Efficient *patikar* (craftsman) of the locality were engaged to weave the *shitalpati*. The unit size of *shitalpati* was 2.3 meter long and 1.38 meter wide. Each of the four qualitative characteristics of *shitalpati* (surface glossy, bright, smooth and comfortable) were evaluated just after weaving the *shitalpati* based on 1 to 7 rating scale, where 1 = Excellent quality, 2 = Very good, 3 = Good, 4 = Moderate, 5 = Poor, 6 = Very poor, and 7 = Worst quality. It can be noted that the excellent quality indicates the highest value of surface glossy, bright, smooth and comfortable of shitalpati. Data were analyzed through Statistix10 computer software and the mean differences were adjudged with Duncan's Multiple Range Test (DMRT).

Results and Discussion

All the quantitative traits viz. p^H (before and after boiling of murta cane), temperature (before dipping of murta cane), temperature (after dipping of cane), surface temperature and qualitative traits of *shitalpati* varied significantly due to different chemical treatments of murta cane (Table 1). Before boiling of cane, the maximum pH value (6.83) was recorded in normal water that was at par to that of T_6 treatment solution (5.62). The lowest pH value (3.18) was recorded in treatment T_3. The treatment solutions of T_4 followed by T_2, T_7, T_2, T_8 and T_5 also showed the lower pH values (3.51, 3.88, 4.09, 4.21, 4.38 and 5.43, respectively) before boiling of cane. During boiling of cane, the highest pH value (8.73) was shown by T_5 treatment solution due to adding detergent powder in water. The pH value for normal water was 7.05. Somewhat lower pH values were also recorded in the solutions of T_6 (5.73) followed by T_1 (5.16), T_8 (4.56), T_7 (4.11) and T_2 (4.04), respectively. The lowest pH value was found in the treatment T_4 and it was statistically similar to that of T_3 (3.78). Before dipping of cane, the temperatures of the treatment solutions were found ranged from 98.10 to 98.70 ^oC. After dipping of cane, the temperatures of the treatment solutions were found ranged from 97.83 to 98.73 ^oC. The highest surface temperature of *shitalpati* (31.43^oC) was recorded in T_3 treatment and the lowest temperature (30.13^oC) in T_7 treatment at 4:30 PM on 23 May, 2021. It is believed that human body comparatively feels cool and pleasant on *shitalpati* during hot weather condition and therefore, surface temperature of *shitalpati* was recorded for supporting the study.

In terms of surface qualitative traits (glossy, bright, smooth and comfortable) of *shitalpati*, the average lowest value (2.58) was recorded in treatment T_7 that denotes from very good to good quality of *shitalpati* which was followed by T_4 treatment (rating 2.67) and T_8 treatment (rating 3.00). The rating from good to moderate qualities of *shitalpati* were found in T_6 (3.33) followed by T_2 (3.42) and T_1 (3.42). On the other hand, treatments T_5 and T_9 produced from poor to very poor qualities of *shitalpati* (average rating 5.50 and 5.25, respectively).

The fermented rice starch and other sour materials like tamarind leaf, cowa leaf, white vinegar and fermented milk functioned as cleaning agents of the spots and dirty portion on the surface of murta cane because they are also slightly acidic in nature. Therefore, cane that treated with boiled water by incorporating these materials becomes glossy and bright. The results are in agreement with the findings of Fukushima *et al.* (2004). Palmer and Gallagher (2022) reported that lactic acid helps to remove old, dull cells on the skin's surface by dissolving the bonds that hold them together. As a result, it gives a brighter complexion, as well as smoother and softer skin. Therefore, murta cane soaked and boiled with fermented rice starch or the cane soaked and boiled with fermented milk made the *shitalpati* glossy, bright and smooth. On the other hand, cane treated with detergent powder make roughness on the cane surface. Roopa and Kasiviswanatham (2015) claimed that tamarind comprises organic acids like high content of tartaric acid 12-18%, malic acid and citric acid. So, boiling of cane with slightly acidic materials (fermented rice starch, tamarind leaf, cowa leaf, white vinegar and fermented milk) make the cane surface glossy, bright and smooth. As a results mankind feel comfort on the *shitalpati* as made from these type of murta cane.

Table 1. Effects of chemical treatment of murta cane on quantitative and qualitative traits of *shitalpati* (Pooled of 2 years)

Treatment	p^H of hot solution		Temperature (^{0}C) of hot solution		Surface temperature of *shitalpati* (^{0}C)
	Before boiling of murta cane	After boiling of murta cane	Before dipping of murta cane	After dipping of murta cane	
T_1	4.21cd	5.16c	98.43b	98.43ab	30.37b-d
T_2	3.88d	4.04de	98.20c	98.30ab	30.47bc
T_3	3.18d	3.78e	98.70a	98.60a	31.43a
T_4	3.51d	3.73e	98.53ab	98.73a	30.37b-d
T_5	5.43bc	8.73a	98.57ab	97.83b	30.53bc
T_6	5.62ab	5.73c	98.17c	98.63a	30.30cd
T_7	4.09d	4.11de	98.50ab	98.63a	30.13d
T_8	4.38cd	4.56d	98.10c	98.50a	30.40b-d
T_9	6.83a	7.03b	98.20c	98.47a	30.63b
CV (%)	15.76	6.63	0.12	0.36	0.53

Table 1. Contd.

Treatment	Qualitative rating of *shitalpati* (1-7 scale)				
	Glossy	Bright	Smooth	Comfortable	Pooled
T_1	3.67bc	3.00de	3.67bc	3.33bc	3.42c
T_2	3.33cd	3.33cd	3.33c	3.67bc	3.42c
T_3	4.33b	4.33bc	4.33b	4.33ab	4.33b
T_4	3.00cd	2.00e	3.00cd	2.67c	2.67d
T_5	5.67a	5.67a	5.67a	5.00a	5.50a
T_6	3.33cd	3.33cd	3.33c	3.33bc	3.33c
T_7	2.67d	2.67de	2.33d	2.67c	2.58d
T_8	3.33cd	2.67de	3.00cd	3.00c	3.00cd
T_9	5.33a	5.33ab	5.33a	5.00a	5.25a
CV (%)	14.13	16.94	13.48	18.18	6.72

Means followed by the same letters within each column do not differ significantly by Duncan's Multiple Range Test (DMRT).

T_1 = Boiled with tamarind leaf + Cowa leaf, T_2 = Boiled with fermented rice starch, T_3 = Boiled with white vinegar, T_4 = Boiled with cowa leaf + Vinegar, T_5 = Boiled with detergent powder, T_6 = Boiled with fermented rice starch + Arrowroot, T_7 = Boiled with Tamarind leaf + Cowa leaf + Rice starch, T_8 = Boiled with rice starch + Fermented milk, and T_9 = Control (no treatment).

Qualitative (surface glossy, bright, smooth and comfortable) rating (1-7 Scale): 1 = Excellent quality, 2 = Very good, 3 = Good, 4 = Moderate, 5 = Poor, 6 = Very poor, and 7 = Worst quality.

Conclusion

Although the traditional art of shitalpati weaving of Bangladesh has been recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as important intangible cultural heritage of the world but the quality of shitalpati should be improved for sustaining the glorious tradition of this handicraft in Bangladesh. Considering the average value of the qualitative traits (brightness, surface glossiness, surface smoothness and comfort), the treatments T_7 (Boiled with Tamarind leaf + Cowa leaf + Rice starch) followed by T_4 (Boiled with Cowa leaf + Vinegar) and T_8 (Boiled with Rice starch + Fermented milk) could be applied for the treatment of murta cane towards weaving very good to good qualities of *shitalpati*.

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EFFECT OF SOIL MOISTURE LEVEL AND NUTRIENT MANAGEMENT ON YIELD, BIO-CHEMICAL PROPERTIES AND WATER PRODUCTIVITY OF BLACK CUMIN

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Abstract

A field experiment was conducted at the Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur farm during *rabi* season of 2017-2018 to evaluate the effects of soil moisture levels and nutrient management on yield, bio-chemical properties and water productivity of black cumin (cv. BARI Kalozira-1) in the Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract). The experiment was set up in a Randomized Complete Block Design (factorial) with three replications comprising 9 treatment combinations having 3 soil moisture levels **(**Irrigation at 10%, 20% and 30% depletion of soil available water at field capacity) and 3 nutrient management packages: 100% RDF (80-45-50-20-5-2 kg ha-1 of N-P-K-S-Zn-B), 75% RDF + 25% N from cowdung and 50% RDF + 50% N from cowdung. The highest seed yield (1027 kg ha^{-1}), biomass yield (2303 kg ha^{-1}), thymoquinone (3286 mg kg^{-1} seed), thymol (149 mg kg^{-1} seed), fixed oil (28.7%), essential oil (0.85%), total consumptive use of water (112 mm) and water productivity (20.5 & 9.14 kg ha^{-1} mm^{-1}, on the basis of biomass & seed yield, respectively) were obtained from irrigation at 10% depletion of available water along with 75% RDF + 1.98 t ha^{-1} cowdung. The application of irrigation water at 10% depletion of available water (112.22 mm) with N, P, K, S, Zn and B @ 60, 45, 50, 20, 5 and 2 kg ha^{-1}, respectively + 1.98 t ha^{-1} cowdung (for supplementing 25% N requirement) appeared to be the best suited treatment package for black cumin cultivation in the study area.

Keywords: Cowdung, Seed yield, Spice crop, Black cumin, Oil content, Water productivity

Introduction

Black cumin (*Nazilla sativa* L.) of the family Ranunculaceae originated in Mediterranean region, is a short-lived annual herb, and is cultivated commercially in many Sub-tropical countries. Its seeds, whole plant and oils are used as medicine, spices, condiments and many culinary purposes since ancient times (Ali *et al*., 2015 and Herlina *et al*., 2017). In Bangladesh, it covers 1007 ha area with

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annual production of 1068 tons showing 1.06 t ha^{-1} (BBS, 2022). The utilization of black cumin is increasing with advancement of time, but the production is constrained due to lack of high yield potential varieties (only one variety BARI has so far developed *i.e.*, BARI Kalozira-1) and efficient soil and crop management (Bhutia *et al.*, 2015; Kara *et al.*, 2015). Both water and nutrient management among others are the major factors for normal growth and development of plants, economical yield and soil health. The plant can be grown under water stress condition, but higher yields are obviously associated with an appropriate irrigation frequency from growth to seed formation stage (Bhanwaria *et al.*, 2022). Soil fertility is a function of nutrient availability indices and its management should follow 4R concept (right source, right rate, right time and right method of fertilizer application).

Black cumin due to its shallow root system often responds to added fertilizers. Thus, black cumin crops when soil moisture and nutrient availability are limited, might suffer from water stress and nutrient deficiencies and consequently produce reduced yields (Ghamarnia *et al*., 2014; Ali *et al*., 2015; Kara *et al*., 2015; Bayati *et al.*, 2022). Hence, the objective of the present study was to assess yield, oil content, medicinal value and water productivity of black cumin under varying levels of soil moisture and integrated nutrient management approaches.

Materials and Methods

The field experiment was carried out at the research field of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during *rabi* season of 2017-18. The geographic coordinates of the experimental location are $24^0 09^/$ North Latitude and $90^0 26^/$ East Longitude with an elevation of 8.2 m from mean sea level. A brief description of basic soil properties and irrigation of the experimental field is presented in Table 1. The experiment was set up in a factorial randomized complete block design with three replications having Factor A: three soil moisture levels (I_1 = Irrigation at 10% depletion of available water, I_2 = Irrigation at 20% depletion of available water and I_3 = Irrigation at 30% depletion of available water) and Factor B: three nutrient management packages (T_1 = 100% Recommended dose of fertilizers (RDF), T_2 = 75% RDF + 25% N from cowdung (1.98 t ha^{-1}) and T_3 = 50% RDF + 50% N from cowdung at 3.96 t ha^{-1}). The 100% rates of N, P, K, S, Zn and B @ 80, 45, 50, 20, 5 and 2 kg ha^{-1}, respectively was selected on soil the basis. The whole amount (as per treatment) of cowdung, TSP, MoP, gypsum, zinc sulphate and boric acid was applied as basal and the urea was applied in three equal splits at 5^{th}, 9^{th} and 11^{th} week after sowing. The cowdung contained 0.99% N, 0.19% P, 0.49% K, 0.11% S, 0.39% Ca and 0.20% Mg on dry weight basis. The seeds of black cumin cv. BARI Kalozira-1 were sown on 12 November 2017 in 3.0 m x 3.0 m plot at a row-to-row distance of 15 cm. Before sowing, the seeds were soaked in water for 24 hours to facilitate germination, and then the seeds were dried under shade. Subsequently, the seeds were treated with

Autostin (carbendazim) @ 2g kg^{-1} seeds to get rid of primary seed-borne diseases. The treated seeds were mixed with some loose soil to allow uniform sowing in rows @ 10 kg ha^{-1} at a depth of about 1 cm. Seeds thus sown were covered immediately with loose soil followed by light irrigation to facilitate normal germination. Thinning was done at 25 DAS and also at 40 DAS, maintaining plant to plant distance at 10 cm. Light irrigation (6 mm) was done immediate after every thinning. Three times hand weeding were done for the control of weed infestation while Autostin @ 2 g l^{-1} of water was sprayed thrice to control damping off disease during the entire cropping period. The crops were harvested on 15 March 2018 early morning to avoid shattering of seeds, when 50 - 60% of the capsules turned into straw color from green. Ten plants were selected randomly from each plot to estimate yield and yield contributing parameters of black cumin. The seed yield per plot was recorded from $1m^2$ area and then converted to yield per hectare. The harvested plants were sun dried for four days and threshing was done by beating with a stick. The seeds were winnowed and cleaned for recording yield and yield related data.

Determination of irrigation water requirement

Field capacity

Soil moisture at field capacity (FC) was determined by selecting a representative plot of 2 m x 2 m surrounded by dikes of 15 cm height. Weeds were removed to avoid transpiration loss of water from the plot. Water was applied into the plot to keep it ponded to a height of 10-12 cm above the soil surface for more than 24 hours to ensure soil saturation up to at least 30 cm depth of the soil profile. After complete depletion of ponded water, the plot was covered by polyethylene sheet to restrict evaporation loss of water and soil samples were collected by sampling auger at different depths of 0-10, 10-20 and 20-30 cm to determine gravimetric soil moisture for a period of 3 days after depletion of ponded surface water in the macro-pores through downward movement by gravitational force, which was allowed to continue for 3 days. The soil moisture at this period decreases every day. When the gravitational water is percolate completely, the soil moisture values remained more or less constant for few days signifying the maximum moisture the soil can hold against the gravitational force which is considered as the soil moisture at FC.

Available water was determined by using the following equation:

AW = FC - WP

Where,

AW = Available soil moisture percentage (by weight basis)

FC = Soil moisture percentage at field capacity (by weight basis)

WP = Soil moisture percentage at wilting point (by weight basis)

(It is assumed that soil moisture at wilting point might be soil moisture at half of field capacity level)

Irrigation requirement was determined by using the following equation (Michael, 1978):

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

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)

Total consumptive use of water (Michael, 1978) was calculated by using the following 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 (Michael, 1978) 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 productivity (WP) was estimated by following formula:

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

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

Soil characteristics	Analytical value	Analytical method	Reference
Textual class	Silty clay loam	Hydrometer method	Bouyoucos, 1962
Bulk density	1.40 g cm^{-3}	Core sampling method	Blake, 1965a
Particle density	2.68 g cm^{-3}	Pycnometer method	Blake, 1965b
Field capacity (% by weight)	29.5	Gravimetric method	Grewal *et al*., 1990
Soil pH	5.91	Soil: water=1:2.5	Jackson, 1962
Organic C (%)	0.89	Wet oxidation method	Walkley and Black, 1934
Total N (%)	0.09	Micro Kjeldhal method	Black, 1965
Available P (ppm)	7.31	Bray and Kurtz method	Bray and Kurtz, 1945
Exchangeable K (meq $100g^{-1}$ soil)	0.08	N NH_4OAc extraction method	Jackson, 1962
Available B (ppm)	0.21	Calcium chloride extraction method	Christian and Feldman, 1970
Exchangeable Ca (meq $100g^{-1}$ soil)	2.60	N NH_4OAc extraction method	Thomas, 1982
Exchangeable Mg (meq $100g^{-1}$ soil)	2.69	N NH_4OAc extraction method	Thomas, 1982
CEC (meq $100g^{-1}$ soil)	8.44	N NH_4OAc extraction method	Schollenberger, 1980
Available Zn (ppm)	0.61	DTPA Extraction method	Christian and Feldman, 1970
Available Cu (ppm)	0.13	DTPA Extraction method	Christian and Feldman, 1970
Available Mn (ppm)	0.73	DTPA Extraction method	Christian and Feldman, 1970
Available S (ppm)	8.1	Calcium dihydrogen phosphate extraction method	Hesse, 1971

Extraction and analysis of essential & fixed oils

Essential oil

Essential oils are basically composed of C, H, O and occasionally N, S and other minerals and vitamins. In order to determine the seed essential oil content, 100 g powdered seed samples in 0.5 L water from each population were extracted by hydro-distillation for 3 hours using Clevenger apparatus following a standard procedure described in European Pharmacopoeia for determining the oil content (v/w, %) (Stainier, 1975).

Fixed oil

Fixed oil characterized by that it is not evaporated and volatile, also not distillated without its hydrolysis, not dissolved in water but dissolved in organic solvents and it does not have strong volatile odor. For determination of fixed oil content (%), about 4 g dry and powdered seed samples from each treatment were extracted with n-hexan for 6 hours by Soxhlet apparatus (Buchi Universal Extraction System B-811, Germany) (Allen *et al.*, 1974).

Measurement of thymoquinone and thymol content

Thymoquinone and thymol in black cumin fixed oil sample of black cumin was estimated following the method as outlined by Al-Saleh *et al.* (2006). An amount of 0.1g ground seed sample was extracted with 1 ml methanol, vortexed for 1 minute and sonicated for 20 minutes. After that it was left over night in constant Rota mix, vortexed for 1 minute and centrifuged for 25 minutes at 1400 rpm. The supernatant was aspirated and aliquot of 20 µL was injected into high-performance liquid chromatography (HPLC) with UV detector at a wavelength of 275 nm. The mobile phase used was methanol: water (75: 25) at 1.0 ml ml^{-1} flow rate. Calibration curves of peak area versus the concentration 20, 40, 80 and 160 µg ml^{-1} for thymoquinone and 2, 4, 8 and 16 µg ml^{-1} for thymol were constructed.

Statistical Analysis

The recorded data on different parameters were statistically analyzed by using *R* version 3.5.0 software to find out the significance of variation resulting from the experimental treatments. The difference between treatment means were judged by Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion

The combined effects of soil moisture levels and nutrient management on some selected plant parameters of black cumin were significant (Table 2) showing that treatment I_1T_2 (irrigation at 10% depletion of available water with application of 75% RDF + 25% N from cowdung) recorded the maximum plant height (63.7 cm), period of flower initiation (65.0 days), period of capsule setting (76.3 days), and number of capsules per plant (42.3) (Table 5). Such values were minimum with treatment I_3T_3 (allowing 30% depletion of available water along with 50% RDF + 50% N from cowdung). The slow decomposition of cowdung and subsequent release of nutrients during winter could be a reason for lesser effect of cowdung on the crop growth in terms of leaf primordial, plant growth and capsule formation. The results are in agreement with the results of Ali and Hasan (2014) and Karim *et al*. (2017).

Table 2. Combined effects of soil moisture levels and nutrient management on growth components of black cumin

Treatment	Plant height (cm)	Days to flower initiation	Days to capsule setting	No. of branch per plant	No. of capsules per plant
I_1T_1	60.0ab	63.7b	74.7ab	6.7b	34.3c
I_1T_2	63.7a	65.0a	76.3a	8.0a	42.3a
I_1T_3	58.0b	63.0b	71.3c	5.7c	29.7d
I_2T_1	56.7b	60.3cd	70.7c	6.7b	39.0b
I_2T_2	60.0ab	61.3c	72.3bc	7.6a	41.0ab
I_2T_3	55.0b	59.3de	71.7c	5.0cd	25.0e
I_3T_1	45.0c	59.3de	71.0c	4.3d	13.7g
I_3T_2	42.7c	59.0de	72.0c	4.3d	17.0f
I_3T_3	35.7d	57.3f	70.3c	2.7e	13.7g
CV (%)	5.68	1.12	1.93	9.30	6.62
LSD (0.05)	5.21	1.18	2.41	0.91	3.26

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

Legend:

I_1 = Irrigation at 10% depletion of available water

I_2 = Irrigation at 20% depletion of available water and

I_3 = Irrigation at 30% depletion of available water

T_1 = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha^{-1} of N-P-K-S-Zn-B)

T_2 = 75% RDF + 25% N from cowdung (1.98 t ha^{-1}) and

T_3 = 50% RDF + 50% N from cowdung at 3.96 t ha^{-1}

Nutrients used for plant growth, development and yield generally come from the internal cycling of reserve and supplied nutrient materials which require water for their solubilization and translocation. Decreasing in soil moisture availability affects the rate of diffusion of many plants nutrients and finally the composition and then total crop morphology. Capsule size (indicted by the length and diameter), number of seed per capsule, 1000-seed weight, seed yield and biomass yield of black cumin were significantly influenced due to interaction effect of soil moisture levels and nutrient management treatments (Table 3). Similar to the results of above stated parameters the maximum capsule size (length 0.88 cm and diameter 0.64 cm), number of seeds per capsule (130.7), 1000-seed weight (2.82 g), seed yield (1026.7 kg ha^{-1}) and biomass yield (2303 $kgha^{-1}$) were recorded with the same treatment I_1T_2 and the minimum capsule size (length 0.38 cm and diameter 0.21 cm), number of seeds per capsule (52.0), 1000-seed weight (1.30 g), seed yield (391.7 kg ha^{-1}) and biomass yield (1195 kg ha^{-1}) were recorded in treatment I_3T_3. In case of seed yield, no significant difference was observed with the highest soil moisture regime along with application of recommended dose fertilizers of which 25% of N being replaced by cowdung I_1T_1 (956.7 kg ha^{-1}) (Table 3). So, it may be recommended that I_1T_2 treatment for black cumin cultivation due to subsidized urea use is reduced on one hand and possible beneficial effect of cowdung on soil and future crop. Supplemental irrigation along with presence of optimum nutrients might have resulted in retention of soil moisture and availability of nutrients to a desired level which leads to higher transpiration and translocation of nutrients that ultimately favored the growth and development of the crops. The research findings of Karim *et al.* (2017), Shahattary & Mansourifar (2017) and Bayati *et al.* (2022) are in agreement with the results of present study.

Table 3. Combined effects of soil moisture levels and nutrient management on yield and yield components of black cumin

Treatment	Capsule length (cm)	Capsule diameter (cm)	No. of seeds per capsule	1000-seed weight (g)	Seed yield ($kgha^{-1}$)	Biomass yield (kg ha^{-1})
I_1T_1	0.82a	0.55ab	118.0b	2.64b	956.7a	2175b
I_1T_2	0.88a	0.64a	130.7a	2.82a	1026.7a	2303a
I_1T_3	0.66b	0.49ab	90.0c	2.10e	790.0b	2001c
I_2T_1	0.68b	0.47ab	96.7c	2.18d	603.3c	1710d
I_2T_2	0.71b	0.54ab	122.7ab	2.50c	773.3b	1993c
I_2T_3	0.59c	0.40bc	80.7d	1.84f	586.7c	1598e
I_3T_1	0.47d	0.24c	56.3f	1.36h	496.7d	1455f
I_3T_2	0.52d	0.50ab	70.0e	1.47g	443.3de	1310g
I_3T_3	0.38e	0.21c	52.0f	1.30i	391.7e	1195h
CV (%)	5.69	26.44	5.6	1.30	6.35	7.25
LSD (0.05)	0.06	0.21	8.79	0.05	74.15	0.12

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

Legend:

I_1 = Irrigation at 10% depletion of available water

I_2 = Irrigation at 20% depletion of available water and

I_3 = Irrigation at 30% depletion of available water

T_1 = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha^{-1} of N-P-K-S-Zn-B)

T_2 = 75% RDF + 25% N from cowdung (1.98 t ha^{-1}) and

T_3 = 50% RDF + 50% N from cowdung at 3.96 t ha^{-1}

Bio-chemical parameters

The combined effects of soil moisture levels and nutrient management on the thymoquinone, thymol, fixed oil and essential oil content of black cumin was significant (Table 4). Where the highest thymoquinone (3286 mg kg^{-1} seed), thymol (149 mg kg^{-1} seed), fixed oil (28.7%) and essential oil (0.85%) contents were recorded in treatment I_1T_2 (Irrigation at 10% depletion of available water and nutrients applied at 75% RDCF + 25% N from cowdung), the lowest values were being noted in treatment I_3T_3 (Table 4). Optimum soil moisture levels and nutrients availability might have influenced morpho-physiological features of plants and increased the seed yields and oil contents of black cumin. Similar results were documented by (Safaei *et al.*, 2014 and Ghamarnia *et al.*, 2014; Sen, 2016; Ariafar and Forouzadeh, 2017; Shnrwe and Ahamed, 2022).

Table 4. Combined effects of soil moisture levels and nutrient management on thymoquinone, thymol, fixed oil and essential oil of black cumin

Treatment	Thymoquinone (mg kg^{-1} seed)	Thymol (mg kg^{-1} seed)	Fixed oil (%)	Essential oil (%)
I_1T_1	3156b	134.63bc	26.7	0.81a
I_1T_2	3286a	148.87a	28.7	0.85a
I_1T_3	2840c	127.00cd	23.3	0.67cd
I_2T_1	2740c	125.47cd	22.0	0.71bc
I_2T_2	2831c	136.90b	25.0	0.75b
I_2T_3	2606d	120.43d	20.0	0.67cd
I_3T_1	2410e	78.53e	16.7	0.59e
I_3T_2	2453e	84.13e	17.7	0.65d
I_3T_3	2036f	58.67f	13.7	0.54e
CV (%)	2.54	4.77	3.16	4.66
LSD (0.05)	118.8	9.31	1.71	0.06

Treatment means followed by the same letter(s) do not differ significantly at 5% level of probability by LSD test.

Legend:

I_1 = Irrigation at 10% depletion of available water

I_2 = Irrigation at 20% depletion of available water and

I_3 = Irrigation at 30% depletion of available water

T_1 = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha^{-1} of N-P-K-S-Zn-B)

T_2 = 75% RDF + 25% N from cowdung (1.98 t ha^{-1}) and

T_3 = 50% RDF + 50% N from cowdung at 3.96 t ha^{-1}

Consumptive use of water and water productivity

Water productivity provides a quick and simple measure of how well available water can be converted into biological and economical parts and thereby is the basic indicator for measuring the effectiveness of water saving agriculture. The maximum consumptive use of water was noted in treatment I_1T_2 (112 mm) followed by I_1T_1 (109 mm), I_1T_3 (106 mm) (Table 5). Hence, water productivity was found higher and proportionately higher seed yield with the judicious management of water. The minimum value was mentioned in treatment I_3T_3 (86.02 mm). The maximum water productivity was found in treatment I_1T_2 (20.52 kg ha^{-1} mm^{-1} for biomass yield and 9.14 kg ha^{-1} mm^{-1} for seed yield) followed by I_1T_1 (19.98 kg ha^{-1} mm^{-1} and 8.79 kg ha^{-1} mm^{-1} for biomass seed yield, respectively). The minimum water productivity (13.89 kg ha^{-1} mm^{-1} for biomass and 4.55 kg ha^{-1} mm^{-1}for seed yield) was recorded in I_3T_3. As the crop was irrigated with required amount of water as per need and fertilized with integrated use of chemical fertilizers and cowdung judiciously, therefore, there was no stress, during the growing period which ultimately contributed to gaining the higher biological and economical yield of black cumin. Similar results were obtained by Ghamarnia *et al.* (2014) and Prajapat *et al.* (2020).

Table 5. Total consumptive use of irrigation water, water productivity of black cumin as influenced by soil moisture levels and nutrient management

Treatment	Total amount of irrigation (mm)	Soil moisture contribution (mm)	Effective rainfall (mm)	Total consumptive use of water (mm)	Water productivity (kg ha^{-1}mm^{-1})	
					On the basis of biomass yield	On the basis of seed yield
I_1T_1	101.3	5.7	1.82	108.82	19.98	8.79
I_1T_2	104.9	5.5	1.82	112.22	20.52	9.14
I_1T_3	98.2	6.0	1.82	106.02	18.87	7.45
I_2T_1	92.2	6.6	1.82	100.62	16.99	5.99
I_2T_2	96.7	6.2	1.82	104.72	19.33	7.38
I_2T_3	90.1	6.8	1.82	98.72	16.18	5.94
I_3T_1	78.2	7.2	1.82	87.22	16.68	5.69
I_3T_2	81.1	7.0	1.82	89.92	14.57	4.93
I_3T_3	76.7	7.5	1.82	86.02	13.89	4.55

Legend:

I_1 = Irrigation at 10% depletion of available water

I_2 = Irrigation at 20% depletion of available water and

I_3 = Irrigation at 30% depletion of available water

T_1 = 100% Recommended dose of fertilizers, RDF (80-45-50-20-5-2 kg ha^{-1} of N-P-K-S-Zn-B)

T_2 = 75% RDF + 25% N from cowdung (1.98 t ha^{-1}) and

T_3 = 50% RDF + 50% N from cowdung at 3.96 t ha^{-1}

Conclusion

It is concluded that both water deficit and nutrient deficiency reduced the seed yield, biomass yield, fixed & essential oils and medicinal properties (Thymoquinone and Thymol) of black cumin. Application of irrigation at 10% depletion of available water along with a package of N, P, K, S, Zn and B @ 60, 45, 50, 20, 5 and 2 kg ha^{-1}, respectively + 1.98 t ha^{-1} cowdung was appeared to be the best suited combination for black cumin cultivation in the Shallow Red-Brown Terrace Soil of Salna series under AEZ-28 (Madhupur Tract) for maximizing the seed yield, oil content and medicinal properties.

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IMPROVEMENT OF BRINJAL-T. AMAN -CABBAGE CROPPING PATTERN IN TANGAIL REGION

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Abstract

The experiment was conducted at the farmers' field of FSRD site Deldwar, Tangail to evaluate the agro-economic performance of Okra-T.Aman-Cabbage cropping pattern against farmers' existing pattern Brinjal-T.Aman rice-Cabbage through incorporation of high yielding varieties and improved management practices during 2018 to 2020. Two cropping pattern viz., Okra-T.Aman rice-Cabbage improved pattern and Brinjal-T.Aman rice-Cabbage farmers' existing pattern were the treatments variables. The experiment was laid out in randomized complete block design with five dispersed replications Mean data showed that the improved management practices for Okra-T.Aman rice-Cabbage cropping pattern provided higher rice equivalent yield (41.42 t ha^{-1}), production efficiency (368 kg ha^{-1} day^{-1}) and land utilization index (78 %) over farmers existing pattern Brinjal-T.Aman rice-Cabbage. Average gross return Tk. 667945 ha^{-1} and gross margin Tk. 452105 ha^{-1} of improved pattern were 24 and 33 % higher, respectively compared to that of farmers' pattern with only 8 % extra cost. The marginal benefit cost ratio, land utilization index and production efficiency indicated the superiority of the improved pattern over the farmers' practices.

Keywords: Cropping pattern, Rice equivalent yield, land utilization index, production efficiency and economic return.

Introduction

Bangladesh is almost self-sufficient in rice production but other food production such as vegetables, pulses, oil crops and other are still deficient to a large extent. Cabbage is one of the most important vegetables crop of Bangladesh grown in *rabi* season. The largest area is still under transplanted aman rice (T.Aman rice) cultivation during monsoon season where covered with long durated T. Aman rice varieties which cause a delay in cabbage transplanting, resulted reduce the yield. November 15 to 30 is the best time for cabbage transplanting. There are 15 major cropping patterns which are practiced by the farmers' of Tangail region among which Vegetable-Vegetable-T.Aman rice is one of the major cropping patterns under irrigated Medium High Land of Delduar, Tangail. This pattern covers around 7-8% of the cultivated land area (DAE, 2020). On-Farm trials with Lady's finger var. BARI Dherosh-2 performed better in Tangail region.

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After harvest of cabbage early sowing of okra instead of brinjal may be higher remunerative. Besides, production cost of brinjal is comparatively higher than okra due to disease and insect management though brings higher economic return. However, the productivity of existing farmers' pattern is low due to use of local varieties and traditional management practices. Alam *et al*., (1998) reported that more than 95% of 8.5 million hectares of net cultivable area is now under cultivation and there is no alternative to meet the ever increasing demand of food for fast growing population except increasing production from the existing available land in the country. In this context, not only the modern production technology and complementary inputs are essential but also the diversification of crops throughout the country is urgently needed. The important aspects in this regard are to explore the possibility to fit a new crop without disturbing the existing ones. Overall productivity as well as profitability of the farmers could be increased considerably by introducing modern varieties and improved management practices. A number of reports on different cropping patterns are available in Bangladesh (Khan *et al*., 2006 and Nazrul *et al*., 2013) but little efforts have been made for on-farm evaluation of the improved technologies of Okra-T.Aman rice-Cabbage cropping pattern. The experiment was therefore, initiated with a view to find out the agro-economic performance of improved package of technologies over the existing farmers' practices.

Materials and Methods

The experiment was conducted at the farmers' field of Farming System Research and Development site under On-Farm Research Division, Bangladesh Agricultural Research Institute, Tangail during 2018 to 2020. The experimental site belongs to Old Brahmaputra Floodplain Agro-ecological Zone (AEZ-9) of Tangail. The geographical position of the area is between $24^0 17'$ N latitude and $89^0 90'$ E longitude. The land type of the site was medium high and general soil type predominantly includes Dark Grey Floodplain soil. Organic matter content is low on the ridges and moderate in the basins, top soils are very strongly acidic to neutral and sub-soils are neutral in reaction. There is lowering of soil pH in high land. Status of N, P, K, S and B is low (FRG, 2018).

The meteorological data of the experimental site showed that the higher average temperature prevails in May to August and the lower in December and January. There is minimum precipitation in December and January. In July, the precipitation reaches its peak with an average of 558.3 mm. Maximum rainfall was received during the months of April to September. The meteorological data in 2018-19, monthly mean maximum 31.3^0C and minimum 20.9^0C air temperature and annual total rainfall 2439 mm and in 2019-20, monthly mean maximum 30.6^0C and minimum 20.6^0C air temperature and annual total rainfall 2240 mm were prevailing in the study area (Appendix 1.)

The experiment was laid out in a randomized complete block design with five dispersed replications. Two cropping pattern viz., improved pattern and farmers' existing pattern were the treatments variables of the experiment. The improved cropping pattern (IP) was tested and compared against the farmers' pattern (FP). Two plots of 600 m^2 were selected for each dispersed replication. Fertilizer management was followed by FRG (2018) and intercultural operations like weeding, mulching, and pest management were done according to recommended practices to support the normal growth of the crops. In the improved cropping pattern, okra (var. BARI Dherosh-2) and T.*Aman* (var. BRRI dhan72) were introduced against brinjal (var. Purple King) and T.*Aman* (var. BR11). The cabbage var. Autumn queen was used in both patterns. Okra was the first crop of the sequence. In improved pattern, BARI Dherosh-2 was seeded as broadcast at @ 5.0 kg ha^{-1} during 09-12 March, 2018 and 07-12 March, 2019 and harvested during 20 April to 25 June 2018 and 18 April to 25 June, 2019. In the farmers' pattern, brinjal var. Purple King was transplanted during 20-25 January, 2018 and 19-26 January 2019 and harvested during 10 March to 30 June, 2018 and 12 March to 29 June 2019. The second crop T.Aman rice was transplanted, 30 days old seedlings with 20 cm × 15 cm spacing during 25-31 July, 2018 and 21-25 July 2019, respectively. The crop was harvested during 25-30 October 2018 and 18-28 October 2019. In farmers' pattern, 35 days old seedlings of T.Aman rice were transplanted with a 20 cm × 15 cm spacing during 08-14 July, 2018 and 09-13 July 2019 and harvested during 24-31 October, 2018 and 22-26 October 2019, respectively. Cabbage was the third crop of the sequence both in improved and farmers, pattern which was planted in line with 60 cm × 45 cm spacing. In improved pattern cabbage was transplanted during 10-16 November 2018 and 12-16 November, 2019 and harvested during 07-17 February, 2019 and 08-17 February, 2020, respectively. In farmers' pattern, cabbage was transplanted on 15-19 November 2018 and 14-18 November on 2019 and harvested on 10-20 February 2019 and 10-19 February 2020, respectively (Table 1).

Yield data were collected from 4m × 3m area of each plot. Grains and straw were sun dried and weighed adjusting at 12 % moisture content for T.Aman rice. Agronomic performance like field duration, rice equivalent yield (REY), production efficiency and land utilization index of cropping patterns were calculated as follows.

Rice equivalent yield (REY): For comparison between crop sequences, the yields of all crops were converted into rice equivalent on the basis of prevailing market prices of individual crop (Verma and Modgal, 1983). Rice equivalent yield (REY) was computed as yield of individual crop multiplied by prevailing market price of that crop divided by market price of rice.

$$\text{Rice equivalent yield (t ha}^{-1}\text{)} = \frac{\text{Yield of individual crop} \times \text{market price of that crop}}{\text{market price of rice}}$$

Production Efficiency (PE): Production efficiency value in terms of $kgha^{-1}day^{-1}$ was calculated by total main product in a cropping pattern divided by total duration of crops in that pattern (Tomar and Tiwari, 1990).

$$\text{Production Efficiency} = \left(\frac{Y_1 + Y_2 + Y_3}{d_1 + d_2 + d_3}\right) kgha^{-1}day^{-1}$$

Where, Y_1= Yield of 1st crop and d_1= Duration of 1st crop of the pattern, Y_2= Yield of 2nd crop and d_2= Duration of 2nd crop of the pattern and Y_3= Yield of 3rd crop and d_3= Duration of 3rd crop of the pattern

Land utilization index (LUI): It was worked-out by taking total duration (days) of crops in an individual cropping pattern divided by 365 (Rahman *et al.* 1989). It was calculated by the following formula:

$$\text{Land utilization index (LUI)} = \frac{d_1 + d_2 + d_3}{365} \times 100$$

Where d_1, d_2 and d_3 the duration of 1st, 2nd and 3rd crop of the pattern

The economic analysis was done for gross return, gross margin and marginal benefit cost ratio and it was calculated on the basis of prevailing market price of the produces. Cost and return analysis involved collection of data on prices and quantities of inputs used and output produced. The inputs used included seed, fertilizer, labour and insecticides. The output and inputs were valued at market prices. The MBCR of the farmer's prevalent pattern and any replacement for it can be computed as the marginal value product ((MVP) over the marginal value cost (MVC). The Marginal of prevalent pattern (F) and any potential replacement (E) for it was computed as (CIMMYT, 1988).

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

Results and Discussion

Crop management: Crop management practices include date of sowing/transplanting, date of harvesting, seedling age, spacing, fertilizer dose used, irrigation, weeding and application of pesticides etc. of improved and existing cropping pattern are shown in Table 1. The mean crop field duration of Okra, T. *Aman* rice and Cabbage under improved cropping pattern Okra (var. BARI Dherosh-2)-T. *Aman* rice (var. BRRI dhan72)-Cabbage (var. Autumn queen) were 106-108, 85-86 and 90-92 days, respectively while, in existing cropping pattern Brinjal (var. Purple King)-T. *Aman* rice (var. BR11) - Cabbage (var. Autumn queen) were 108-110, 110-112 and 88-90 days for Brinjal, T. *Aman* and Cabbage, respectively. Total field duration of improved cropping pattern and existing cropping pattern were 283-284 and 308-310 days, respectively. The crop duration of T. *Aman* rice under existing cropping pattern was higher (110-112 days) than that of improved cropping pattern (85-86 days) due to use of long duration BR11 variety in T. *Aman* rice. But in improved cropping pattern, short duration T. *Aman* rice (var. BRRI dhan72) was cultivated and it was harvested during 18-30 October in both years. After harvesting of T. *Aman* rice, okra was easily sown in optimum period. Turnaround times for improved and existing cropping pattern were 81-82 and 55-57 days, respectively.

Yield Performance: Results of the two years experimentation of improved cropping pattern (Okra-T.Aman-Cabbage) and farmer's existing pattern (Brinjal-T.*Aman* rice-Cabbage) are presented in Table 2-4. Fruit yield of okra were 16.15 and 16.56 t ha^{-1} in two consecutive years, respectively with average fruit yield of okra was 16.36 t ha^{-1}. Grain and straw yields of T.*Aman* rice were 5.34, 5.30,5.17 and 5.11 t ha^{-1} in two successive years where mean grain and straw yield of T.Aman rice were 5.32 and 5.14 t ha^{-1}. Head yields of cabbage were 80.55 t ha^{-1} in the 1st year and 85.50 t ha^{-1} in the 2nd year. Mean head yields of cabbage were 83.03 tha^{-1}. It was found that all the component crops under improved pattern (Okra-T.Aman rice-Cabbage) gave higher yield (Table 2). Average yield of *T.Aman rice* in improved pattern increased by 21.46 % over farmers' practice (FP). The yield of improved pattern was higher presumably due to change of variety with improved production technologies and timely sowing of the component crops. Similar results were also obtained by Nazrul *et al*. (2013) and Khan *et al*. (2019). In farmers' pattern, T.*Aman* rice gave less grain yield due to use of imbalance fertilizers and poor management practices. Rice var. BRRI dhan72 in improved pattern performed better than BR11 in farmers' practices due to use of balance fertilizer and improved management practices.

Rice equivalent yield (REY):

Total productivity of improved and farmers' cropping patterns were evaluated in terms of rice equivalent yield (REY) and it was calculated from yield of component crops. Improved cropping pattern produced higher mean rice equivalent yield (41.42 tha^{-1}) over farmers' (33.50 tha^{-1}) existing pattern (Table 3). Introduction of high yielding varieties of crop and recommended management practices in the improved pattern increased rice equivalent yield of 23.64 % compared to farmers' existing pattern. Lower rice equivalent yield was obtained in the farmers' pattern due to old variety and traditional management practices. These results are in agreement with that of Khan *et al*. (2019) who reported that total productivity increased by 83.26% over farmers practice due to change of variety and use modern management practices in the pattern.

Table 1. Agronomic parameters of improved pattern and farmers' existing pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Parameters	Years	Improved Pattern (IP)			Farmers' Pattern (FP)		
Crop	2018-19	Okra	T.Aman	Cabbage	Brinjal	T.Aman	Cabbage
	2019-20	Okra	T.Aman	Cabbage	Brinjal	T.Aman	Cabbage
Variety	2018-19	BARI Dherosh-2	BRRI dhan72	Autumn queen	Purple King	BR11	Autumn queen
	2019-20	BARI Dherosh-2	BRRI dhan72	Autumn queen	Purple King	BR11	Autumn queen
Sowing/ planting time	2018-19	09-12 March	25-31 Jul.	10-16 Nov.	20-25 Jan.	08-14 Jul.	15-19 Nov.
	2019-20	07-12 March	21-25 Jul.	12-16 Nov.	19-26 Jan.	09-13 Jul	14-18 Nov.
Seedling age (days)	2018-19	-	25-30	30-35	40-45	30-35	30-35
	2019-20	-	25-30	30-33	40-45	30-35	30-33
Spacing (cm)	2018-19	45 × 30	20 × 15	60 × 45	100 × 75	20 × 15	60 × 45
	2019-20	45 × 30	20 × 15	60 × 45	100 × 75	20 × 15	60 × 45
Fert. dose (N-P-K-S-Zn-B kg ha^{-1})	2018-19	70-20-75-0-0-0	70-10-40-10-2	140-40-125-20-0-1	140-50-100-16-0-2	90-20-40-20	120-40-75-0-0-0
	2019-20	70-20-75-0-0-0	70-10-40-10-2	140-40-125-20-0-1	140-50-100-16-0-2	90-20-40-20	120-40-75-0-0-0
Harvesting time	2018-19	20 Apr. to 25 Jun.	25-30 Oct.	07-17 Feb.	10 Mar.-30 Jun.	24-31 Oct.	10-20 Feb.
	2019-20	18 Apr. to 25 Jun.	18-28 Oct.	08-17 Feb.	12 Mar.-29 Jun.	22-26 Oct.	10-19 Feb.
Field duration (days)	2018-19	108	86	90	110	112	88
	2019-20	106	85	92	108	110	90
Total field duration (days)	2018-19		284			310	
	2019-20		283			308	
TAT (days)	2018-19	25	30	26	15	24	16
	2019-20	26	28	28	17	22	18

Note: IP= Improved Pattern and FP=Farmers' Pattern.

Table 2. Fruit/Grain/Head yield and By-product of improved cropping patterns and farmer's existing pattern at the FSRD site Atia, Tangail during 2018-19 and 2019-20.

Year	Fruit/Grain/Head yield (t ha^{-1})							
	Improved Pattern				Farmers Pattern			
	Fruit yield	T. Aman		Head yield	Fruit yield	T. Aman		Head yield
	Okra	Grain	Straw	Cabbage	Brinjal	Grain	Straw	Cabbage
2018-19	16.15	5.34	5.17	80.55	12.90	4.23	4.18	78.40
2019-20	16.56	5.30	5.11	85.50	13.30	4.53	4.31	82.40
Mean	16.36	5.32	5.14	83.03	13.10	4.38	4.25	80.40

Production efficiency (PE):

Average maximum production efficiency (368) in terms of kg $ha^{-1}day^{-1}$ was obtained from improved cropping pattern and 317 in the farmers' existing pattern (Table 3). The higher production efficiency of improved cropping pattern might be due to the new crop varieties and recommended management practices. Production efficiency in improved cropping pattern increased by 16 kg $ha^{-1}day^{-1}$ over farmers' practice. Similar trend were reported by Nazrul *et al*. (2013) and Khan *et al*. (2019).

Land utilization index (LUI):

Land utilization index (LUI) is the effective use of land in a cropping year, which depends on individual crop duration. Mean land utilization index indicated that improved pattern used the land for 78 % period of the year, whereas farmers' pattern used the land for 84 % period of the year (Table 3). Land use efficiency was 8 % higher in farmers' practice than improved pattern because this pattern occupied the field for longer duration (309 days), whereas improved pattern occupied the field for 284 days of the year. As a result labour utilization could be more in the farmers' pattern than improved cropping pattern.

Harvest Index

Improved cropping pattern Okra (Var. BARI Dherosh-2)- T. *Aman* rice (Var. BRRI dhan72)- Cabbage (var. Autumn queen) recorded the higher harvest index (48%) over existing cropping pattern Brinjal (Var. Purple King) - T. *Aman* rice (Var. BR 11) - Cabbage (var. Autumn queen). The harvest index of improved cropping pattern had higher value due to replacing crop and varieties which contributed the higher economic and biological yield (Table 3).

Table 3. Rice equivalent yield, production efficiency, land utilization index and harvest index of improved pattern and farmers' practices at the FSRD site Atia, Tangail during 2018-19 and 2019-20.

Year	Cropping Pattern	Rice equivalent yield (t ha^{-1})	Production efficiency (kg$ha^{-1}day^{-1}$)	Land utilization index (%)	Harvest Index (%)
2018-19	IP	40.62	357	78	48
	FP	31.89	308	84	46
2019-20	IP	42.21	379	78	48
	FP	35.11	325	84	46
Mean	IP	41.42	368	78	48
	FP	33.50	317	84	46

REY = Rice equivalent yield, PE = production efficiency and LUI = land utilization index

Cost benefit analysis

The cost and return analysis indicated the higher return of the improved cropping pattern (Okra-T. Aman rice-Cabbage) over the farmers' pattern (Brinjal-T.Aman rice-Cabbage). Average gross return of the improved cropping pattern was Tk. 667945 ha^{-1} which was 24 % higher than farmers' pattern (Table 4). Average gross margin was substantially higher in the improved pattern (Tk. 452105 ha^{-1}) than farmers' pattern (Tk. 340165 ha^{-1}). The higher gross margin of the improved pattern was achieved mainly due to higher yield advantages of the component crops. Additional gross margin (33%) was achieved by adding 8 % extra cost in the improved pattern through slightly higher cost was involved in this pattern. Mean marginal benefit cost ratio (MBCR) was found 6.66 which further indicated the profitability of the improved pattern over the farmers' one. Thus, changing variety, crops and use modern technology in the existing pattern might be agronomically suitable and economically profitable for the farmers' in the study area.

Table 4. Cost and return analysis of improved cropping pattern and farmers' cropping pattern at FSRD site Atia, Tangail during 2018-19 and 2019-20

Year	Pattern	Gross return (Tk. ha^{-1})	Total variable cost (Tk.ha^{-1})	Gross margin (Tk. ha^{-1})	MBCR
2018-19	IP	649890	210730	439160	6.34
	FP	510280	196710	313570	
2019-20	IP	686000	220950	465050	6.98
	FP	571280	204520	366760	
Mean	IP	667945	215840	452105	6.66
	FP	540780	200615	340165	

Price (Tk. kg^{-1}): Okra-15.0, T.aman-16.0, Cabbage: 4.00, Brinjal-10.0, Stover-1.0 and Straw-2.0

Conclusion

The total crop productivity (in terms of REY), production efficiency and profitability of improved cropping pattern okra (var. BARI Dherosh-2) -T. *Aman* (var. BRRI dhan72)- Cabbage (var. Autumn queen) were higher than existing cropping pattern Brinjal (var. Purple King)-T. *Aman* rice (var. BR 11)-Cabbage (var. Autumn queen) due to replacing variety, crops and use modern technology. The improved cropping pattern okra (var. BARI Dherosh-2) - T. *Aman* (var. BRRI dhan72) - Cabbage (var. Autumn queen) was found agronomically and economically suitable. So, the farmers' could be suggested to practice this pattern for higher profit.

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Appendix 1. Monthly air temperature, relative humidity and total rainfall in the experimental area of Tangail, during 2018 to 2020

Month	Temperature (ºC)				Average RH (%)		Total rainfall (mm)	
	Avr. Max		Avr. Min					
	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20	2018-19	2019-20
July	33.99	33.38	27.36	25.74	80.61	82.74	540.50	576.10
August	33.44	34.13	26.85	26.68	82.68	79.00	356.50	200.10
September	33.54	33.07	25.99	25.71	81.69	82.90	270.50	254.30
October	31.45	31.99	22.80	23.10	80.68	82.00	75.80	163.60
November	29.84	29.92	17.89	19.22	76.83	82.00	46.00	19.50
December	25.63	24.31	13.29	13.51	78.35	85.30	22.80	10.00
January	26.31	23.15	11.57	11.87	74.71	83.58	00.00	44.30
February	28.09	26.26	14.73	13.29	71.71	74.25	73.60	01.00
March	31.26	31.51	19.10	18.47	67.52	66.80	99.70	44.60
April	33.18	33.13	22.37	21.48	74.70	74.77	281.20	273.30
May	34.79	32.93	24.36	23.09	77.13	79.00	360.30	350.40
June	34.13	33.57	25.32	25.45	80.8 0	82.73	312.40	303.40
Yearly average	31.30	30.61	20.97	20.63	77.28	79.59	2439.30	2240.60

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PREPARATION AND PRESERVATION OF MAIZE STALK FODDER

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Abstract

Shortage of feed supply of the cattle during the dry season or flood period is an important issue which could be partially met by maize stalk. An experiment was conducted to prepare maize stalk fodder for cattle. The BARI chopper was improved for chopping maize stalk (MS) in smaller size (7-8mm) by adding blades and make the chopper safe by adding casing. The capacity of the BARI chopper was 745 and 425 kg/h with fresh and dried maize stalk, respectively. Total chopping cost per hour was Taka 0.23 per kg. The chopped maize stalk in both fresh and dried conditions with different combinations were served to the cattle and found that smaller sized chopped piece of both dried and fresh maize stalk could be feed in both raw and mixing with salt, wheat bran and water with little molasses. Maize stalk block also prepared with different combinations and found that block made by liquid *Gur* was better in both physically and cattle likeness. Total cost of block per kg was Tk. 13.85, 31.35, 28.85 and 36.35 for MS block 1, MS block 2, MS block 3 and MS block 4, respectively. Chopped and dried maize stalk were preserved in polybag, open drum and store room were liked by the cattle up to three months of the storage. Flatten and dried maize stalk were not liked by the cattle due to their long size and hardness.

Keywords: Maize stalk, Fodder, BARI Chopper, Capacity, Storage

Introduction

Fodder refers particularly to food given to the animals (including plants cut and carried to them), rather than that which they forage for themselves (called forage). Fodder includes hay, straw, silage, compressed and pelleted feeds, oils and mixed rations, and sprouted grains and legumes (such as bean sprouts, fresh malt, or spent malt). Most animal feed is from plants, but some manufacturers add ingredients to processed feeds that are of animal origin. The traditional feeding system for dairy cattle is based on the use of rice straw, natural grasses supplemented with a little or no concentrates. Rice straw is the main roughage for dairy cows, which is low in nutritive value and palatability but it contributes 90% of the roughage feed to animals (Khan *et al.*, 2009). The quantity and quality of fodder available from natural pasture shows seasonal fluctuation. There is an acute shortage of feed supply during the dry season and the available feed during this period is of very poor quality (Khan *et al.*, 2009). The various types of fodder available in

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Bangladesh a forage grass, green grass, dry corn straw, wheat stalk etc. All of these fodders are chopped into small pieces to mix it together as it prevents animals from rejecting any part of their food. Cereal milling by-products, grains and oilcakes are the three major types of ingredients constitute concentrate feed in the country. Methane, a major component of greenhouse gas, produced in the rumen at the expense of up to 15% of the dietary digestible energy when it lacks supplementation of protein and soluble carbohydrate. It may be reduced up to 30%when rice straw diet is supplemented with urea and molasses (Huque and Chowdhury1997). Introduction of densified complete feed block can improve nutritive value instead of poor quality and bulky roughages (Salem and Nefzaoui, 2003). The densified complete feed block technology offers a variety of benefits to the farmers and the feed manufacturers (Walli, 2011; FAO, 2012). Thus, molasses in addition to its contribution to farm animal production also can help mitigation of environment pollution. Promma *et al.* (1985) demonstrated that dairy cows fed with urea-treated rice straw has similar milk yield that of cows feed with fresh grass, and intake of the cows fed urea treated rice had a higher milk fat content and net income as compared with the milk produced by cows fed untreated straw. Now a days, maize of different varieties is widely cultivated in different areas of the country, after harvesting grain the remaining stalks can fed after processing (Jamee *et al.,* 2019). Nutrient composition of corn stover on dried and fresh condition are dry matter 92.9 and 28.9%, Crude protein 3.7 and 6.9%, crude fibre 42.4 and 30.1%, lignin 8.4 and 4.8%, ether extract 0.6 and 1.2%, ash 6.6 and 6.7%, total sugars 17.9 and 18.1%, gross energy 92.9 and 28.9 MJ/kg, calcium 2.9 and 3.7 g/kg, phosphorus 0.7 and 2.0 g/kg, potassium 13.6 and 18.7 g/kg, respectively (Bhandari and Bahadur, 2019).

The main component of the operating cost of dairy farming is the feed cost. Diversification and production of quality feeds and fodders are important for achieving economically sustainable animal production systems. Dual purpose crop introduction in the existing cultivation system potential of plantation crops, in a tropical country like Bangladesh, as animal feeds may be explored (Huque and Sarker, 2014). The primary concern with feeding corn stalks to dairy cattle is the physical nature of the stalks. Dairy cattle fodder (especially maize stalk) needs to be chopped prior to feeding. Therefore, this research was undertaken to improve the BARI chopper for effective size of maize stalk, to determine suitable mixture of molasses and stalk pieces and to find out the storability of maize stalk feed.

Materials and Methods

A straw chopper was available at Farm Machinery and Postharvest Process Engineering Division, Bangladesh Agricultural Research Institute, Gazipur. This chopper was suitable for chopping rice straw. The chopper was modified for chopping maize stalk in small pieces (Figure 1). The number of blades, feeding tray and power transmission systems were modified during 2017–18. The description of different parts of the chopper are described below:

1) Feeding tray: A tray was made of sheet metal. The length of the tray was revised to feed the maize stalk and store. The tray dimension was 500x180x 16mm.
2) Feeding sprocket: There were two oppositely rotating feeding sprockets with 75 mm diameter and 180 mm length.
3) Cutting blade: Cutting blades were attached in 710 mm diameter wheel made of MS rod. There were two blades (300mm X 100 mm) which was made of high carbon steel settled on blade base (340 mm x 120 x 20 mm). Additional two blades with same dimension were added with it.
4) Blade casing: The blades were covered with a casing made of sheet metal. It was a round box having 900 mm diameter and 160 mm width. It increases safety of users. The casing was not available in previous models.
5) Delivery chute: The chopped maize stalk was delivered with a chute. The dimension of the chute was 360 x 280 x 120 mm where top side was open.
6) Frame: The main frame was carrying all load of the machine. The hopper, blades with casing and delivery chute was attached with it. Dimension was 1550 x 570 x 640 mm. But, the overall dimension was 1550 x 1380 x 1270 mm.

The chopper was tested with fresh and dried maize stalks. Two different sizes of stalks were feed the cows to evaluate their interest in eating. The chopped stalks were also served to the cow with different recipe.

Fig. 1. Operation of BARI chopper for chopping maize stalk

To prepare alternative animal feed the maize stalks were formulated to cubic silage like cake. Different silage blocks were prepared with various ratio of maize stalk and binding materials during 2017-18. The maize variety was BARI Hybrid

Maize-9. The maize stalk was dried at 7.5% MC. The binding materials were molasses, sugar, liquid and solid Gur. For all combinations, the binding material were heated for 15-20 minute up to the sticky phase come. About 250ml water was added with 1 kg liquid or solid Gur before heating. Then chopped maize stalks were mixed with binding materials with 1:1 by weight ratio. Then keep them to be cool for 5 minutes and after then the mixture was inserted and pressed to a 200 mm X 100 mm cubic frame to give a shape. The following combinations were tried: i) Block 1= Molasses+ maize stalk, ii) Block 2= Sugar + maize stalk, iii) Block 3= Liquid Gur + maize stalk and iv) Block 4= Solid Gur + maize stalk. Physical appearance of the blocks was evaluated. The developed blocks were feed to the cattle and their liking behavior were observed.

Dried and chopped maize stalk were preserved with four different forms. Those forms were: i) Form 1= Chopped (7-8mm) and dried maize stalk preserved in polybag, ii) Form 2= Chopped (7-8mm) and dried maize stalk preserved in open floor , iii) Form 3= Chopped (7-8mm) and iv) dried maize stalk preserved in store room and iv) Form 4= Flatten (0.75-1.25mm) and dried maize stalk preserved in store room. The liking behavior of cattle to eat dried maize stalk in different forms were studied with randomly selected 15 cattle having 130-145kg body weight. Storability of those forms were evaluated in terms of weight loss, physical appearance and fungus attack.Weight loss was calculated periodically. Physical appearance and fungus attack were observed periodically by investigators..

Results and Discussion

Performance of chopper for different types of maize stalk (MS) is shown in Table 1. Average of 20 chopped piece of maize stalk was 18.45 mm and 7.10 mm for fresh stalk with 2 and 4 blades respectively. Again, chopped piece of dried maize stalk was 18.85 mm and 7.12 mm for fresh stalk with 2 and 4 blades, respectively. Fresh copped size was little small as they were shrunk by losing moisture before taking measurement. Capacity of the chopper was more for chopping fresh stalk than the dried stalk. Similarly, Capacity of bigger size chopping was little more than smaller size though the blade shaft rpm was similar. It was happened due to operator's scope to push more length before coming the next blade to cut the stalk. Average capacity of the chopper was 744 kg/h and 700 kg/h for chopping fresh maize stalk with bigger and smaller size respectively. On the other hand, for dried stalk chopping with 2 and 4 blades the capacity of the chopper was 425 and 372 kg/h, respectively.

Table 1. Performance of chopper for different types of maize stalk (MS)

State of MS	Average Size, mm	Rep.	No of Blade	RPM of Engine	RPM of Blade shaft	Feeding amount (kg)	Time (min)	Capacity (kg/h)	Average capacity (kg/h)
Fresh	18.45	1	02	2000	212	50	4.00	750	
		2	02	2017	214	48	4.10	702	744
		3	02	2011	213	52	4.00	780	
	7.10	1	04	2000	212	48	4.00	720	
		2	04	2015	214	45	4.00	675	700
		3	04	2010	213	47	4.00	705	
Dried	18.85	1	02	2000	211	27	4.05	405	
		2	02	2011	212	28	4.00	420	425
		3	02	2010	213	30	4.00	450	
	7.12	1	04	2000	212	25	4.00	375	
		2	04	2015	214	24	4.00	360	372
		3	04	2010	213	26	4.10	380	

Chopped maize stalks were feed to cattle to check the likeness. Feeding likeness of different combinations of maize stalk (MS) is shown in Table 2. Small pieces (both fresh and dried) were liked much by the cattle than the bigger chopped maize stalk. The dried maize stalk with bigger size was disliked by the cattle. The likeness increased when the chopped maize stalks were served with salt and water. However, the cattle finished quickly showing their more demand when chopped maize stalks were served with salt, wheat bran and water mixing with some molasses.

The chopped dried maize stalks were made block with different combination of binding materials (combination in methodology). Physical appearance of different maize stalk (MS) blocks is shown in Table 3. Maize stalk block 3 was physically better in terms of appearance, smell, oil stickiness and compactness than others. . Maize stalk block 1 was physically worst. Santhiralingam and Sinniah (2018) were also prepared block with different agricultural waste.

Prepared all blocks were served to cattle with different combinations. Feeding likeness of different combinations of maize stalk (MS) blocks were shown in Table 4. Maize stalk block 1 was disliked by the cattle due to bad smell. Other blocks were liked. But when blocks were feed mixing with salt, and water, the cattle liked much. Use of chopped maize stocks as fodder also suggested by Surla and Krishna (2021).

Table 2. Feeding likeness of different combinations of maize stalk (MS)

Treatment	Feeding Rank			
	Like much	Like	Moderate	Dislike
Fresh MS size 15-20 mm			√	
Fresh MS size 7-8mm	√			
Dried MS size 15-20 mm				√
Dried MS size 7-8 mm		√		
Fresh MS size 15-20 mm + Salt+ Water			√	
Fresh MS size 7-8 mm + Salt+ Water	√			
Dried MS size 15-20 mm + Salt + Water		√		
Dried MS size 7-8 mm + Salt + Water	√			
Fresh MS size 15-20 mm + Salt+ Wheat Bran + Water + Molasses		√		
Fresh MS size 7-8 mm + Salt+ Wheat Bran + Water + Molasses	√			
Dried MS size 15-20 mm + Salt + Wheat Brun + Water + Molasses		√		
Dried MS size 7-8 mm + Salt+ Wheat Bran + Water + Molasses	√			

Table 3. Physical appearance of different maize stalk (MS) blocks

	MS Block 1	MS Block 2	MS Block 3	MS Block 4
Appearance	Not block	Partial block	Good block	Moderate block
Smell	Bad	Acceptable	Good	Good
Oil stickiness	Oily	Oily	Non-sticky	Non-sticky
Compactness	Bad	Partial	Very Good	Good

Table 4. Feeding likeness of different combinations of maize stalk (MS) blocks

Treatment	Feeding Rank			
	Like much	Like	Moderate	Dislike
MS Block 1				√
MS Block 2		√		
MS Block 3		√		
MS Block 4		√		

Cost analysis of BARI Chopper is shown in Table 5. Price of the BARI chopper was Tk. 50000. All fixed cost (Tk. 7.75 /h) and variable costs (Tk. 120 /h) were considered for this analysis with average capacity of both dried and fresh stalk chopping. Total chopping cost per hour was Tk. 0.23 . Preparation cost of different blocks were also calculated (Table 6). Total cost of block per kg was Tk. 13.85, 31.35, 28.85 and 36.35 for MS block 1, MS block 2, MS block 3 and MS block 4, respectively. Considering feeding likeness, Physical appearance and cost, MS block 3 (As shown in Fig 3) is an advisable option as alternate dry feed for cattle.

Table 5. Cost analysis of BARI Chopper

Sl. No.	Items		Fixed cost(Tk.)
1	Price (P), Tk.		50000
2	Salvage value (S), Tk. (10% of P)		5000
3	Working life (L), yr		10
4	Average annual use (Au), h/ yr		1200
5	*Fixed Cost*		
	i)	Annual depreciation, D=(P-S)/L	4500
	ii)	Interest on investment, I=(P+S)/2*I, where rate of interest is 12%	3300
	iii)	Tax and insurance, T=3% of P	1500
	iv)	Total fixed cost (D+I+T), Tk./ yr	9300
	v)	*Total fixed cost, Tk./h*	7.75
6	*Variable cost*		
	a) No. of labour , *Tk./h (1day-hour=400 taka)*		50
	b) Fuel for chopping (*Tk./)h*		70
	c) Repair and maintenance cost (Tk./h)		1.46
	Total operating cost (*Tk./h)*		121.46
7	*Total cost (4+5)(Tk./h)*		*129.21*
8	*Total chopping cost, Tk./kg (Average Capacity 560 kg/h)*		*0.23*

Table 6. Preparation cost of different blocks

	MS Block 1	MS Block 2	MS Block 3	MS Block 4
Price of MS (Tk./kg)	0.50	0.50	0.50	0.50
Cost for MS chopping(Tk./kg)	0.21	0.21	0.21	0.21
Price of binding material (Tk./kg)	25	60	55	70
Labour (Tk./kg)	2	2	2	2
Total cost of block (Tk./kg)	13.85	31.35	28.85	36.35
Total cost of block (Tk./ton)	13850	31350	28850	36350

a) Block

b) Feeding blocks

c) Maize stack fodder

d) Flatten stock

e) Dried maize stock

Fig. 3. Pictorial views of different forms of maize stalk fodder

Storability of dried maize stalk (MS) and Block is shown in Table 7. All forms of dried maize stalk and selected block were good in all storage systems up to three months except some colour change in the samples those were stored in open floor and store room. Feeding likeness of different forms of dried maize stalk (MS) are shown in Table 8. Chopped (7-8mm) and dried maize stalk were preserved in polybag, open drum and store room were liked by the cattle up to three months of the storage. Flatten and dried maize stalk were not liked by the cattle due to their long size. It may again feed after chopping but chopping in this stage was hard. Flatten sample took more space to store than the chopped sample.

Table 7. Storability of dried maize stalk (MS) and Block

Treatment	Initial			After 1 month			After 2 months			After 3 months		
	W (Kg)	A.	SP	W (Kg)	A.	SP	W (kg)	A.	SP	W (kg)	A.	SP
Form 1	2.25	B	Nil	2.25	B	Nil	2.25	B	Nil	2.25	B	Nil
Form 2	5.00	B	Nil	5.00	B	Nil	5.15	FB	Nil	5.20	FB	Nil
Form 3	5.00	B	Nil	5.00	B	Nil	5.05	B	Nil	5.10	FB	Nil
Form 4	5.00	B	Nil	5.00	B	Nil	5.10	FB	Nil	5.15	FB	Nil

W=Weight, A. =Appearance and SP= Spoilage, B=Brown, FB=Fate Brown,

Table 8. Feeding likeness of different forms of dried maize stalk (MS)

Treatment	Feeding Rank		
	Like	Moderate	Dislike
Form 1= Chopped (7-8mm) and dried maize stalk preserved in polybag	√		
Form 2= Chopped (7-8mm) and dried maize stalk preserved in open floor	√		
Form 3= Chopped (7-8mm) and dried maize stalk preserved in store room	√		
Form 4= Flatten (0.75-1.25mm) and dried maize stalk preserved in store room			√

Conclusion

Increasing maize production can open a new era of using maize stock as fodder for cattle Maize stalk could be served by chopping in 7-8 mm size with BARI chopper and stored after dry in air tied bags. The chopped maize stalk could be feed either in fresh or dried conditions. The maize stalk block made with liquid gur (molasses) also could be prepared and feed to the cattle as an alternative fodder. Thus, the maize stalk could be stored in different form for cattle which can be feed the cattle to meet the demand during disasters. However, a detail feeding trial is required to evaluate the cattle growth rate and feed conversion efficiency of maize stack and to select the best feed block.

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EFFECT OF PLANTING TIME AND FERTILIZER LEVELS ON GROWTH, YIELD AND ECONOMICS OF BETA-CAROTENE RICH BARI SWEET POTATO

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Abstract

The experiment was conducted at the Tuber Crops Research Sub-Centre, Bangladesh Agricultural Research Institute (BARI), Bogura, Bangladesh during rabi 2020-2021 to investigate growth, yield and profitability of the beta-carotene rich of sweet potato var. BARI Mistialu-12 as influenced by the date of plantings and fertilizer doses. The experiment consisted four levels of planting dates viz. D_1 = 30 October, D_2 = 10 November, D_3 = 20 November and D_4 = 30 November along with four levels of fertilizers viz. F_0 = control, F_1= 60-55-80 kg of NPK, F_2 = 80-75-100 kg of NPK and F_3= 100-95-20 kg of NPK fertilizer per hectare. The experiment was laid out in a spilt plot design with three replications assigning planting dates in the main plots and fertilizer doses in the sub-plots. The results indicated that among all treatment combinations planting on 20 November with 100-95-120 kg of NPK fertilizer per hectare performed better in considering length of tubers (13.57 cm), breadth of tubers (41.95 cm), number of tubers per plant (9.93), yield (46.99 t ha^{-1}), gross margin (Tk. 795,131/ha) and BCR (4.62). Marketable yield increased with the increasing of fertilizer doses.

Keywords: Sweet potato, planting time, fertilizer, growth and yield.

Introduction

Sweet potato is one of the important tuber crops in Bangladesh. It varies in flesh and skin colour, texture, leaf shape and vine length. It plays an important role in compensating the demand for cereals among the indigent people of Bangladesh. Tuber is the main usable part of the sweet potato, although leaves can also be used. It is consumed in several forms, with the tuber being consumed raw, boiled, as porridge or pounded into flour. The main nutritional material in sweet potato tubers are carbohydrates (starch 15-28% and sugars 3-6 %), protein, dietary fibre, fat and fat-soluble vitamins (Harvat *et al.,* 1991). Moreover, cultivars with a yellow and purple flesh also contain significant amounts of carotenes and anthocyanin (Maloney *et al.*, 2012 and Allen *et al.,* 2012). The area, total production and yield of sweet potato in Bangladesh have not changed much during the last decade. Factors that affect the quality of sweet potato are planting time, rate of fertilizer application, variety selection, mineral nutrients, plant population, water, soil moisture and rainfall, pest management, harvesting time, harvesting method,

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spacing and storing (Amajor *et al*., 2011). Sweet potato production in Bangladesh is very low due to lack of high yielding modern varieties, lack of efficient cultivation technique and knowledge, lack of proper agronomic management practices as well as nutrient. Tropical soils are inherently low in nutrients particularly nitrogen and phosphorus (Haruna *et al*., 2013). So, the study aimed at identifying the most appropriate planting dates and fertilizer doses for optimum yield of beta-carotene rich sweet potato variety in Bogura condition.

Materials and Methods

The experiment was carried out at the Tuber Crops Research Sub-Center, Bangladesh Agricultural Research Institute (BARI), Bogura, Bangladesh during October 2020 to March 2021 to investigate growth and yield of the BARI Mistialu-12 as influenced by the date of plantings and fertilizer doses. The experimental site was located at 24.51^0 N latitude and 89.18^0 E longitudes which is 17 m above sea level. The experiment consisted four levels of planting dates viz. D_1 = 30 October, D_2 = 10 November, D_3 = 20 November and D_4 = 30 November along with four levels of fertilizers viz. F_0 =control, F_1=60-55-80 kg of NPK, F_2=80-75-100 kg of NPK and F_3= 100-95-20 kg of NPK per hectare. The experiment was laid out in a spilt -plot design with three replications assigning planting dates in the main plots and fertilizer doses in the sub-plots. Size of each unit plot was 3.0 m x 3.0 m. Beta-carotene rich sweet potato variety BARI Mistialu-12 was used as a test crop . The site is under the sub-tropical climatic zone characterized by relatively scanty rainfall, low humidity and low temperature, short day and long clear sunshine period during October to March. The meteorological data of the experimental site during crop period (October/ 2020-March/ 2021) are presented in Table 1

Table 1. The meteorological data of the experimental site during crop period (October-March).

Months	Mean temperature (^{0}C)	Relative Humidity (%)	Rainfall (mm)
	2020-2021	2020-2021	2020-2021
October	28.89	94.00	105
November	25.33	89.67	-
December	16.18	88.12	-
January	20.11	86.55	-
February	21.88	91.01	23
March	25.50	92.22	-

Source: Meteorological Department, Khander, Bogura.

The land type and soil of experimental area were medium high with sandy loam in texture, poorly drained, and developed on shallowly weathered soil having a pH in the ranges of 6.0 to 6.5 and belonging to the Barind Level Tract "AEZ 25" (UNDP and FAO, 1988). The land was prepared with a power tiller by ploughing and cross ploughing followed by leveling with a ladder to obtain the desirable tilth. All the weeds, stubble and crop residues were removed from the experimental plot. The experimental plots were fertilized with blanket doses of cow dung = 10-ton, gypsum =80 kg, boric acid = 6 kg, zinc sulphate =10 kg per hectare. Half of urea and full dose of all fertilizers were applied immediately before final land preparation and mixed properly with the soil. The remaining amount of urea was applied as a side dressing at 30 days after planting. Irrigation, weeding, earthing up and other intercultural operations were done as and where necessary for raising a good crop. The crop was not sprayed through any pesticides to protect diseases and insects. The crop was harvested sequentially on 30 February, 10 March, 20 March and 30 March 2021. Data were recorded on different parameters as percent of ground coverage by vines, length of vines (cm), number of branch per plant, length of tubers (cm), breadth of tubers (cm), number of tubers per plant, marketable tuber yield (t ha^{-1}).

Statistical analysis

The recorded data were analyzed statistically following the computer package MSTAT-C and mean differences were evaluated by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

Results and Discussion

Effect of planting time and fertilizers on growth parameters, yield contributing characters and yield of sweet potato

Percent of ground coverage of vines

The percent ground coverage of vines was significantly influenced by the date of planting (Table 2). The maximum percent of ground coverage (84.11%) was recorded from 30 October planting, while the lowest in 30 November planting (71.25%). It might be due to sweet potato plants planted on 30 October (D_1) received more rainfall than other three dates which promotes more vegetative growth of the crop. These results agree with the findings of Amajor *et al.* (2011) and Martin (1987). Ground coverage of vines was significantly influenced by fertilizers (Table 3). The maximum percent of ground coverage (90.41%) was recorded from 100-95-120 kg of NPK fertilizer per hectare, while the lowest in control plot (51.25%). Here, it is observed that vine ground coverage is increasing with increasing fertilizer doses. It might be due to effect of nitrogen, phosphorus and potassium which are essential for the growth of all the plants and needed to restore soil fertility. Ground coverage of vines showed significant variation in combined effect (Table 4).The highest percentage of ground coverage (95.00%) was obtained from 20 November planting and 100-95-120 kg of NPK fertilizer per hectare, while the lowest (51.45%) was obtained from 30 October with the control plot.

Length of vines

The date of planting had a significant influence on vine length (Table 2). The maximum length of vines (66.32 cm) was recorded from 30 October planting, while the lowest in 30 November planting (57.05 cm). The result revealed that the vine length decreased gradually with the delay in planting dates. It might be due to congenial weather conditions, a favorable soil temperature and moisture. The result is supported by Alloli *et al.* (2011). Length of vines was significantly influenced by fertilizers (Table 3). The maximum length of vines (64.99 cm) was recorded for 100-95-120 kg of NPK fertilizer per hectare which was similar to 80-75-100 kg of NPK fertilizer per hectare (63.10 cm), while the lowest in control plot (54.81cm). The differences in length of vine could be attributed to fertilizer rate on the plants. This result is in total agreement with the findings reported by Satapathy *et al.* (2005) and Mitra (2012) who noted that a high rate of fertilizer application encourages vine growth rather than storage root development. The length of vines showed significant variation in combined effect (Table 4).The longest vines (75.10 cm) were found on 30 October planting and 100-95-120 kg of NPK fertilizer per hectare, while the shortest (47.07 cm) on 30 November and the control plot.

Length of tubers

The length of tubers was significantly influenced by date of planting (Table 2).The maximum length of tubers (13.04 cm) was recorded from 20 November planting, while the lowest in 30 October planting (10.10 cm). It might be due to favourable climatic condition, soil and atmospheric temperature during 20 November planting. On the other hand, in October the soil and atmospheric temperatures were higher, and this affected the growth and development of sweet potato. This finding was supported by Alloli *et al.* (2011) and Yenagi *et al.* (2004). The length of tubers was significantly influenced by fertilizers (Table 3). The maximum length of tubers (13.45 cm) was recorded from 100-95-120 kg of NPK fertilizer per ha, while the lowest in control plot (11.38 cm). Here, observed that length of tuber increases with the increases apply of fertilizers. . It could be because of the increased nutrient use efficiency from chemical fertilizers. These results agree with the findings of Asghar *et al.* (2006) and O' Sullivan (1997). The length of tubers showed significant variation in combined effect (Table 4). The maximum length of tubers (13.57 cm) was recorded from 20 November planting and 100-95-120 kg of NPK fertilizer per hectare which was statistically identical to 20 November

planting and 80-75-100 kg of NPK fertilizer per hectare (13.07 cm), 20 November planting and 60-55-80 kg of NPK fertilizer per hectare(12.84 cm), 10 November planting and 100-95-120 kg of NPK fertilizer per hectare(13.07 cm) and 30 October planting and 100-95-120 kg of NPK fertilizer per hectare(13.00 cm), while the lowest in 30 October planting and control plot (9.73 cm).

Breadth of tubers

The breadth of tubers was significantly influenced by date of planting (Table 2).The maximum breadth of tubers (37.02 cm) was recorded from 20 November planting, while the lowest in 30 October planting (25.90 cm). The breadth of tubers differed with the planting dates due to the variation of temperature, rainfall, sunlight etc. during the growth period. It might be due to the variation of weather condition and other environmental effects. These results agree with the findings of Ghosh *et al.* (2008). Breadth of tubers was significantly influenced by fertilizers (Table 3).The maximum breadth of tubers (35.49 cm) was recorded from 100-95-120 kg of NPK fertilizer per hectare, while the lowest in control plot (33.81 cm). It might be due to good root extension, bulking capacity of soil and increased fertilizer doses. These results agree with the findings of (Adhikari, 2009). Breadth of tubers showed significant variation in combined effect (Table 4).The maximum tuber breadth (41.95 cm) was obtained from the 20 November planting and 100-95-120 kg of NPK fertilizer per hectare, while the lowest (21.69 cm) from the 30 October planting and control plot.

Number of tubers per plant

Number of tubers per plant was significantly influenced by date of planting (Table 2).The highest number of tubers per plant (9.05) were produced from 20 November planting, while the lowest from 30 October planting (5.93). It might be due to favourable climatic condition, soil and atmospheric temperature during 20 November planting. On the other hand, in October the soil and atmospheric temperatures were higher, and the waterlogged condition of the soil due to caused by heavy rainfall resulted in poor growth of storage root. This finding was supported by Fredrick *et al.* (1996); Alloli *et al.* (2011) and Yenagi *et al.* (2004). Number of tubers per plant was significantly influenced by fertilizers (Table 2). The maximum number of tubers per plant (8.13) were produced from 100-95-120 kg of NPK fertilizer per hectare, which was similar with 80-75-100 kg of NPK fertilizer per ha (7.91) and 60-55-80 kg of NPK fertilizer per hectare (7.82 cm), while the lowest produced from control plot (6.55). It might be due to the effect of NPK. The nutrients which greatly affect potato productivity are the elements N, P and K. It was reported by Damari *et al.* (2015). The number of tubers per plant showed significant variation in combined effect (Table 4). The maximum number of tubers per plant (9.93) were produced from 20 November planting and100-95-120 kg of NPK fertilizer per hectare, which was statistically identical to 20 November planting and 80-75-100 kg of NPK fertilizer per hectare (9.55) and 20 November planting and 60-55-80 kg of NPK fertilizer per hectare (9.33), while the lowest from 30 October planting and control plot (5.20).

Marketable tuber yield

Marketable tuber yield was significantly influenced by date of planting (Table 2).The highest marketable tuber yield (38.04 t ha^{-1}) was obtained from 20 November planting, while the lowest in 10 November planting (22.3 t ha^{-1}). This might be due to the growth period passing through favorable temperatures, relative humidity and good moisture conditions on 20 November, which improve the yield of sweet potato. The similar findings were also recorded by Kushwah *et al.* (2011) and Alloli *et al.* (2011) in sweet potato. Marketable tuber yield was significantly influenced by fertilizers (Table 3). The highest (35.52 t ha^{-1}) was obtained from 100-95-120 kg of NPK fertilizer per hectare, while the lowest in control plot (21.14 t ha^{-1}). It might be due to effect of NPK. The nutrients that greatly affect potato productivity are the elements N, P and K (Damari *et al.*, 2015). Marketable tuber yield showed significant variation in combined effect (Table 4).The highest marketable tuber yield (46.99 t ha^{-1}) was obtained from 20 November planting and 100-95-120 kg NPK fertilizer per hectare, while the lowest yield (15.04 t ha^{-1}) from 30 October planting and the control plot.

Table 2. Effect of date of planting on plant growth, yield contributing characters and yield of sweet potato var. BARI Mistialu-12

Date of sowing	Ground coverage of vines(%)	Length of vines(cm)	Branch per plant (no)	Length of tubers (cm)	Breadth of tubers (cm)	Tubers per plant(no)	Marketable tuber yield (t ha^{-1})
D_1 = 30 October	84.11a	66.32a	3.57	10.10c	25.90c	5.93c	23.38c
D_2 = 10 November	75.00c	58.41c	3.00	12.30b	36.22b	6.33b	22.34c
D_3 = 20 November	81.25b	63.33b	2.30	13.04a	37.02a	9.05a	38.04a
D_4 = 30 November	71.25d	57.05d	2.20	12.31b	36.42b	7.43b	31.88b
LSD (0.05)	2.30	1.25	NS	0.56	0.66	1.56	3.67
CV (%)	3.21	2.58	2.87	2.03	1.85	2.65	2.90

Table 3. Effect of fertilizers on plant growth, yield contributing characters and yield of sweet potato var. of BARI Mistialu-12

Fertilizer doses	Ground coverage (%)	Length of vines (cm)	Branch Per plant (no.)	Length of tubers (cm)	Breadth of tubers (cm)	Tubers per plant (no.)	Marketable yield (t ha^{-1})
F_0 =control	56.19d	54.81c	2.51	11.38c	33.81c	6.55b	21.14d
F_1= 60-55-80 kg NPK/ha	80.00c	62.21b	2.85	11.91b	32.24d	7.82ab	28.19c
F_2 = 80-75-100 kg NPK/ha	85.00b	63.10ab	2.90	12.17b	34.03b	7.91ab	30.81b
F_3= 100:95:120 kg NPK/ha	90.41a	64.99a	2.80	13.45a	35.49a	8.13a	35.52a
LSD (0.05)	3.33	2.01	NS	1.54	0.99	1.00	2.23
CV (%)	8.42	7.74	2.95	5.43	3.53	4.83	8.79

Table 4. Interaction effect of planting dates and fertilizer doses on plant growth, yield contributing characters and yield of Sweet potato var. BARI Mistialu-12.

Planting dates and fertilizer doses	Ground coverage (%)	Length of vines (cm)	Branch per plant (no)	Length of tubers (cm)	Breadth of tubers(cm)	Tubers per plant(no)	Marketable tuber yield (t ha^{-1})
D_1xF_0	71.45e	61.80c	3.33	9.73d	21.69d	5.20c	15.04e
D_1xF_1	90.00b	65.53bc	3.73	10.40c	28.51cd	6.73bc	20.10d
D_1xF_2	86.67cd	62.87c	3.90	10.60c	31.36cd	6.20bc	25.30c
D_1xF_3	88.33bc	75.10a	3.33	9.67e	22.04d	7.20bc	33.12bc
D_2xF_0	51.67g	50.93d	2.87	11.67bc	34.55bc	4.93d	17.26de
D_2xF_1	78.33cde	58.93cde	3.07	12.00b	33.03c	6.40bc	22.75d
D_2xF_2	80.00cde	62.93c	2.93	12.50b	35.38bc	6.47bc	24.36cd
D_2xF_3	90.00b	60.87cd	3.13	13.07a	34.19bc	5.93c	25.01c
D_3xF_0	51.67g	59.47d	2.00	12.68b	35.47bc	7.40bc	28.65c
D_3xF_1	86.67cd	65.27bc	2.40	12.84ab	38.00b	9.33a	35.06bc
D_3xF_2	91.67b	68.13b	2.40	13.07a	38.03b	9.55a	41.49b
D_3xF_3	95.00a	60.47cd	2.40	13.57a	41.95a	9.93a	46.99a
D_4xF_0	50.00g	47.07f	1.87	11.47bc	36.72bc	7.07bc	23.61cd
D_4xF_1	65.00f	59.13d	2.20	12.40b	36.23bc	7.40bc	34.85bc
D_4xF_2	81.67cde	58.47cde	2.40	13.00a	37.19b	8.00b	32.09bc
D_4xF_3	88.33bc	63.53c	2.33	12.40b	37.95b	7.27bc	36.98bc
LSD	3.24	2.72	NS	0.75	1.20	1.11	4.56
CV (%)	8.42	7.74	2.95	5.43	3.53	4.83	8.79

Mean values in a column having the same letters do not differ significantly while those with dissimilar letters differ significantly as per DMRT.

N.B.: D_1 = 30 October, D_2 = 10 November, D_3 = 20 November, D_4 = 30 November

F_0 = control, F_1= 60-55-80 kg of NPK/ha, F_2 = 80-75-100 kg of NPK/ha, F_3= 100:95:120 kg of NPK/ha

Economic Analysis

According to cost and return analysis, among all interaction of planting time and fertilizers, the highest gross margin (Tk. 795,131/ha) and BCR (4.62) were estimated from 20 November planting and 100:95:120 kg of NPK fertilizer per hectare (Table 7), while the lowest were gross margin (Tk. 163,416/ha) and BCR (1.05) was estimated from 30 October planting and control plot.

Table 5. Comparative agro-economic performance of Sweet potato var. BARI Mistialu-12 under interaction of planting date and fertilizer doses

Interaction (planting date and fertilizer doses)	Yield (t ha^{-1})		Total variable cost (Taka ha^{-1})	Gross return (Taka ha^{-1})	Gross margin (Taka ha^{-1})	BCR
	Tuber	Green Stover				
D_1xF_0	15.04	8.88	155144/-	318,560/-	163,416/-	1.05
D_1xF_1	20.10	10.00	165299/-	422,000/-	256,701/-	1.55
D_1xF_2	25.30	11.11	172069/-	528,220/-	356,151/-	2.06
D_1xF_3	33.12	13.33	168653/-	689,060/-	520,407/-	3.08
D_2xF_0	17.26	8.50	155144/-	362,200/-	207,056/-	1.33
D_2xF_1	22.75	10.25	165299/-	475,500/-	310,201/-	1.87
D_2xF_2	24.36	11.33	168653/-	509,860/-	341,207/-	2.02
D_2xF_3	25.01	13.40	172069/-	527,000/-	354,931/-	2.06
D_3xF_0	28.65	8.35	155144/-	589,700/-	434,556/-	2.80
D_3xF_1	35.06	10.32	165299/-	721,840/-	556541/-	3.36
D_3xF_2	41.49	11.61	168653/-	853,020/-	684,367/-	4.05
D_3xF_3	46.99	13.70	172069/-	967,200/-	795,131/-	4.62
D_4xF_0	23.61	8.20	155144/-	488,600/-	333,456/-	2.14
D_4xF_1	34.85	10.12	165299/-	697,000/- 717,240/-	551,941/-	3.33
$D_4 x F_2$	32.09	11.26	168653/-	664,320/-	495,667/-	2.93
$D_4 x F_3$	36.98	13.14	172069/-	765,880/-	593,811/-	3.45

N.B.: Urea = Tk. 16.00 /kg, TSP = Tk. 22.00 /kg, MOP = Tk. 15.00 /kg, Boric acid = Tk. 160 /Kg, Gypsum =Tk. 10.00 /kg, Manures =Tk. 1.00 /kg, Labour = Tk. 450.00/ 8 hr /head, Irrigation = Tk. 8000 /ha, Ploughing = Tk 1500/plough/ha, Potato= TK.20 /kg, Vine = Tk. 1.00 /kg

Conclusion

From the above results, it may be concluded that Sweet potato var. BARI Mistialu-12 planted on 20 November with 100-95-120 kg of NPK fertilizer per hectare found optimum in considering length of tubers (13.57 cm), breadth of tubers (41.95 cm), number of tubers per plant (9.93), yield (46.99 t ha^{-1}), gross margin (Tk. Table 4). Interaction effect of planting dates and fertilizer doses on plant growth, yield contributing characters and yield of BARI Mistialu-12.

Interaction (planting dates and fertilizer doses)	Ground coverage (%)	Length of vines (cm)	Branch per plant (no)	Length of tubers (cm)	Breadth of tubers(cm)	Tubers per plant(no)	Marketable tuber yield (t ha^{-1})
D_1xF_0	71.45e	61.80c	3.33	9.73d	21.69d	5.20c	15.04e
D_1xF_1	90.00b	65.53bc	3.73	10.40c	28.51cd	6.73bc	20.10d
D_1xF_2	86.67cd	62.87c	3.90	10.60c	31.36cd	6.20bc	25.30c
D_1xF_3	88.33bc	75.10a	3.33	9.67e	22.04d	7.20bc	33.12bc
D_2xF_0	51.67g	50.93d	2.87	11.67bc	34.55bc	4.93d	17.26de
D_2xF_1	78.33cde	58.93cde	3.07	12.00b	33.03c	6.40bc	22.75d
D_2xF_2	80.00cde	62.93c	2.93	12.50b	35.38bc	6.47bc	24.36cd
D_2xF_3	90.00b	60.87cd	3.13	13.07a	34.19bc	5.93c	25.01c
D_3xF_0	51.67g	59.47d	2.00	12.68b	35.47bc	7.40bc	28.65c
D_3xF_1	86.67cd	65.27bc	2.40	12.84ab	38.00b	9.33a	35.06bc
D_3xF_2	91.67b	68.13b	2.40	13.07a	38.03b	9.55a	41.49b
D_3xF_3	95.00a	60.47cd	2.40	13.57a	41.95a	9.93a	46.99a
D_4xF_0	50.00g	47.07f	1.87	11.47bc	36.72bc	7.07bc	23.61cd
D_4xF_1	65.00f	59.13d	2.20	12.40b	36.23bc	7.40bc	34.85bc
D_4xF_2	81.67cde	58.47cde	2.40	13.00a	37.19b	8.00b	32.09bc
D_4xF_3	88.33bc	63.53c	2.33	12.40b	37.95b	7.27bc	36.98bc
LSD	3.24	2.72	NS	0.75	1.20	1.11	4.56
CV (%)	8.42	7.74	2.95	5.43	3.53	4.83	8.79

Mean values in a column having the same letters do not differ significantly while those with dissimilarletters differ significantly as per DMRT.

N.B.: D_1 = 30 October, D_2 = 10 November, D_3 = 20 November, D_4 = 30 November

F_0 = control, F_1= 60-55-80 kg of NPK/ha, F_2 = 80-75-100 kg of NPK/ha, F_3= 100:95:120 kg of NPK/ha

Table 4. Interaction effect of planting dates and fertilizer doses on plant growth, yield contributing characters and yield of sweet potato var. BARI Mistialu-12.

Interaction (planting dates and fertilizer doses)	Ground coverage (%)	Length of vines (cm)	Branch per plant (no)	Length of tubers (cm)	Breadth of tubers(cm)	Tubers per plant(no)	Marketable tuber yield (t ha^{-1})
D_1xF_0	71.45e	61.80c	3.33	9.73d	21.69d	5.20c	15.04e
D_1xF_1	90.00b	65.53bc	3.73	10.40c	28.51cd	6.73bc	20.10d
D_1xF_2	86.67cd	62.87c	3.90	10.60c	31.36cd	6.20bc	25.30c
D_1xF_3	88.33bc	75.10a	3.33	9.67e	22.04d	7.20bc	33.12bc
D_2xF_0	51.67g	50.93d	2.87	11.67bc	34.55bc	4.93d	17.26de
D_2xF_1	78.33cde	58.93cde	3.07	12.00b	33.03c	6.40bc	22.75d
D_2xF_2	80.00cde	62.93c	2.93	12.50b	35.38bc	6.47bc	24.36cd
D_2xF_3	90.00b	60.87cd	3.13	13.07a	34.19bc	5.93c	25.01c
D_3xF_0	51.67g	59.47d	2.00	12.68b	35.47bc	7.40bc	28.65c
D_3xF_1	86.67cd	65.27bc	2.40	12.84ab	38.00b	9.33a	35.06bc
D_3xF_2	91.67b	68.13b	2.40	13.07a	38.03b	9.55a	41.49b
D_3xF_3	95.00a	60.47cd	2.40	13.57a	41.95a	9.93a	46.99a
D_4xF_0	50.00g	47.07f	1.87	11.47bc	36.72bc	7.07bc	23.61cd
D_4xF_1	65.00f	59.13d	2.20	12.40b	36.23bc	7.40bc	34.85bc
D_4xF_2	81.67cde	58.47cde	2.40	13.00a	37.19b	8.00b	32.09bc
D_4xF_3	88.33bc	63.53c	2.33	12.40b	37.95b	7.27bc	36.98bc
LSD	3.24	2.72	NS	0.75	1.20	1.11	4.56
CV (%)	8.42	7.74	2.95	5.43	3.53	4.83	8.79

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N.B.: D_1 = 30 October, D_2 = 10 November, D_3 = 20 November, D_4 = 30 November

F_0 = control, F_1= 60-55-80 kg of NPK/ha, F_2 = 80-75-100 kg of NPK/ha, F_3= 100:95:120 kg of NPK/ha 795,131/ha) and BCR (4.62) for sweet potato cultivation in Bogura region.

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