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Obituary

Advisory Board Member of the IJBSSR, Mr. Kazi Golam Akhtar, Rtd. Accounts Officer, Comptroller General of Accounts, Bangladesh (CGA), Sagunbagicha, Dhaka, Bangladesh, passed away on February 11, 2022, due to cardiac arrest. Inna Lillahi wa Inna Ilaihi Raziun. May Allah grant him Jannatul Ferdows, the highest peak of Paradise, and forgive his sins.

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COMPARISON ON GROWTH AND YIELD CHARACTERISTICS OF THREE TOMATO VARIETIES

AFM Jamal Uddin[1*], K.U. Mumtahina[2], T. Dastagir[1], F.T.J. Chaitee[1] and M. A. Husna[1]

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Abstract

The experiment was carried out at Horticulture Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to evaluate the growth and yield characteristics of three tomato varieties. A Random Complete Block Design (RCBD) with three replications was employed for the experimental layout. The variety Bahuboli (V_3) exhibited the tallest plant height (95.0cm), the maximum fruit number (45.0), the maximum fruit weight (195.4g), the highest fruit yield per plant (8.1kg), and the highest fruit yield per plot (123.0 kg), thus displaying superior performance in terms of growth and yield parameters. Conversely, TOH1220 (V_1) demonstrated the lowest fruit number (38), the lowest fruit weight (101.6 g), the lowest fruit yield per plant (3.9 kg), and the lowest fruit yield per plot (57.8 kg) among the varieties considered. However, the present study identified Bahuboli (V_3) as a promising tomato variety with excellent growth and yield characteristics, making it a profitable and preferred option for commercial tomato cultivation.

Key words: tomato, characteristics, Bahuboli, growth and yield.

Introduction

Tomato (*Lycopersicon esculentum*) a member of Solanaceae family, is a widely cultivated crop across the world with numerous varieties which are available to the farmers. Tomatoes are second most produced crop after potatoes. However, when it comes to processing, tomatoes are most preferable crops among all other crops (AGRISNET, 2010). It contains a wide range of vitamins, minerals and antioxidants. They are also rich in Vit C and Potassium. Its general demand is increasing daily due to its palatability and vitamin composition (Zaman *et al.,*2006), there is a growing demand for tomatoes in both domestic and international markets due to their nutritional value and diverse processing qualities (Hossain *et al.,* 1999). As a result, tomato production and usage have been increasing throughout the country. The usage of improved tomato varieties is a known strategy for farmers to achieve higher production and market value. It is widely acknowledged that using improved tomato varieties is an effective way for farmers to maximize their profits and meet market expectations (Mohiuddin *et al.,* 2007). Yield of tomato is very promising but farmers face different types of problem in terms of cultivation period including adverse climatic condition, pest management and lack of suitable variety of tomato.

Khatun *et al.,* (2012) studied the challenges faced by tomato production, particularly post-harvest losses. To overcome these challenges farmers, need to use improved variety which is suitable to cultivate. The production and quality of tomatoes vary significantly depending on the variety used. For this reason, it is necessary to evaluate the different tomato varieties to identify most suitable ones for special growing condition. In these circumstances, three tomato varieties were studied to evaluate the growth, yield and quality in Bangladesh condition. By evaluating the growth and yield of different tomato varieties will help the farmers to take decision which leads to increase productivity and profitability of tomato production.

Methodology

The Experiment was conducted at Horticultural Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the winter season. The sandy loam with rich in organic matter soil was used in this experiment. The soil pH level was in between 6-6.5. The seeds of three tomato varieties were used as planting materials. Three tomato varieties, TOH1220 (V_1), TM016 (V_2) and Bahuboli (V_3) were evaluated in this experiment and seeds were collected from AR Malik Seeds Pvt. Ltd. Dhaka. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Size of each plot was 2m x 1.15 m was divided into three blocks and each block was divided into three equal plots where three varieties were transplanted randomly.

Recommended chemical fertilizers were applied as basal doses during final land preparation before transplanting (FRG 2018). Fertilizer dose was equal for each plot. The urea was applied 1/2 at basal dose after 25 days of transplanting. Healthy and uniform sized 21 days old seedlings were transplanted in the experimental field with maintaining spacing of 40 cm x 40 cm spacing. After seedling were transplanted, regular intercultural operations

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were applied to facilitate the improved growth and development of the plants. Weeding was carried out whenever necessary to keep the crop free from weeds. Bamboo stake are used for staking to provide a stable structure and each plant was attached with an individual stake.

Sucker which are usually the side shoots which grown between the main stem and the branch of tomato plant at the age of 4–6-week plant was identified and removed by pinching with fingers. The lower and upper unnecessary branches and masses of leaves were removed manually by hand to provide more sunlight to the fruit. Tomatoes were harvested when they have reached full size and have changed to their mature red color. Three plants were randomly selected from each plot to record the data from the sample plants during the study period. Data was collected on the following parameter; Plant height (cm), Number of leaves / plant, Number of branches / plant, SPAD (%), Leaf area (Sq. cm), Number of flowers/ cluster, Number of fruits/plant, Single fruit weight (g), Fruit weight/plant (kg) and Fruit yield/plot.

The measurement of plant height is taken from the base of the stem, where it emerges from soil to top of the highest point of growth by ruler. Using a handheld chlorophyll content SPAD-502 Plus (KONKA MINOLLTA)., the amount of chlorophyll in leaves was measured (Plate 2). Each evaluation's content was measured three times from each of the plant's three leaves at various places, with the average serving as the basis for analysis.

Plate 2. Data collection a) Measurement of plant height b) measuring SPAD Value c) measuring leaf area

The recorded data on various parameters were statistically analyzed by using Statistics 10 package program to find out the significance of variation resulting from the experimental treatments. The mean for the treatments were calculated and analysis of variance for each of the character was performed by 5 % level of probability.

Results and Discussion

The results of the present study have been presented and discussed with the table and graph in this chapter under following headings.

Plant height was recorded at different growing stages of tomato plant. Result shows that plant height varied significantly among three varieties with different days after planting (DAT). After 55 days of transplanting (DAT), V_3 had the maximum plant height (105.0 cm) whereas V_2 had the minimum plant height (74.0 cm). These result states that V_3 shows the highest plant height as well as vigorous growth than V_1 and V_2 (Fig. 1).

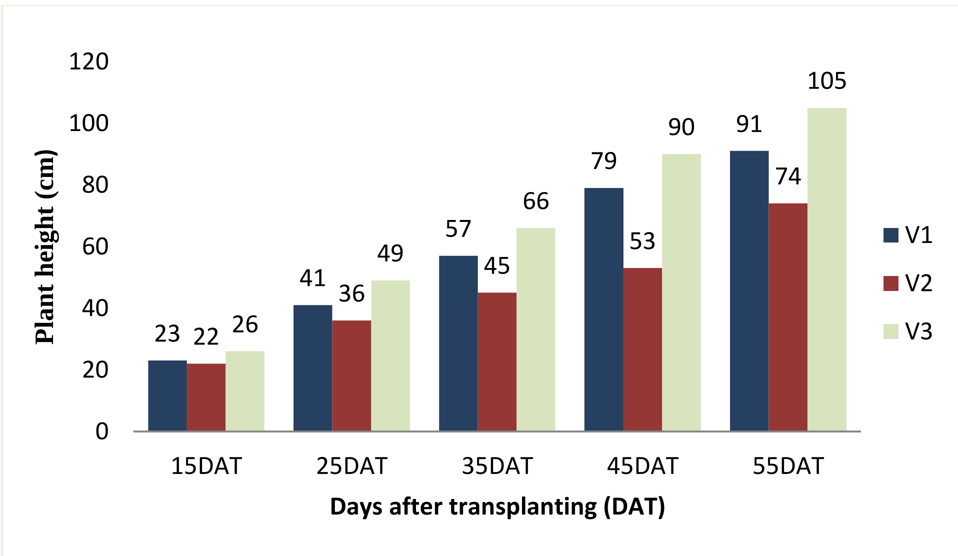

Fig. 1: Plant height at different days after transplanting of three varieties. a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

Significant variation of leaf number at different days after transplanting of three tomato varieties. The highest leaf number was recorded at 15 DAT and 25 DAT on both V_1 (6.0) and V_3 (8.0). On the other hand, V_2 recorded the lowest number of leaves. After 35 days of transplanting, V_3 had the maximum number of leaves (18.0) whereas V_2 had the minimum number of leaves (13.0). These result states that V_3 shows the highest number of leaves than V_1 and V_2 (Fig. 2). Leaf number play crucial role in tomato plant as it directly impacts the plant ability to photosynthesis and allows to produce more energy for vigorous growth (Mohiuddin et al. 2007).

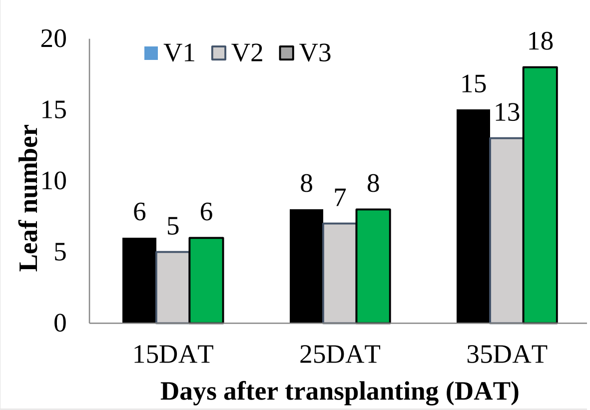

Fig. 2: Comparison of different stages of leaf number among three varieties. a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

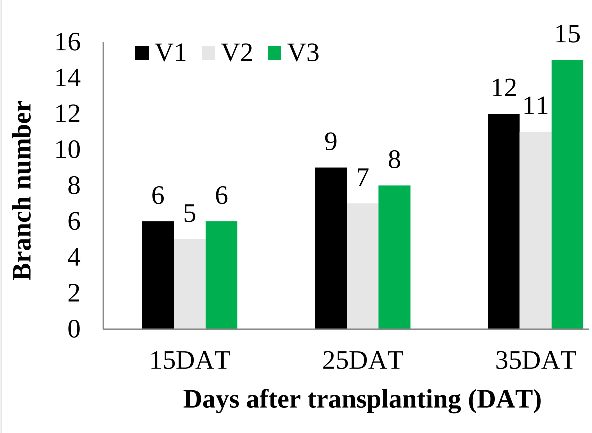

Fig. 3: Comparison of different stages of branch number among three varieties. a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

The variations in branch number among the various treatments were significant. After 35 days of transplanting, V_3 had the mean maximum branch number (15.0), whereas V_2 had the mean minimum branch number (11.0) (Fig. 3). Branch number has a favorable relation with the production of tomato because the more branch number has greater potential to produce more cluster of tomato (Mohiuddin *et al*. 2007).

The results showed significant variation of SAPD value among three treatment varieties (Fig. 4). The greatest and minimum SPAD values were 74.5 in V_3 and 34.6 in V_2, respectively. Values from the SPAD meter measure express the presence of chlorophyll in the leaf.

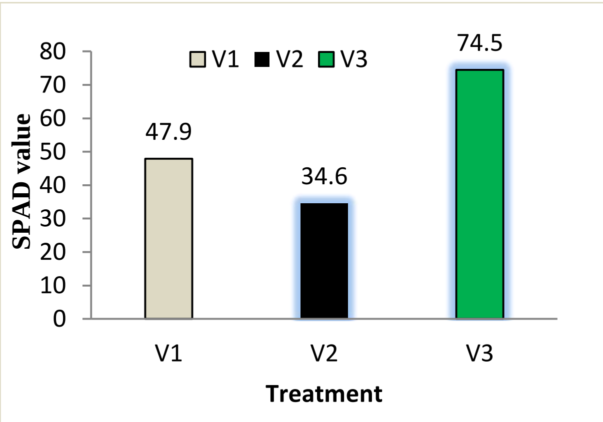

Fig. 4: Comparison of SPAD value among three varieties (a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli)

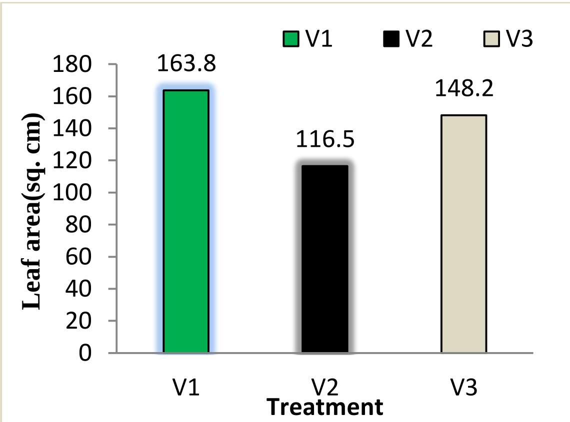

Fig. 5: Comparison of leaf area among three varieties. a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

The mean highest value was recorded in V_1 (163.8 sq. cm) and the mean lowest value was recorded in V_2 (116.5 sq. cm) (Fig. 5).

Significant variation of flower numbers per plant was found with three tomato varieties. Among three varieties, Bahuboli (V_3) holds the highest number of flowers. Highest number of flowers (48.3) was found with V_3. On the other hand, lowest flower number (31.1) was recorded with TM016 (V_2) (Table 1).

Table 1. Evaluation of number of flowers/ plant, number of fruits/plant, single fruit weight, fruit weight/plant and yield/plot of three tomato varieties

Treatment*	Number of flowers	Number of fruits	Single fruit weight (g)	Fruit weight/plant (kg)	Fruit yield/Plot (kg)
V_1	41.6 b	38.0 b	101.6 c	3.9 c	57.8 c
V_2	31.3 c	40.6 ab	119.3 b	4.8 b	72.9 b
V_3	48.3 a	45.0 a	195.4 a	8.1 a	123.0 a
LSD	5.8	3.2	12.4	0.45	6.85
CV	6.36	3.61	3.92	3.59	3.58

*a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

Number of fruits per plant varied significantly among three varieties. Bahuboli (V_3) plant had the largest number of fruits per plant (45.0), while the TOH1220 (V_1) plant had the lowest number of fruits per plant (38.0), as shown in table 1.

Plate 3. Fruits of the three tomato varieties a) V_1; TOH1220 b) V_2; TM016 and V_3; Bahuboli

A significant variation was observed in single fruit weight among three varieties (table 1). The maximum single fruit weight was recorded in Bahuboli (V_3) (195.4 g) where the lowest single fruit weight was recorded in TOH1220 (V_1) (101.6 g).

Significant differences found in yield per plant among the varieties. The maximum yield (8.1 kg) was found in Bahuboli (V_3) and minimum yield was found in the TOH1220 (V_1) (3.9 kg) (Table 1).

Significant yield per plot differences found among the three different varieties. The highest yield (123 kg) was found with Bahuboli (V_3) and lowest yield (57.8 kg) found from TOH1220 (V_1) (Table 1).

Conclusion

Based on higher yield, strong growth, and desirable characteristics of Bahuboli can contribute to maximum profitability for farmers. Increased yield and better marketability can result in maximum returns on investment, making financially a better option for tomato cultivation.

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PERFORMANCE OF INDUSTRIAL TYPE POTATO CLONES: SUITABLE FOR FRENCH FRIES

Mehedi Hasan[1], Mohsina Afreen[2], Mubashshir Muntaha Bari [2], Tasnin Khan Eusufzai[2], Mohammad Ataur Rahman[2], Abu Shamim Mohammad Nahiyan[2], Tahmina Khan[1] and A. F. M. Jamal Uddin[*1]

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Abstract

The study at the Farm of Horticulture Innovation Lab. BD., Department of Horticulture in Sher-e-Bangla Agricultural University, Bangladesh, aimed to assess potato clones (P 1106 and P 1117) and checks (Check 1 and Check 2) for production potential and industrial traits. To determine yield performance and industrial suitability growth parameters and quality traits were examined. P 1117 demonstrated swift emergence (14 DAP) and taller plants (95.00 cm) at 60 DAP than checks. Both clones achieved full foliage coverage (100%) and higher main stems per hill (6.57), indicating robust growth. Quicker days to tuber initiation (39.00 days for P 1117) suggested better overall tuber development. At 90 DAP, P 1106 had more tubers per hill (14.2), while P 1117 excelled in weight (715.3 g) and yield (55.3 Mt/Ha), showcasing its potential. P 1117's high dry matter content (23.17%) suited for French fry production. P 1106 and P 1117 had lower reducing sugar levels, minimizing browning, and showed low oil absorption (2.87% and 2.83%), aligning with health-conscious demands. Morphological analysis highlighted uniform skin, flesh color and tuber shape in P 1106 and P 1117 ideal for consistent appearance. In conclusion, P 1117's promising yield potential, industrial traits, and robust growth emphasize its suitability for French fry production. Selecting suitable potato varieties is pivotal for efficiency and quality-driven production.

Key words: Dry matter, Industrial potato, Reducing sugar, Solanum tuberosum, Yield.

Introduction

Potatoes (*Solanum tuberosum*) rank as the second most popular vegetable in Bangladesh following grains. Originally native to South America, potatoes belong to the annual dicotyledonous herbaceous tetraploid Solanaceae family and hold a significant position as a key food crop. Potatoes now stand as Bangladesh's third-largest food in terms of tonnage output (Ahmed *et al.*, 2013). Their versatility makes them a global staple for both human and animal consumption. Research findings by Hassanpanah *et al.*, (2006) indicate their value as a raw material for starch production, in addition to their role as a dietary vegetable, with the potential to become a staple food.

Despite being the world's fifth-largest potato-growing area, Bangladesh produces relatively fewer potatoes than other potato-growing nations (Anon., 1997). With an output of around 16–19 tons per hectare. However, the rising population, as projected to reach 172.9 million by 2020, poses a significant challenge. To address this issue and boost agricultural output, high-productivity crops like potatoes emerge as a key solution (Roy *et al.*, 2017).

Understanding consumer preferences and identifying cultivars that bridge the gap between evolving market trends and production circumstances, as proposed by Connor *et al.* (2001), is crucial. The quality of potato tubers, encompassing starch content, dry matter levels, and tuber form, plays a vital role in satisfying industry demands (FAO, 2008).

While table-purpose potatoes are occasionally employed by industries due to a lack of suitable cultivars, there is a growing demand for processing-type potato cultivars, driven by the expanding market for processed potato products (Pandey and Sarkar, 2013). Marwaha *et al.* (2010) predict a substantial increase in demand for processing-type potatoes with desired characteristics by 2050.

One striking statistic, noted by Roy *et al.* (2017), is that only two-thirds of produced potatoes are consumed directly, while the remainder is processed. This surplus of potatoes can be addressed through exports or processing. The demand for processed potato products is on the rise due to urbanization, the popularity of fast food, changing dietary preferences, and increasing income levels.

To meet these demands, potatoes intended for industrial use must possess specific traits that differ from table potatoes. When considering French fry and processing-type potatoes, their unique traits become pivotal. These industrial varieties must differ from table potatoes to meet the specific demands of processing. Kumar *et al.* (2014) underscore the importance of higher yields, elevated dry matter content, reduced reducing sugar content, lower

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phenol and glycoalkaloid levels, appealing color, and minimized defects for processing cultivars. Key quality attributes for potatoes include dry matter content, specific gravity, reducing sugar content, and chip color.

Reducing sugars influence processing due to the Maillard reaction during frying (Pandey *et al.*, 2009). Dry matter content, specific gravity, reducing sugar content, and chip color score are recognized as crucial for potatoes. Tuber dry matter, which affects product recovery and oil content in chips, stands out as the most pivotal quality factor (Das *et al*., 2021). Tuber dry matter and reducing sugar content are affected by factors like tuber maturity, growth conditions, water uptake, and nutrient absorption (Westermann *et al.*, 1994).

Another crucial trait for potatoes used in industrial settings is oil uptake, vital for achieving desired product texture and quality during frying at high temperatures (Baumann & Escher, 1995). Potato chips, a leading processed potato product, exhibit oil content ranging from 35% to 45%, contributing to their distinct texture and flavor (Garayo and Moreira, 2002).

This study contributes to the ongoing research on consumer and industry-preferred potatoes by focusing on evaluating the yield potential of developed potato cultivars suited for industrial applications, especially for the production of French fries and other processed potato products.

Material and methods

Experimental design

The research was conducted at the Farm of Horticulture Innovation Lab. BD., Dept. of Horticulture in Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, in order to evaluate the production potential along with industrial traits of 02 selected potato clones and 02 check varieties. The clones used in this study were labeled as P 1106, P 1117, Check 1 and Check 2. The experimental layout followed a randomized completely block design (RCBD) with three replications. Gross plot size was 3 m × 3 m. Spacing between rows and plants were 60 cm × 25 cm, respectively. There were 12 hills per row and 5 rows per unit plot.

Intercultural practices

Efficient land preparation and achieving favorable soil texture were essential for successful potato cultivation. Well-sprouted whole seed tubers were carefully selected for planting. To optimize soil fertility, the land was prepared by applying 1 ton/ha of organic fertilizer and 15 kg/ha of Furadan 5G. For proper crop nutrition, the following fertilizers were applied: Urea (350 kg/ha), Triple Super Phosphate (TSP) (220 kg/ha), Muriate of Potash (MoP) (260 kg/ha), Borax (10 kg/ha), Gypsum (120 kg/ha), Magnesium Sulphate (100 kg/ha), and Zinc Sulphate (12.5 kg/ha). The unit plots received full doses of TSP, Gypsum, Borax, Zinc Sulphate, and Magnesium Sulphate before planting. Urea and MoP were applied as top dressing, with 50% of each applied during the first earthing up and the remaining 50% during the second earthing up.

Disease control measures were implemented by applying Pencozeb and Acrobate MZ at every 7-day intervals, starting from 30 days after planting (DAP) and continuing up to 85 DAP, to inhibit the growth of pathogenic fungi. To address potential aphid infestations, 3 ml/L of Imitaf was mixed with the fungicides during each application. Precise irrigation management was employed based on soil and crop conditions, ensuring optimal growth conditions for the potatoes. These comprehensive agricultural practices ensured the optimal growth and health of the potato crop, leading to successful potato production.

Data analysis

During the study, data on various growth parameters of the plants were recorded, including the number of days for 80% emergence of seedlings, plant height, number of main stems per hill, number of tubers per hill, weight of tubers per hill, yield in Mt/ha, foliage coverage percentage at 60 DAP, tuber size, tuber shape, eye position, eye color, tuber skin color, tuber flesh color, percentage of dry matter contents, percentage of reducing sugar, percentage of oil absorption, and overall performance of harvested tubers. The recorded data underwent statistical analysis using the statistical software R, at a 5% significance level to ascertain differences between treatments. Furthermore, the study aimed to determine the yield performance and industrial traits among the selected samples.

III. Results and Discussion

The potato clones P1106 and P1117 were tested on various quantitative parameters in comparison to the control variants Check-1 and Check-2. The parameters included general yield related traits, industrially important traits as well as marketable traits such as flesh and skin color of the potatoes.

Qualitative traits in terms yield potential

A comprehensive overview of various growth parameters for 02 distinct potato clones P1106 and P1117 were compared with check 1 as well as check 2 to analyze yield potential. The data includes emergence rates at 80% DAP, plant height at 60 DAP, foliage coverage at 60 DAP, number of main stems per hill at 60 DAP, days to tuber initiation, number of tubers per hill at 90 DAP, weight of tubers per hill at 90 DAP, yield, and duration.

The P 1117 clone had the quickest 80% crop emergence at 14 DAP which was faster than the quickest check, which was Check-1 at 15 DAP. The P 1117 clone also has a significantly tallest plant height of 95.00 cm at 60 DAP which outperformed both check variants check 1 at 58.40 cm, and check 2 at 56.70 cm as well as the other developed variant (Table 01). These variations suggest potential differences in early growth behaviors. Taller plants often indicate robust growth and potential for increased photosynthesis and yield.

Foliage coverage at 60 DAP, recorded as the percentage of land covered, and reflects the extent of canopy development. P1106 and P1117 exhibit full coverage at 100%, while check 1 and check 2 maintain slightly lower values of 97.30% and 97.50% (Table 01). Complete foliage coverage contributes to effective sunlight interception, which is critical for maximizing photosynthetic efficiency and subsequently influencing tuber yield.

P1117 also had the highest number of main stem/hill (at 60 DAP) at a value of 6.57, which was slightly higher than the other developed variant P1106, both of which had outperformed the check varieties, check 1(5.00) and check 2 (5.40) (Table 01).

The days to tuber initiation provide an indication of when the potato plants initiate tuber formation. P1106 requires 40.00 days, P1117 needs 39.00 days, and check 1 takes 42.00 days, and check 2 takes 41.00 days. Quicker tuber initiation can be associated with better overall tuber development and potentially higher yield potential (Table 01).

At 90 DAP, the number of tubers per hill provides insights into each studied material tuberization. P1106, however, outperformed P1117 in the criteria of the number of tubers per hill during harvest at 90 DAP which was 14.2 followed by check 1 (11.0) and check 2 (10.0). The weight of tubers per hill at harvest and the final yield highlight the potential productivity of each variety. P 1117 boasts the highest weight of tubers per hill at 715.3 g, followed by Check 2 (686.0 g), P 1106 (695.4 g), and Check 1 (633.0 g) (Table 01). Despite that, in the yield category, P1117 had 55.3 Mt/Ha, which was significantly higher than the values of P1106 (42.2 Mt/Ha) and the two check varieties Check 1 (38.40 Mt/Ha), Check 2 (40.00 Mt/Ha) (Table 01). These weights and yield combined with the duration of growth of P 1106 and P 1117 that determines the overall yield potentiality of each variety.

Table 01: Yield components of 2 selected clones and 2 check varieties

Clones	80% Emergence (DAP)	Plant Height (cm) at 60 DAP	Foliage Coverage (%) at 60 DAP	No. of Main Stem /Hill at 60DAP	Days to tuber initiation	No. of Tuber/Hill at 90 DAP	Wt. of Tuber/Hill at 90 DAP	Yield Mt/Ha	Duration (Days)
P 1106	15.00 ± 1.15	73.60 ± 0.39	100.00 ± 0.00	6.20 ± 0.16	40.00 ± 0.00	14.20 ± 0.70	695.40 ± 1.27	42.20 ± 0.42	97.50 ± 0.38
P 1117	14.00 ± 1.15	95.00 ± 0.20	100.00 ± 0.00	6.57 ± 0.07	39.00 ± 0.58	13.60 ± 0.35	715.30 ± 2.18	55.30 ± 0.22	97.50 ± 0.38
Check-1	15.00 ± 0.58	58.40 ± 0.56	97.30 ± 0.33	5.00 ± 0.58	42.00 ± 1.73	11.00 ± 0.58	633.00 ± 1.52	38.40 ± 0.17	87.20 ± 0.10
Check-2	18.00 ± 1.00	56.70 ± 0.55	97.50 ± 0.33	5.40 ± 0.58	41.00 ± 0.58	10.30 ± 0.33	686.00 ± 2.52	40.00 ± 0.32	87.20 ± 0.10
Mean p-value	ns 0.38	ns 0.27	ns 0.62	s 0.19	s 0.61	s 0.29	s 0.18	s 0.57	ns 0.17

Means followed by (s) within a column are significantly different or (ns) are not significantly different at 5 % level of significance

Morphological characterization

The crucial varietal traits of four distinct potato samples: P 1106, P 1117, Check 1, and Check 2. These traits encompass skin color, flesh color, tuber shape, eye color, and eye depth. While these attributes might appear insignificant, they hold profound significance, particularly in the territory of industrial potato production, especially for the production of one of the most beloved potato products - French fries.

Potato skin and flesh color significantly influence the appearance and quality of processed potato products. For French fries, uniformity in color is paramount. In the table, P 1106, P 1117, and Check 1 feature white skin and flesh, ensuring a consistent appearance after processing. Uniform white-fleshed potatoes are preferred for traditional French fries due to their consistent color after frying, providing the desired golden-brown appearance that consumers expect (Table 02).

Tuber shape plays a critical role in French fry processing. Uniformity in shape ensures consistent slicing, resulting in evenly sized French fries. P 1106 and Check 2 both exhibit a long tuber shape, while P 1117 and Check 1 showcase oblong to long and oblong shapes respectively. Varieties with long and uniform tuber shapes are highly desirable for French fry processing. This ensures that the slices are of similar length, facilitating uniform cooking and maintaining a consistent texture in the final product (Table 02).

The characteristics of potato eyes, including their color and depth, can impact the appearance and quality of processed products. In the table, all varieties share shallow eyes, which are desirable in French fry processing. Shallow eyes minimize waste during the peeling and slicing process. While eye color isn't a primary factor in French fry production, it contributes to the overall appearance of the final product, especially when the skin is retained, as in some gourmet-style French fries (Table 02).

Table 02: Morphological characterization of selected clones and varieties

Clones	Tuber Skin color	Tuber Flesh color	Tuber Shape	Tuber Eye Color	Tuber Eye Depth
P 1106	White	White	Long	White	Shallow
P 1117	White	White	Oblong to Long	White	Shallow
Check-1	White	White	Oblong	White	Shallow
Check-2	Red	Yellow	Long	Red	Shallow

Uniform skin and flesh colors, as seen in P 1106, P 1117, and Check 1, are ideal for industrial French fry processing. They ensure that the fries maintain a consistent appearance after frying, contributing to the desired golden-brown color that consumers associate with high-quality French fries. Uniform tuber shapes, as exhibited by P 1106, P 1117, and Check 2, are essential for efficient slicing (Figure 01). They allow for streamlined production processes, minimizing variations in fry size and promoting even cooking. Consumer preferences for French fries extend beyond taste; they encompass appearance and texture. Consistency in appearance and texture creates a sense of reliability and meets consumers' subconscious expectations. The traits highlighted in the table contribute to fulfilling these expectations and play a role in establishing brand loyalty.

P 1106

P 1117

Check-1

Check-2

Figure 01: Presentation of two selected clones and two check varieties through photography

Color assessment of the potato's external surface was conducted using the IWAVE WF32 precision colorimeter, specifically the model from Shenzhen Wave. The measurements were based on the CIELab color scale, encompassing three coordinates: L* for lightness, a* and b* for two Cartesian coordinates (Jamal Uddin et al., 2019). Furthermore, Chroma (C*) and Hue angle (hab) were derived from these coordinates. Potato color values were recorded through the CIE L*, a*, b* scale, employing the standard observer 100 and standard illumination D65 in the evaluation process. In the context of Table, the P 1106 variant exhibited higher scores than P 1117 across all categories, except for a*. Specifically, P 1117 displayed elevated a* values for both skin and flesh color, measuring 5.63 and 2.42, respectively (Table 03). Overall, the P 1106 variant shared traits with the Check-1 variety but featured notably higher values across the board.

Table 03: Phenotypic tuber characterization through a precision colorimeter, IWAVE WF32 (Shenzhen Wave)

Clones	Skin color					Flesh Color				
	L*	a*	b*	c*	hab	L*	a*	b*	c*	hab
P 1106	66.48	4.55	31.03	31.37	81.47	62.63	1.19	22.09	22.12	86.91
P 1117	50.68	5.63	27.6	28.17	78.47	44.33	2.42	21.1	21.23	83.46
Check-1	61.57	8.05	30.73	31.77	75.32	60.57	2.14	30.65	30.73	86.01
Check-2	53.64	14.72	16.88	22.4	48.9	58.74	2.43	28.25	28.35	85.08

Specific traits for processing type potato

The cultivation of potatoes isn't merely about yield; it extends to the intricate balance between genetics, agronomy, and the final product's intended use. The presented table offers insights into key quality parameters for four distinct potato samples: P 1106, P 1117, Check 1, and Check 2. These parameters - dry matter content, reducing sugar levels, and oil absorption percentages are critical in determining the suitability of potatoes for various industrial processes, such as chip and French fry production.

Dry Matter Content

Dry matter content is a pivotal parameter for industrial potato processing as it influences the texture, flavor, and quality of the final product. It refers to the proportion of solid material in a potato's composition, excluding water content. In the context of the table, P 1117 displays the highest dry matter content at 23.17%, followed by Check 2 (19.77%), P 1106 (20.43%), and Check 1 (18.43%). Potatoes with higher dry matter content are often preferred for manufacturing crispy and golden-brown potato chips and French fries. According to Ezekiel & Rani (2006), oil update of potato and potato chips have a highly negative relation with the dry matter content in potatoes. The data indicates that P 1117 is particularly suitable for processing into these products due to its elevated dry matter content (Table 04).

Reducing Sugar Levels

Reducing sugar levels are of paramount importance in industrial potato processing, particularly for applications such as chip and fry production. Excessive sugar content can lead to undesirable browning during frying, impacting both the appearance and taste of the final product. Among the varieties, Check 1 demonstrates the highest reducing sugar content at 1.10%, followed by Check 2 (0.97%), P 1106 (0.36%), and P 1117 (0.28%). Lower reducing sugar levels are sought after, as they contribute to minimal browning and produce visually appealing and flavorful potato products. The low sugar content in P 1106 and P 1117 positions these varieties as favorable choices for processors aiming to achieve consistent product quality and reduced browning effects during frying (Table 04).

Table 04: Evaluation of special traits for processing type potato production through selection

Clones	Dry Matter content (%) (St.>20%)	Reducing Sugar content (%) St.<0.5%)	Oil Absorption (%) (St. max %)
P 1106	20.43 ± 0.33	0.36 ± 0.01	2.87 ± 0.04
P 1117	23.17 ± 0.58	0.28 ± 0.00	2.83 ± 0.04
Check-1	18.43 ± 0.41	1.10 ± 0.13	3.87 ± 0.05
Check-2	19.77 ± 0.55	0.97 ± 0.01	3.33 ± 0.12
Mean	s	s	s
p-value	0.41	0.21	0.42

Means followed by (s) within a column are significantly different or (ns) are not significantly different at 5 % level of significance

Oil Absorption

Oil absorption percentage is a critical parameter that directly influences the texture, flavor, and perceived quality of fried potato products. Varieties with lower oil absorption percentages are preferred in industrial applications as they reduce oil consumption and result in products with lower fat content. In the table, P 1106 exhibits the lowest oil absorption at 2.87%, followed by P 1117 (2.83%), Check 2 (3.33%), and Check 1 (3.87%). The low oil absorption values of P 1106 and P 1117 render them attractive options for processors focused on creating healthier fried potato products with reduced oil content. This parameter aligns with the growing consumer demand for nutritious and balanced snacking options (Table 04).

The quality parameters highlighted in this table have significant implications for industrial potato processing. The industrial potato processing sector is driven by consumer preferences, health-conscious trends, and market trends. The food industry demands consistent, high-quality raw materials to produce uniform and appealing products for consumers. In this context, the data underscores the potential suitability of P 1117 for chip and fry production due to its high dry matter content. Both P 1106 and P 1117 possess lower reducing sugar levels, making them favorable choices for minimizing undesirable browning during frying. The low oil absorption values of P 1106 and P 1117 are particularly important in light of the growing demand for healthier snacks and food products. The quality parameters discussed also tie into broader sustainability considerations. Varieties with low oil absorption, for example, contribute to resource efficiency by reducing the amount of cooking oil required. This aligns with sustainability goals within the food industry, highlighting the multifaceted impact of seemingly isolated quality parameters. These varieties can contribute to the development of low-fat or reduced-calorie potato-based products, aligning with consumer preferences for healthier options.

Conclusion

In conclusion, the study underscores the suitability of P 1117 for French fry production due to its robust growth, high yield potential, and desirable industrial traits. With rapid emergence, taller plants, and complete foliage coverage, P 1117 exhibits promising growth parameters. Its high dry matter content, low reducing sugar levels, and low oil absorption make it an ideal choice for producing crispy and appealing potato products. Additionally, the uniform skin and flesh color, along with consistent tuber shape, further enhance its industrial value. The findings emphasize the importance of selecting varieties that combine yield potential with attributes required for efficient and quality-driven potato processing, contributing to a successful and sustainable potato production industry.

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INFLUENCE OF BORDEAUX MIXTURE AND CLYBIO ON GROWTH AND YIELD OF INDIAN SPINACH (*Basella alba* L.)

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Abstract

The experiment was conducted at the Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period of May to July 2023. The single factor experiment was laid out in Completely Randomized Design (CRD) with three replications to determine the growth and yield of Indian Spinach (*Basella alba* L.). The experiment consisted of three treatments, namely: T_1: Control; T_2: Bordeaux Mixture (three times with ten days interval) and T_3: Clybio (three times with ten days interval). Significant variations were observed in all treatments when data pertaining to various growth and yield parameters were collected, where the average tallest plant (187.3 cm), maximum SPAD value (37.9), maximum leaf area (252.6 sq cm), stem diameter (21.4 mm), maximum root weight (39.4 g), highest yield per plant (484.9 g) and highest yield per ha (17.81 ton) were found in (T_3: Clybio) application, while the shortest plant (42.8 cm), minimum SPAD value (30.3), minimum leaf area (112.1 sq cm), lowest yield per plant (420.5 g), and lowest yield per ha (15.6 tons) were found in Bordeaux Mixture (T_2). On the basis of the whole experiment, it can be concluded that Clybio as a bio-fertilizer, possesses the inherent potential to enhance the growth and yield of Indian spinach, thereby indicating its capacity to exert a positive influence on the overall development and productivity of this leafy green crop.

Key words: Indian spinach, biostimulator, clybio, leaf area.

Introduction

Indian Spinach (*Basella alba* L.) is a widely cherished leafy vegetable in Bangladesh, appreciated for its adaptability to diverse soil and climatic conditions, (Mondal *et al*., 2011). It is grown in practically all backyard gardens as well as in open fields in Bangladesh. Notably, it's tender shoots and leaves boast significant nutritional value, rich in essential salts and vitamins. Indian spinach is a perennial vine that grows quickly. It is widely grown and known as a popular summer-season vegetable all over the world. The Bangladesh Agriculture Research Institute has developed high-yielding Indian spinach varieties known as BARI puishak 1 and BARI puishak 2, which are widely cultivated by local farmers for commercial purposes. Regrettably, a prevailing issue in Bangladesh's Indian spinach farming is the indiscriminate use of chemical pesticides and fertilizers, which pose risks to both human health and the environment. To address this concern, a study has introduced an organic stimulant, Clybio, as a safer alternative. Clybio, a Japanese organic fungicide, is a composite blend of yeast fungus, bacillus natto, and lactobacillus. It has demonstrated the ability to enhance vegetable yield and quality while effectively controlling fungal pathogens. The unscientific application of pesticides and synthetic fertilizers in agriculture has far-reaching consequences, including health hazards and environmental degradation, leading to soil quality deterioration and a negative impact on vegetable flavor. Recognizing the need for safe food production, the Bangladeshi government advocates reducing or discontinuing the use of synthetic fertilizers. Soil health is pivotal in ensuring safe food production. Consequently, this study was initiated to assess the impact of Bordeaux mixture and Clybio on the growth and yield of Indian spinach, offering an eco-friendly alternative to conventional farming practices. Considering these factors, the current study was designed to evaluate the influence of the Bordeaux mixture and Clybio on the growth and yield of Indian spinach.

Materials and methods

The experiment was conducted at Horticulture Farm, Sher-e-Bangla Agricultural University during the period of May - July 2023. Experiment was laid out in Completely Randomized Design (CRD) with three replications. The experiment was setup in half plastic drum, soil was prepared by mixing 5 kg dry cow dung with 25 kg sandy loam soil each drum. Three seeds were sown in each half drum. After 7 days of seed germination, single seedling per drum was kept and the rest of the seedling was removed. The experiment was consisted of three treatments namely; T_1: Control (No treatment); T_2: Bordeaux Mixture (three times with ten days interval) and T_3: Clybio (three times with ten days interval). Treatments were applied to plants three times every ten days from seven days after seed

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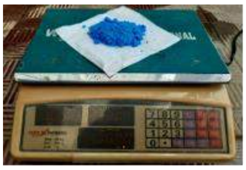
germination.

Bordeaux mixture preparation: Bordeaux mixture was prepared by adding 5-liter water in 100g copper sulphate and again 5-liter water in 100 g lime were soaked overnight. These two solutions are mixed well in a large bowl to form a Bordeaux mixture (Plate 1). Clybio application: Clybio was collected from Conpass Corporation, Bangladesh and was applied as recommended by Conpass Corporation (4ml/ L) for this experiment (Plate 2).


$CuSO_4$ (100g)


$CaCO_3$ (100g)


Dissolve in 5L water


Dissolve in 5L water


Mix up


Ready to spray

Plate 1. Bordeaux mixture composition and preparation


Clybio


Clybio 4ml/L


Foliar application of Clybio

Plate 2. Clybio application method

Irrigation and weeding were done when it was necessary. Light trap was used to control the insect infestation during the production period. Data on plant height, SPAD value, leaf area, stem diameter, root weight, yield per plant and disease observation were collected during the research period. Final harvest was done at 45 days after sowing. Plant height was measured at 15, 25, 35, and 45 days after sowing (DAS). The plant height was measured distance from the soil surface to the tip of the highest leaf in centimeter. Measurement of SPAD value using a hand-held SPAD-502 Plus (KONKA MINOLTA) meter. For each evaluation, the content was measured in 3 times from three leaves at different positions per plant and the average was used for analysis. Leaf areas were measured using Top instrument machine and was expressed in sq cm. The diameter of the stem for each of the three plants was measured using a digital slide caliper at last harvest stage in millimeters (mm). Stem and root fresh weights were calculated using a digital balance. The number of leaves per plant was counted from the three selected plants and their average was taken as the number of green leaves per plant. Pest infestation was observed on eye estimation. Yield per plant was calculated by averaging the yields of three plants per treatment and yield per hectare were calculated as ton per hectare. The statistical analyses were conducted using the STATISTIX 10 statistical program. The analysis of variance (ANOVA) was conducted to assess the differences between treatments. The Least Significance Difference (LSD) test, as Gomez and Gomez (1984) proposed, was employed at a significance level of 5%.

Results and discussion

Plant height: A significant variation was found on plant height with different treatments at different days after sowing. It was found tallest plant height (187.3 cm) at final harvest (45 DAS) with $T_{3,}$ whereas the lowest plant height (140.3 cm) with T_1 (Fig.1). The vegetative and reproductive growth potential of plants is responsible for superior plant height. Furthermore, the probable reason could be that the optimum amount of Clybio application resulted in increased physiological growth of spinach. It improved the plant's ability to utilize light, water, and nutrients, leading to the development of more established plants. Similar findings reported by (Fahad *et al*., 2006). They proved how exogenously applied growth regulators improve the morpho-physiological development of plants. Soil microbes to the ecosystem is reviewed, with particular emphasis on the role of plant growth-promoting rhizobacteria, arbuscular mycorrhizal fungi, and endophytic bacteria in providing necessary nutrients for plant growth (Miransari *et al*., 2011).

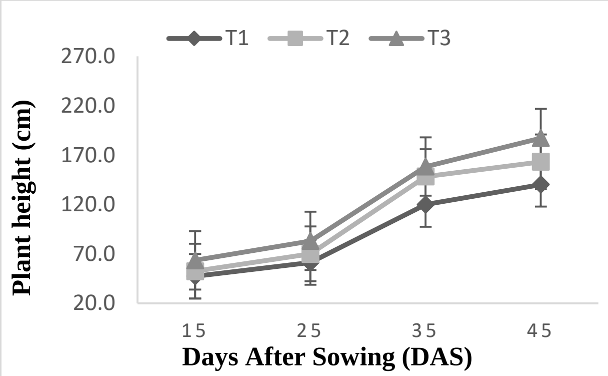


Figure 1. Influence of Bordeaux mixture and Clybio on plant height (T_1: Control, T_2: Bordeaux Mixture, T_3: Clybio).

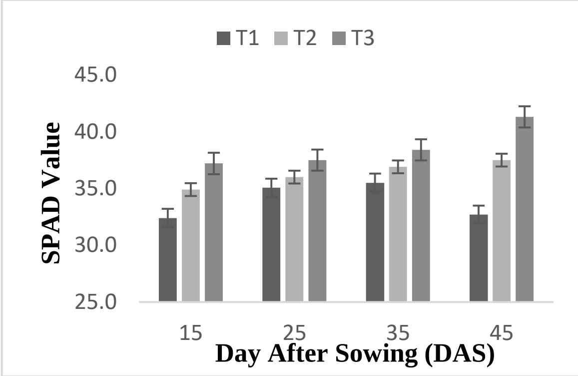


Figure 2. Influence of Bordeaux mixture and Clybio on SPAD values of Indian Spinach leaves (T_1: Control, T_2: Bordeaux Mixture, T_3: Clybio).

SPAD value: A significant variation was found among the treatments. The highest recorded SPAD value (41.3) in T_3, and the lowest value (32.7) in T_1 application (Fig. 2). The content was measured three times from three distinct leaves for evaluation, with the average being used for analysis. The SPAD meter readings correlate with the amount of green in the leaf. Treatments such as T_1, T_2, and T_3 show the SPAD value. It's may be the effect of Clybio. The development and increased chlorophyll content are facilitated by the vital amino acids, vitamins, and phytohormones that are promoted by the yeast-derived substance Clybio (Taha *et al*., 2020).

T_1 T_2 T_3

Plate 3: Variations of leaf area with different treatments at final harvest

Leaf area: A significant variation was found in leaf area with different treatments (plate 3). Highest leaf area was measured (252.6 sq. cm) at final harvest with T_3 application, whereas the lowest value of leaf area (112.1 sq.cm.) in T_1 application (Table 1). The most probable cause could be that, leaf grown more physiologically after absorbing the certain amount of Clybio treatment.

Stem Diameter: Among the treatment, T_3 showed the highest stem diameter (21.4 mm) while T_1 showed the lowest (17.4 mm) stem diameter at final harvest (Table 1). Clybio is the unique and complex microbe that contains bacteria like Lactic acid bacteria, Bacillus natto bacteria and yeast fungus and the improving tendency of plant growth and development (Uddin *et al.,* 2021).

Root weight: Significant variations found in root weight due to the different treatments. The highest root weight (39.4 g) at final harvest with T_3 treatment, whereas the lowest value of root weight (28.9 g) in T_1 treatment (Table 1). Microbes are beneficial to plant growth through colonizing plant roots and inducing mechanisms by which plant growth increases (Miransari *et al*., 2011).

Disease infestation: Significant variations in disease infestation due to the different treatments were observed. The highest percentage of infected leaves was found in T_1 (10.0) and the lowest percentage of infected leaves was found in T_3 (1.6) at final harvest (Table 1). Observing the plant, we can claim that the T_3 treatment performed very well in the case of disease observation during harvesting time. Clybio is a special complex microorganism that includes yeast fungi, bacteria like Lactic acid bacteria, Bacillus natto bacteria, and bacteria that are improving plant diseases.

Table 1: Influence of Bordeaux mixture and Clybio on leaf area, stem diameter, root weight, disease infestation of Indian Spinach

Treatment*	leaf area (sq. cm)	Stem diameter (mm)	Root wt. (g)	Disease infestation (%)	Fresh wt. /Plant (g)	Yield (t/ha)
T_1	112.1 c	17.4 b	28.9 b	10.0 a	420.5 b	15.6 b
T_2	116.9 b	17.5 b	38.3 a	5.3 b	426.1 b	15.7 b
T_3	252.6 a	21.4 a	39.4 a	1.6 c	578.2 a	21.2 a
CV%	0.52	6.9	3.6	14.4	1.16	1.1
LSD	2.4	3.7	3.7	2.3	15.9	0.38

* T_1: Control, T_2: Bordeaux Mixture, T_3: Clybio

** According to the 0.05 threshold of provability, means in a column with similar letters are statistically the same, whereas those with differing latter differ significantly

Fresh wt./plant: The significant variation is noted by the application of treatments where, highest weight per plant (578.2 g) was recorded in T_3 application while T_2 performed well and weight per plant was recorded (426.1g), (Table 1). Lactobacillus bacteria which help to nitrogen fixation and accumulation of auxin and cytokinin that trigger plant growth, flowering stage (Higdon *et al*., 2020); Bacillus solubilize soil P, enhance nitrogen fixation, and produce siderophores that promote its growth (Hashem *et al*., 2019); yeast stimulates plant hormones like auxins, gibberellins, cytokines, synthesis of vitamins, antifungal and antibiotic compounds, ability to solubilize minerals like phosphorus and other nutrients that enhances plant growth, enhance photosynthesis (Agamy *et al*., 2013). Bordeaux mixture is a combination of copper sulfate, lime, and water, and is an effective fungicide and bactericide that has been used for decades to control diseases for crop production, these natural minerals provide long-lasting protection to plants against diseases and yield losses due to disease (Teng *et al*., 1984). In addition, a presence of critical nutrients as calcium and copper (Uddin *et al*., 2021) increased crop development and yield (Nurul *et al*., 2014).

Calculated Yield: The plant yield differences among the treatments with respect to stem weight. The significantly highest plant yield was recorded in the T_3 (21.2 t/ha) treatment and T_1 (15.6 t/ha) was recorded significantly the lowest yield (Table 1), which is attributed mainly due to the less effectivity of the treatment per plant, minimum yield, and poor response of these treatments in environmental conditions (Akther *et al*., 2019).

Conclusion: The Indian Spinach (*Basella alba* L.) treatments T_3 (apply clybio for three times with ten days interval) demonstrated good yield performance and the potential for higher growth, highest quality, and high yield of Indian Spinach based on the aforementioned description. Hence, it is advisable to propose the use of Clybio at a concentration of 4 ml/L to stimulate Indian spinach production, potentially motivating farmers to consider cultivating this crop during the summer.

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A GEOSPATIAL ANALYSIS ON RIVER DYNAMICS IN UPPER ACTIVE BRAHMAPUTRA-JAMUNA FLOODPLAIN REGION, BANGLADESH

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Abstract

The hydro-geomorphic dynamism of the Brahmaputra-Jamuna River system in Bangladesh poses critical challenges for sustainable river management, given the country's vulnerability to climate change and riverbank erosion. The present study employs a longitudinal analysis of Landsat and Sentinel images from 1988 to 2023, integrated with Remote Sensing (RS) and Geographic Information Systems (GIS), to provide a temporal assessment of the river's dynamic behavior. Results reveal significant temporal and seasonal fluctuations in the riverbed's spatial extent, dynamism rate, and common area, underlining the system's inherent volatility. Between 1988 and 2023, the riverbed's area exhibited marked variability, ranging from 237.9537 km² to 365.8552 km². Seasonal evaluations also pinpointed pronounced changes, particularly in pre-monsoon and monsoon periods, revealing substantial variations in dynamism area and rates. The study uncovers intriguing patterns, such as the anomalous high dynamism area in 2020 and the surge in winter dynamism rate in 2022, calling for a deeper inquiry into potential climatic anomalies or anthropogenic influences and the need for ongoing monitoring and adaptive river management, particularly under increased environmental stress from climate change.

Key words: River dynamics; Time Series Analysis; Seasonal River Dynamics; Remote Sensing; River Management; SAR.

Introduction

Bangladesh is highly affected by global warming and climate change for its geographical location. Its vulnerability is heightened by its vast floodplains, proximity to the sea, and complex natural environment. A major challenge it faces is riverbank erosion, which significantly impacts the country's sustainability and the livelihoods of its people.

Geomorphological hazards, as described by Gares et al. (1994), refer to the earth's surface instabilities that threaten human settlements, especially in areas with dynamic landforms. In Bangladesh, significant rivers like the Meghna, Jamuna, and Padma have eroded about 1590 km² of floodplains since 1973, displacing around 1.6 million people. This erosion impacts floodplain residents and those living on temporary sandbars, known as char lands (Aktar, 2013). The Jamuna River, a significant part of Bangladesh's deltaic floodplain, has a complex geomorphic history. It originates from the Tibetan plateau and extends 2740 kilometers, joining the Ganges and Meghna before flowing into the Bay of Bengal. Despite its relatively stable course over the past 250 years, the river is known for its dynamic nature and braided structure, leading to unstable banks and high lateral movement. Climate change is expected to further influence Jamuna's hydrology, with predictions of increased discharge due to heightened rainfall and accelerated snowmelt in its catchment area (Rajib et al., 2011). The 4th IPCC Report projects more intense monsoon rains in South Asia, potentially worsening river flow and bank erosion (Rahman et al., 2010).

This research aims to elucidate the Brahmaputra-Jamuna river's historical dynamism, examining its water-spread area and seasonal variations as well as life cycle of watered area. Given the absence of comprehensive records on riverbank erosion, active channel areas, unvegetated bars, and vegetated islands, this study employs satellite imagery to bridge the gap. Specifically, it integrates Remote Sensing (RS) and Geographic Information Systems (GIS) to analyze Landsat images from 1988-2023 for historically water area shifting and Sentinel (SAR) images from 2017-2023 for seasonal dynamism. Besides life cycle of this river is also analysis to explore the whole scenario of water within a year. This analysis will provide insights into the active channel area and the patterns of shifting along the riverbanks.

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Methodology

Study Area

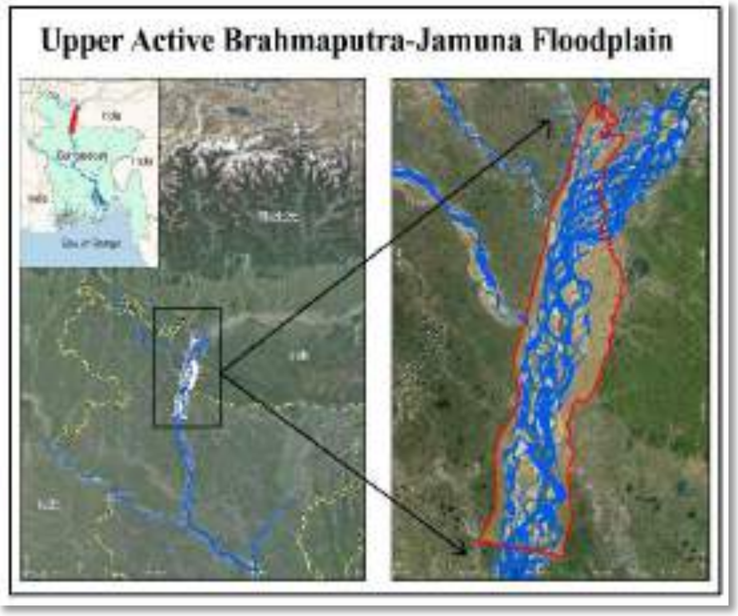


Figure 1: The Study Area

The Brahmaputra-Jamuna River system is a major river system in South Asia, originating from the Himalayas and entering Bangladesh after flowing through India, the Jamuna merges with the Ganges to form the extensive and fertile delta region, the Sundarbans, before emptying into the Bay of Bengal. Its major tributary in Bangladesh is the Teesta River.. It stands as one of the world's most expansive braided fluvial networks. Its geomorphological evolution is deeply intertwined with both climatic and tectonic forces. This active, braided river undergoes significant erosion and accretion, with 2000 to 3000 km of banks eroding yearly (Islam and Islam, 1985). Sarker (1996) and Bristow (1999) observed that following the 1770-1830 avulsion, the Jamuna initially had a meandering planform, predominantly braided in its upper reaches, and later developed into a fully braided planform. Coleman (1969) suggested that the increase in discharge due to the Teesta River's joining led to the Jamuna's braiding. The river's sediments negatively affect both the floodplain and charlands, leading to frequent migrations of char people due to extensive floods and erosion (Baqee, 1993; 1998). Notably, due to anomalous flooding events coupled with significant tectonic shifts, the Brahmaputra River began charting a new course in 1787, which is now recognized as the Jamuna (Uddin et al., 2011). Millions live along these dynamic riverbanks and on newly formed lands (Lein, 2000).

Table 1. The study area at a glance

Location	**:**	Eastern part of Kurigram, Gaibandha, Bogra, Sirajganj and Jamalpur districts.
Extent	:	1825 km²
Land type	:	Medium high land (flooded up to about 90cm deep during the flooding season): 37% Medium low land flooded between 90 and 180 cm deep during flooding season): 20% Others land: 43%
Organic matter content	:	Low
Fertility level	:	Low to middle
Suitable crops	:	Kharif: B. Aus, B. Aman, Jute, Kaon, T. Aman, Rabi: maize, Wheat, Sweet, Mustard, Potato, Cheena, Groundnut

Source: Moslehuddin et al, 2008; Rahman S. 2016

Data Collection

Satellite Image Selection: The study used images from Landsat satellites 4-5, 8, and 9, spanning from 1988 to 2023. These images were accessed through the USGS Earth Explorer website. Only images from the dry seasons were selected for analysis to focus on water content in vegetation during periods of low water availability.

NDWI Analysis: The selected images were analyzed using the Normalized Difference Water Index (NDWI). NDWI is a method used to measure the amount of liquid water in vegetation. This analysis involved using specific Near-Infrared and Infrared bands of light. NDWI values range from -1.0 (low water content) to 1.0 (high water content).

Atmospheric Correction: Atmospheric corrections were applied to the NDWI values. This step, following Chavez's 1996 methodology, improves accuracy by removing atmospheric effects that could distort the data.

Additional Satellite Data: The study also used data from the Sentinel satellites. These satellites have Synthetic Aperture Radar (SAR) sensor, which provides detailed images of the Earth's surface in all weather conditions.

Data Processing for Analysis: For a detailed analysis, specific Landsat datasets were used, namely LANDSAT/LT05/C01/T1_8DAY_NDWI and LANDSAT/LC08/C01/T1_32DAY_NDWI. The analysis was performed using Google earth engine in JavaScript programming language. This allowed for a comprehensive evaluation of the NDWI data throughout the year.

Table 2. Data Sources

Date (yyyy/mm/dd)	Resolution	Source Satellite	Date (yyyy/mm/dd)	Resolution	Source Satellite
1988/01/17	30m	Landsat 5	**2019/04/02**	10m	Sentinel 1
1993/01/17	30m	Landsat 5	**2019/07/07**	10m	Sentinel 1
1998/01/17	30m	Landsat 5	**2019/10/01**	10m	Sentinel 1
2003/03/05	30m	Landsat 5	**2020/01/03**	10m	Sentinel 1
2008/01/09	30m	Landsat 5	**2020/04/08**	10m	Sentinel 1
2014/02/02	30m	Landsat 8	**2020/07/01**	10m	Sentinel 1
2018/02/02	30m	Landsat 8	**2020/10/05**	10m	Sentinel 1
2023/02/18	30m	Landsat 9	**2021/01/09**	10m	Sentinel 1
2017/04/02	10m	Sentinel 1	**2021/04/03**	10m	Sentinel 1
2017/07/05	10m	Sentinel 1	**2021/07/08**	10m	Sentinel 1
2017/10/09	10m	Sentinel 1	**2021/10/02**	10m	Sentinel 1
2018/01/01	10m	Sentinel 1	**2022/01/04**	10m	Sentinel 1
2018/04/07	10m	Sentinel 1	**2022/04/10**	10m	Sentinel 1
2018/07/02	10m	Sentinel 1	**2022/07/03**	10m	Sentinel 1
2018/10/04	10m	Sentinel 1	**2022/10/07**	10m	Sentinel 1
2019/01/08	10m	Sentinel 1	**2023/01/01**	10m	Sentinel 1

Source: Landsat-5,8,9 image courtesy of the U.S. Geological Survey; ESA, 2023

Image analysis

Utilizing satellite images from 1988 and 2023, essential data about the study area is obtained. Figure 2 illustrates a detailed methodology for extracting information from LS images.

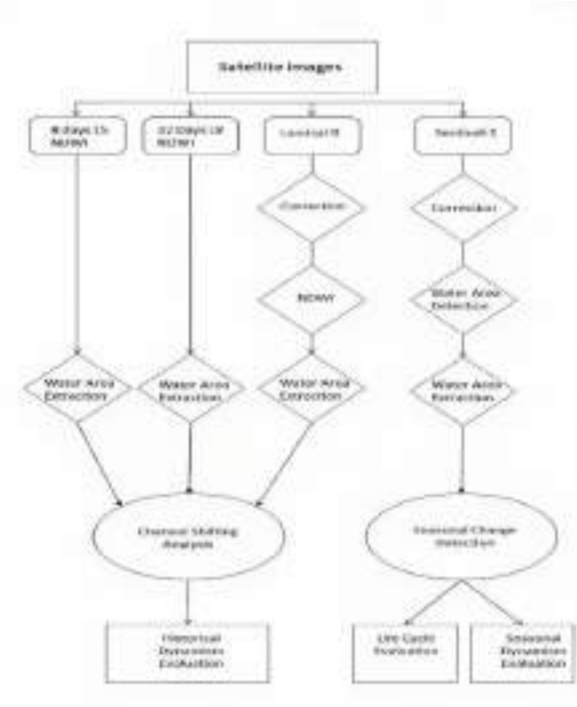


Figure 2 : Flow chart of data analysis

Landsat NDWI Analysis:

The Normalized Difference Water Index (NDWI) is a crucial tool for water detection and mapping, distinguishing water bodies from features like vegetation and barren land. It offers valuable data for various uses, including hydrological studies, urban planning, and environmental monitoring. For the Landsat satellites, the NDWI calculation is as follows:

$$NDWI= \frac{Green\ \ - Near\ Infrared}{Green\ + Near\ Infrared}$$

To facilitate the analysis of NDWI data, we employ the Google Earth Engine, utilizing its powerful JavaScript interface.

Demarcation of the channel of Brahmaputra-Jamuna River

From 1988 to 2023, satellite images have been used to identify and define river channels, employing NDWI images to distinguish them. Challenges in interpretation arise with newly deposited silt and sand near riverbanks, which may be confused with shallow water channels. In satellite imagery, darker tones indicate higher water content, while spots near active water channels show lower water content with brighter indications. NDWI helps differentiate between higher and lower moisture levels, not just the bank line and includes areas recently flooded as part of the river. ArcGIS Pro software was used to demarcate the Jamuna River channel for each year from 1988 to 2023, identifying both right and left banks using GIS software.

Sentinel-1 (SAR) data processing:

Google Earth Engine (GEE) serves as a vital platform for processing Synthetic Aperture Radar (SAR) data from Sentinel-1. GEE simplifies the handling of large SAR datasets through a suite of functions including preprocessing, analysis, visualization, and exporting. This efficient system accelerates the SAR data processing workflow and ensures precise analysis of extensive datasets.

The preprocessing of SAR data is crucial for removing noise, calibrating data, and rendering it meaningful. Four main key procedures are followed in this process:

1. **Radiometric Calibration**: This step adjusts the pixel values in the SAR image to accurately represent the true radar backscatter of the ground surface. It's critical for ensuring the accuracy and comparability of data across different images (Zebker and Goldstein,1986).
2. **Terrain Correction**: Given SAR data's sensitivity to topographical variations, this procedure corrects distortions caused by the terrain. This correction ensures the geometric accuracy of the data (Small, 2011).
3. **Speckle Filtering**: SAR images are prone to a granular 'salt and pepper' noise known as speckle. Filtering out this noise improves the quality of the image, making subsequent analyses more reliable (Lee, 1980).
4. **Geometric Registration**: This process aligns the SAR data with a reference image or map, ensuring spatial consistency and accuracy.

Post preprocessing, the focus shifts to image analysis tasks using the processed SAR data. These tasks include change detection, land cover classification, object detection, and time-series analysis. For these analyses, ArcGIS Pro offers a range of tools and algorithms, such as filters, statistical functions, and classification methods. The integration of Google Earth Engine for preprocessing and ArcGIS Pro for image analysis forms a comprehensive and efficient workflow, greatly enhancing the study of river morphology.

Historical and Seasonal Dynamism Evaluation:

To determine the historical dynamism rate, Landsat image NDWI-based water channel area analysis was used, and it is elaborated in Table 3. Sentinel-1 (SAR) images from four different months representing each season were utilized to assess the seasonal dynamism rate. The seasons considered are:

- Pre-Monsoon = April
- Monsoon = July
- Post Monsoon = October
- Winter = January

Table 3. Equation for dynamism

Title	Formula	Description
Exploring Common Area within a Period	$CA = TA_1 \cap TA_2$	CA is the common area, and TA_1 and TA_2 are the total areas at two different time points.
Identifying New Channels within the Period	$DA = TA_2 - CA$	Where DA represents the newly formed channel area.
Area Calculation	-	The area was calculated using ArcGIS Pro's built-in calculate geometry method.
Dynamism Rate Calculation	$DR = \frac{DA}{TA_2} \times 100\%$	This formula calculates the rate of change in the river channel over a specific period.
Yearly Dynamism Rate	$YDR = \frac{DR}{P}$	Where P is the period in years, this provides an annualized rate of change.

Results and Discussion

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

Historical Dynamism Evaluation:

From the analysis, a series of different Landsat images from 1988 to 2023 reveal the yearly rates of dynamism and their differences with different time in following figure & the tables:

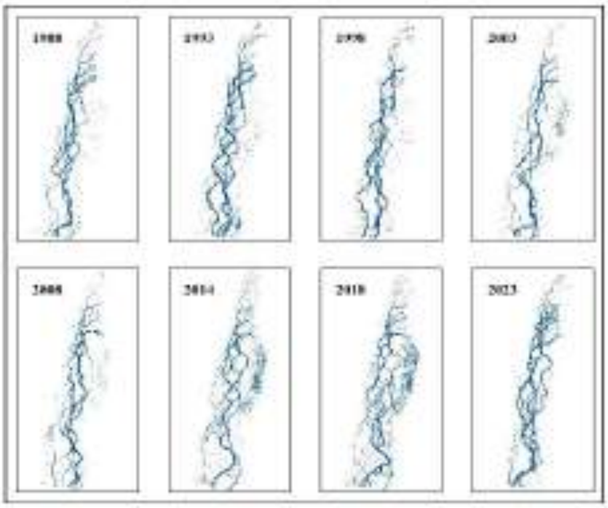
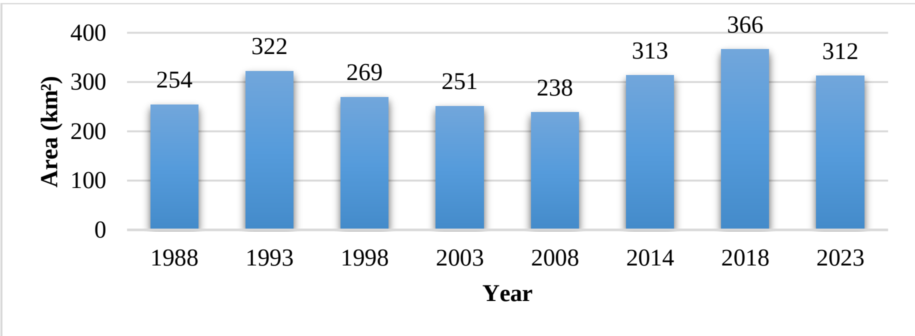


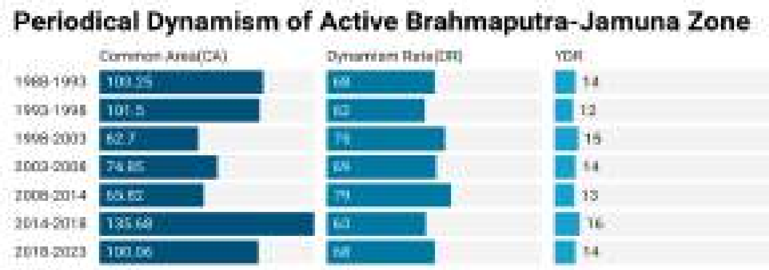
Figure 3: Historical River channel shifting in Active Brahmaputra-Jamuna of 1988 to 2023.

Figure 3 maps and Graph 1 present a temporal analysis of the riverbed's spatial extent, measured in km², over 35 years. Commencing in 1988 with an expanse of 254.0608 km², the riverbed experienced an expansion, reaching a peak of 322.1171 km² by 1993. Subsequent years witnessed a contraction, with the minimum extent of 237.9537 km² observed in 2008. A resurgence in the riverbed's area was noted post-2008, culminating in its zenith at 365.8552 km² in 2018. However, by 2023, a modest reduction brought the area to 312.6935 km². This temporal variability underscores the dynamic nature of fluvial systems and necessitates continuous monitoring for sustainable river management.

Graph 1. Total river channel area



The longitudinal analysis spanning from 1988 to 2023 revealed intriguing patterns in the common area (CA) and dynamism rates (both DR and YDR) across the studied periods.



The study area's common area (CA) showed significant changes over time. From a low of 62.69 km² in 1998-2003 to a high of 135.67 km² in 2014-2018, these fluctuations highlight the dynamic nature of the environment. The dip and subsequent rise in CA may indicate external impacts or natural cycles.

The dynamism rate (DR) varied between 62% and 79%, with the lowest in 1993-1998 and the highest in 2008-2014. This suggests significant environmental changes or disturbances in those periods, affecting ecosystem resilience and sustainability. The peak DR period may mainly reflect rapid changes or environmental stressors.

The yearly dynamism rate (YDR) was more consistent, ranging from 12% to 16%, indicating a relatively stable annual rate of change. Despite periodic disturbances, this consistency suggests the system maintains an annual equilibrium level, balancing stress and adaptation.

Seasonal Dynamism Evaluation:

While the year-to-year evaluation showed that the river maintains a semblance of equilibrium, seasonal dynamism presents a contrasting picture. Table 4 illustrates the details:

Table 4. Seasonal dynamism area and rate

Pre-Monsoon	Dynamism area	Dynamism Rate	Monsoon	Dynamism area	Dynamism Rate
2017	171.925	85%	2017	499.0905	80%
2018	158.4056	64%	2018	440.7947	70%
2019	176.0312	70%	2019	460.6473	68%
2020	692.4252	70%	2020	68.84869	10%
2021	269.6898	45%	2021	107.8881	23%
2022	399.8991	93%	2022	272.6061	52%

Post-Monsoon	Dynamism area	Dynamism Rate	Winter	Dynamism area	Dynamism Rate
2017	64.46942	18%	2018	49.48349	17%
2018	28.72332	9%	2019	48.81331	24%
2019	20.42409	7%	2020	133.2175	41%
2020	58.70818	17%	2021	149.3934	35%
2021	65.94857	30%	2022	55.12235	83%
2022	57.34716	22%	2023	140.7477	38%

Pre-Monsoon Dynamics:

The pre-monsoon period is crucial in the hydrological cycle of the Brahmaputra-Jamuna River system, setting the stage for the monsoon season. From 2017 to 2022, the dynamism area showed significant yearly changes. For example, 2020 had an unusually large dynamism area of 692.42 km², which might be due to prior moisture conditions or sediment movement from the previous year.

The dynamism rate followed a cyclical pattern. Notably, 2022 and 2017 had high dynamism rates of 93% and 85%, suggesting a period of intense geomorphic activity or possibly external human influences.

Monsoon Dynamics:

During the monsoon season, influenced by Southwest monsoon winds, the Brahmaputra-Jamuna system experiences significant hydrodynamic changes. In 2020, a shallow dynamism area of 68.84 km² was recorded, indicating a need to investigate climatic anomalies or upstream changes. From 2017 to 2020, there was a declining trend in dynamism rate, with a slight recovery afterward, pointing to potential alterations in sediment dynamics or river channel shifts.

Post-Monsoon Dynamics:

In the post-monsoon phase, the river system adjusts towards a hydro-geomorphic balance as the monsoon wanes. Dynamism areas during this time are typically lower, reflecting the river's recovery phase. Notably, 2019 and 2021 saw the lowest and highest dynamism areas, indicating varying rates of sediment deposition and channel migration. The dynamism rates fluctuated within a limited range, reflecting the river's tendency to stabilize after monsoon activity.

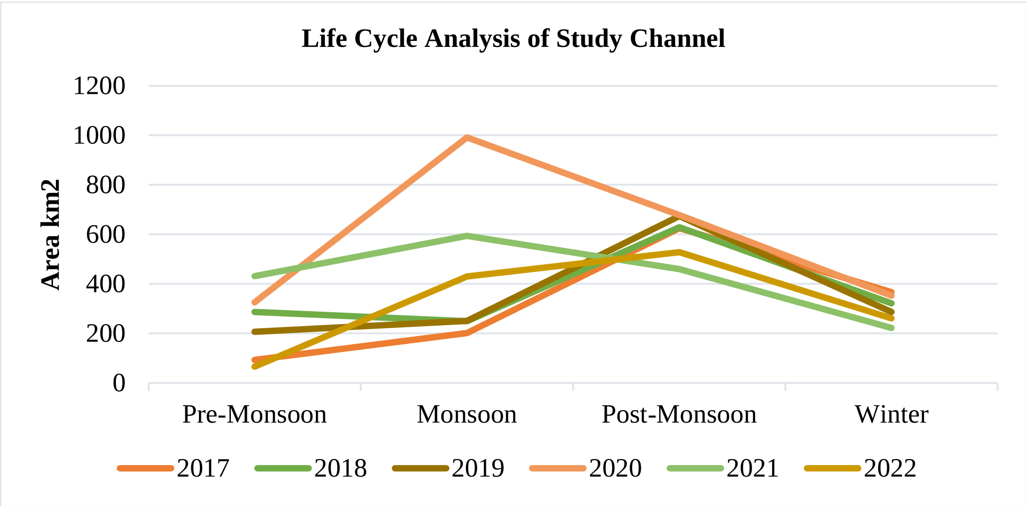
Winter Dynamics:

Reduced hydrological activity in the Brahmaputra-Jamuna basin's winter reveals the river's base flow and sediment dynamics. The dynamism area saw notable increases in 2020 and 2021, potentially due to factors like past seasonal impacts or glacial meltwaters. Despite the typically low activity, the dynamism rate in winter 2022 reached 83%, indicating intense, localized geomorphic processes possibly caused by sediment compaction, bank failures, or human impact.

Graph 2. Seasonal dynamism trend

Graph 2 describes the seasonal analysis reveals that the Brahmaputra-Jamuna River is most dynamic during the monsoon season, as expected due to the heavy rains. However, the significant dip in dynamism in 2020 suggests a possible anomaly or external factor that affected the river's behavior. The post-monsoon season consistently sees lower dynamism, implying a return to stability after the monsoon's tumult. Despite a relatively lower dynamism area, the high dynamism rate during the winter of 2022 points towards a more significant change within a smaller area, indicating a localized event or disturbance.

Life Cycle Analysis



Graph 3. Seasonal Life Cycle trend

Overall, annual volumetric fluctuations in the channel's water content exhibit relative consistency. Seasonal variations, however, are pronounced. Graph 3 shows that during the pre-monsoon phase, there is a marginal deviation in the water volume. Significant oscillations in the Monsoon period contrast this. Subsequent to this, the post-monsoon season witnesses a reduction in water volume, while the winter season consolidates the annual water volume. This pattern suggests that despite intra-annual variations, the cumulative annual volume remains relatively stable over successive years.

Conclusion

The Brahmaputra-Jamuna River's seasonal dynamism reflects its response to environmental changes, with important implications for river management and community safety. Over 35 years, the riverbed size varied significantly, from 254.0608 km² in 1988 to 312.6935 km² by 2023, highlighting the river's inherent fluctuation and the importance of continuous monitoring.

Seasonal analysis revealed diverse patterns. The pre-monsoon period predicts monsoon intensity, with notable fluctuations like the high dynamism in 2020. Monsoon seasons showed a decreasing trend in dynamism from 2017 to 2020, while post-monsoon and winter periods indicated more stable and localized geomorphic activities, respectively. These variations underscore the river's natural adaptations and the potential influence of external factors.

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ON-FARM TRIAL OF FOUR BOTTLE GOURD VARIETIES IN HILL VALLEYS OF BANDARBAN DISTRICT

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Abstract

A field experiment was carried out in the Bikricchara hill valleys of Bandarban district during the rabi seasons of 2020-21 and 2021-22 to assess the efficacy of four bottle gourd varieties (BARI Lau-3, BARI Lau-4, BARI Lau-5, and Hybrid Khet Lau) in farmers' fields. The experiment was designed as RCBD with six dispersed replications. The result exhibited that BARI Lau-4 was a standout performer, with the highest number of fruits per plant (9.42), maximum fruit weight (2.43 kg), and an impressive yield of 38.03 t ha^{-1}. Hybrid Khet Lau closely followed, with a yield of 31.16 t ha^{-1}, while BARI Lau-5 showed the lowest yield potentiality (24.47 t ha^{-1}) among all varieties. The highest gross return (501750 Tk. ha^{-1}), gross margin (352450 Tk. ha^{-1}), and benefit-cost ratio (BCR) (3.36) were observed in the BARI Lau-4. Overall, BARI Lau-4 and Hybrid Khet Lau showed promising potential for higher yields among varieties.

Key words: BARI Lau, BCR, Bottle gourd, Hill valleys, Varietal trial, Yield.

Introduction

In Bangladesh, bottle gourd is commonly called "Lau" or "Kodu", which is grown year-round on fields and homesteads throughout the country. During 2021-2022, the area under bottle gourd cultivation in Bangladesh was 20719 ha of land with 2.84 lakh tons of produce (BBS, 2022). Because of its culinary and medicinal benefits, it is also popular worldwide. The nutritional deficit will worsen if not enough vegetables are provided. Bottle gourd fruit has 12kcal of energy per 100g of fresh weight, 96.1% water, 0.2g protein, 2.5g carbs, 0.1g fat, 0.5g minerals, 0.3mg thiamine, 0.01mg riboflavin, and 0.2mg niacin (Singh *et al.,* 2008). Commercial production of bottle gourds in hilly locations may be the best option to meet the daily demand for vegetables. As a result of the high demand in the international ethnic market, Bangladesh may soon be exporting vegetables (BBS, 2022). This plant has also been associated with a range of properties that are advantageous for human health (Yash *et al.,* 2014) and beneficial against cough, asthma, bronchial problems, ulcers, and fever (Upaganlawar and Balaraman, 2010).

Nowadays, climate change is intricately linked to issues like crop productivity, soil erosion, land and forest degradation, mostly in hilly areas (Hossain, 2011). Bottle gourds have various possible environmental adaptations due to their high morphological and genetic characteristics (Koffi, 2009). In Bandarban, farmers are used to cultivating local bottle gourd varieties, which are generally low-yielders. Different new commercial varieties are also being introduced among the farmers at different times. Moreover, BARI has developed some high-yielding bottle gourd varieties from which BARI Lau-3, BARI Lau-4, and BARI Lau-5 found promising in different multi-location trials nationwide. However, the performance of these varieties has not yet been evaluated in this region. This was the primary consideration of the trial to explore their adaptability and profitability in the unique climate and soil conditions of the hill valleys of Bandarban.

Materials and Methods

Experimental site: The experimental study was carried out in the Bikricchara hill valleys of Bandarban Sadar Upazila, located at coordinates 22°13'31" N and 92°12'48" E. This area is representative of the Agro-Ecological Zone 29 (AEZ-29). The experimental trials were conducted over two consecutive years, specifically from 2020-2021 and 2021-2022, encompassing the winter season. The experiment site is categorized as a lower hill medium slope, with a soil texture of clay loam and a relatively low organic matter content of 2.72%. The pH of the soil is measured at 5.90. The average temperature ranged from 18°C to 31°C during the experimental period, and the total rainfall was 782 mm in 2020-2021 and 1270 mm in 2021-2022.

Designs and treatments: The experiment was laid out in a randomized complete block design (RCBD) with six dispersed replications (each farmer's field represented as a replication). A hybrid cultivar of Lau (Khet Lau from Lal Teer) was chosen as a control, while BARI Lau-3, BARI Lau-4, and BARI Lau-5 were utilized as the remaining three experimental treatments. The dimension of the unit plot was 15 m × 14 m, which was assigned

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for each variety, and the spacing between pit-pit within the plot was 2 m×2 m. Two plants were allowed in each pit to grow.

Crop management: Seeds were sown on 03 December, 2020 and 15 November, 2021. Fertilizers were applied at the rate of 81-30-87-19-4-2 NPKSZnB kg ha^{-1} in the form of urea, TSP and MoP, Gypsum, Zinc, and Borax, respectively. Cowdung was applied @ 5.0 t ha^{-1}. Half of the cow dung and MoP, and the total amount of TSP were applied as basal during final land preparation. The remaining half of cow dung was applied during pit preparation. The entire urea and remaining MoP were applied 10, 25, and 40 days after transplanting. The field was irrigated three times on the same day of top dressing. Two weddings were done at 40 and 56 DAT. The crops were harvested from March to April in both years. Data on yield and yield contributing character were recorded and analyzed statistically. Data were collected on the number of fruits $plant^{-1}$, fruit length, fruit diameter, single fruit weight, and yield ha^{-1}.

Cost-return analysis: The calculation of cost and return assessments determined gross margin and benefit-cost ratio (BCR). The cost, return, and benefit-cost ratio (BCR) were calculated based on the market price of all the applied inputs and the wholesale prices of the produce.

Data analysis: The statistical analyses were conducted using the STATISTIX 10 statistical program. The analysis of variance (ANOVA) was conducted to assess the differences between treatments. The Least Significance Difference (LSD) test, as Gomez and Gomez (1984) proposed, was employed at a significance level of 5%.

Results and discussion

Fruit length: In the growing season 2020-2022, the fruit length was measured and found significant. Among varieties, the highest fruit length was found in Hybrid Khet Lau (46.32 cm), followed by BARI Lau-4 (43.21 cm) and BARI Lau-5 (42.77 cm), while BARI Lau-3 (38.05 cm) was the shortest. Quamruzzaman *et al.* (2017) found that the length of BARI Lau-4 (43.67cm) was higher than that of BARI Lau-3 (34.00cm).

Fruit diameter: The thickest fruit was found from BARI Lau-4 (15.41 cm), followed by Hybrid Khet Lau (14.65 cm) and BARI Lau-3 (13.82 cm). BARI Lau-5 (13.32 cm) was the thinnest among them. The diameter of the fruits from these four varieties was close to each other. However, some studies revealed that different bottle gourd genotypes might also vary significantly, ranging from 6.47 cm to 16.3 cm (Harika *et al*., 2012).

Single fruit weight: A significant difference was observed in single fruit weight. Among varieties, BARI Lau-4 had the highest fruit weight (2.43 kg), and BARI Lau-5 showed the lowest (1.89 kg). Quamruzzaman *et al.* (2019) also found more fruit weight in BARI Lau-4 (2.11 kg) over BARI Lau-3 (2.10 Kg), and Masud *et al.* (2021) revealed a wide range (1.31kg to 2.04kg) of fruit weight while working with twenty-one cross combinations to select parental bottle gourd materials.

Number of fruits per plant: In the growing season 2020-2022, significant variation was observed in fruit number among varieties. The number of fruits per plant was higher in BARI Lau-4 (9.42), and the lowest was found in BARI Lau-3 (7.49). Masud *et al.* (2021) found that fruit numbers may vary significantly in different lines and varieties from 3.03 to 11. Akhtar *et al.* (2015) observed a similar fruit number range (6.26-8.5) in BARI Lau-3 for different USG and NPK briquette applications.

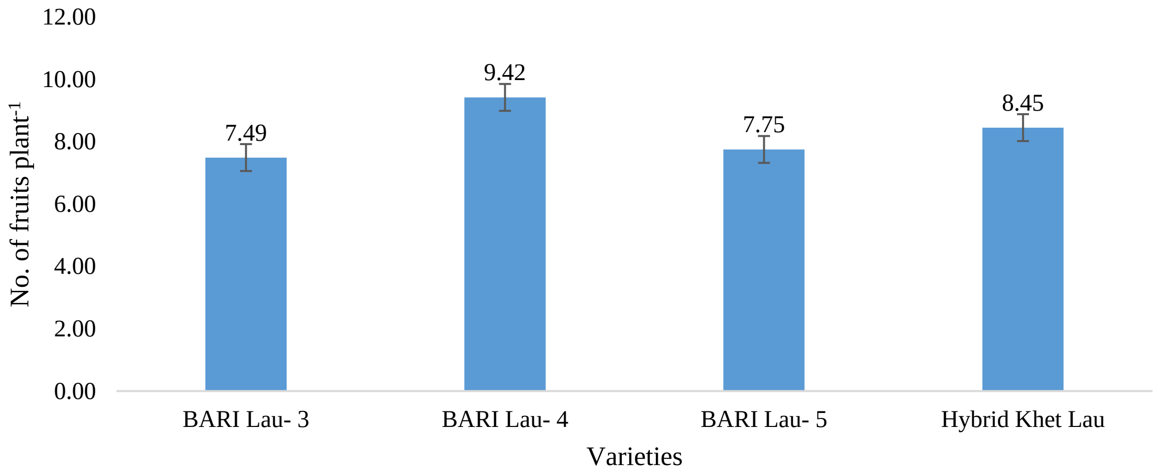

Figure 1. No. of fruits $plant^{-1}$ of bottle gourd varieties at hill valleys of Bandarban district

Yield: BARI Lau-4 showed the highest yield potentiality (38.03 t ha^{-1}) among all varieties, followed by Hybrid Khet Lau (31.16 t ha^{-1}) and BARI Lau-5 exhibited the lowest yield potentiality (24.47 t ha^{-1}). In a study conducted by Uddin *et al.* (2014), it was observed that the yield performance of eleven bottle gourd lines varied from 18.1 t ha^{-1} to 54.9 t ha^{-1}, and our yield performance was within this range for all varieties. Another study by Quamruzzaman *et al.* (2019) showed that the BARI Lau-4 exhibited a higher yield of 34.00 t ha^{-1} compared to the BARI Lau-3, which yielded 29.93 t ha^{-1}.

Table 1. Yield and yield attributing characteristics of the bottle gourd varieties in the hill valleys of Bandarban during the Rabi season of 2020-2021 and 2021-2022 (pooled)

Treatment	Fruit length (cm)	Fruit diameter (cm)	Single fruit wt. (kg)	Yield (t ha^{-1})
BARI Lau- 3	38.05	13.82	2.11	26.78
BARI Lau- 4	43.21	15.41	2.43	38.03
BARI Lau- 5	42.77	13.32	1.89	24.47
Hybrid Khet Lau	46.32	14.65	2.26	31.16
CV (%)	3.73	7.27	8.01	10.39
LSD (0.05)	3.17	2.08	0.35	6.25

Cost return analysis: Cultivation of bottle gourd was profitable in the hill valleys of Bandarban. Highest gross return (Tk.ha^{-1}), gross margin (Tk.ha^{-1}), and BCR were obtained from BARI Lau-4 (501750 Tk.ha^{-1}, 352450 Tk.ha^{-1} and 3.36, respectively) followed by Hybrid Khet Lau (411690 Tk.ha^{-1}, 262390 Tk.ha^{-1} and 2.76, respectively) and BARI Lau- 3 (349950 Tk.ha^{-1}, 200650 Tk.ha^{-1} and 2.34, respectively). Economic return from BARI Lau-5 was lowest in terms of gross return (323100 Tk. ha^{-1}), gross margin (173800 Tk. ha^{-1}), and BCR (2.16). Hasan *et al.* (2014) also depicted the profitability of bottle gourd in Mymensing, Cumilla and Rajshahi districts. A decade ago, Khayer *et al.* (2011) found that bottle gourd production cost was even lower at 105344 Tk. ha^{-1} in Mymensingh in 2009. Chandra *et al.* (2020) revealed a relatively high variable cost (190425 Tk. ha^{-1}) for summer bottle gourd production with a high gross margin (483175 Tk. ha^{-1}) and BCR (3.54). Haque *et al.* (2021) observed the effect of irrigation in bottle gourd where irrigation at three times intervals costs about 175590 Tk. ha^{-1} with a gross margin of 676500 Tk. ha^{-1} and a BCR of 3.29, which has similarity in terms of profitability with BARI Lau-4.

Table 2. Cost-return analysis of bottle gourd varieties at Bikricchara hill valleys of Bandarban during the Rabi season of 2020-2021 and 2021-2022 (pooled)

Treatment	Yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total variable cost (Tk. ha^{-1})	Gross margin (Tk. ha^{-1})	BCR
BARI Lau- 3	26.78	349950.00	149300.00	200650.00	2.34
BARI Lau- 4	38.03	501750.00	149300.00	352450.00	3.36
BARI Lau- 5	24.47	323100.00	149300.00	173800.00	2.16
Hybrid Khet Lau	31.16	411690.00	149300.00	262390.00	2.76

Price (Tk. kg^{-1}): 12 (2021) and 15 (2022)

Conclusion

BARI Lau-4 is an excellent variety in size, shape, color, and bearing, which performed best among other varieties in the hill valleys of Bandarban for consecutive years from 2020 to 2022.

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STUDY ON BIOLOGY OF MANGO MEALYBUG AND THEIR CHEMICAL CONTROL IN LABORATORY

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Abstract

The experiment was conducted at Entomology laboratory of Sher-e-Bangla Agricultural University campus Dhaka during the period from September, 2021 to June, 2022 to study the biology and chemical control of mango mealybug *Drosicha mangiferae* (Green). Seven chemical insecticides treatments viz. T_1 = Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water, T_2 = Karate 2.5 EC(Lambda Cyhalothrin) @ 1ml/L of water, T_3 = Imitaf 20 SL (Imidacloprid) @0.5ml/L of water, T_4 = Ripcord 10 EC (Cypermethrin) @1ml/L of water, T_5 = Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water, T_6 = Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water, T_7 = Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @0.5gm/L of water and T_0= Untreated control were tested on mealybug. In laboratory, completely randomized design (CRD) with three replications was used. The color of the first, second and third instar nymphs are recorded as yellowish, grey brown with black and greenish respectively with their mean lengths and breadth 0.67±0.09 mm and 0.41±0.05 mm; 0.92±0.04 mm and 0.55±0.05 mm; 1.06±0.13 mm and 0.69±0.04 mm respectively. The crimsoncoloured adult male are 1.38±0.10 mm and 0.78±0.03 mm in length and width respectively. Adult female bugs are white colour, elliptical shape and body is covered with numerous minute hairs. Female bugs are 2.18±0.28 mm and 1.35±0.15 in length and width respectively. The longevity of first, second and third instar nymph are 49.33±2.52, 23.00±1.73 and 13.00±2.00 days where the longevity of adult male and female are 3.33±1.15 and 14.00±1.36 days respectively. Karate 2.5 EC (Lambda Cyhalothrin) was the most effective insecticide against mango mealybug which reduced maximum population of mango mealybug (93.67% after 12, 24, 36, 72 hours of spray followed by Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) 93.25% after 12, 24, 36, 72 hours of spray.

Key words: Mango mealybug, Biology, Instar, longevity, Chlorantraniliprole.

Introduction

Mango (*Mangifera indica* L.), the king of fruits is a member of family Anacardiaceae and is known for its strong aroma, delicious taste and high nutritive value (Sahoo and Jha, 2009). Mango ranks third in terms of production and first in terms of area in Bangladesh. Insect pests are the major threat to the mango production accounting for huge seasonal loss (Ishaq *et al.,* 2004). Mangos are attacked by a variety of insects from the fruit's development to maturity. Grossly, 400 insects and non-insect pests have been recorded from Indian subcontinents as pests. Among all of the mango insect pests, mealybug (*Drosicha mangiferae*) is one of the notorious and destructive pests rendering huge scale of fruit loss (Karar *et al.* 2006). The mango mealy bug, *Drosicha mangiferae* (Green) is a severe and destructive pest of mango, *Mangifera indica* (Rao *et al.,* 2006; Arora and Gupta *et al.,* 2021) due to its larger range, rapid dissemination, and polyphagous nature (Gupta et al. 2021). It adversely influences fruit yield both quantitatively and qualitatively due to its infestation by nymphs and female bugs on roots, tender leaves, twigs, inflorescence and fruits. It secretes honeydew, which leads to the following growth of sooty mold (Bhagat, 2004, Ibrahim *et al.* 2021). Mealy bugs are difficult to control with insecticides because of their waxy covering as adults and their tendency to aggregate and settle in cracks and crevices as nymphal instars (Lo and Walker 2011; Gupta et al. 2021; Subramanian et al. 2021). (Mani and Shivaraju, 2016). The mode of transfer and infestation usually occurs through the crawlers that are transferred by wind, rains, birds, ants, clothing and vehicles and settled on new plants. In addition to destroying crops, an alarming number of mischievous insects that release sticky honeydew and sooty mold cause buildings to be defaced (Arora and Gupta, 2021). Meanwhile, newly hatched nymphs climb trees, settle on inflorescences, and feed by sucking sap, which results in flower drop and interferes with photosynthetic activity (Pruthi and Batra, 1960). Severe infestation often leads to fruit drops or makes the fruit unfit for marketing (Karar *et al*., 2013). Further the sooty mould of *D. mangiferae* provides an effective medium for rapid growth of black and sooty fungi which decolorizes the fruit and makes it unacceptable to consumer (CABI, 2005). All over the world scientists are working to find out the chemical control strategies to overcome the yield losses in crop plants due to mealybug attack. Knowledge of the life history of an insect is very

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helpful in predicting its development, emergence, distribution and abundance. This information can further assist to device appropriate management tactics. It is important to study its life history of this mealybug. Management of mealybugs is often difficult because plant protection products are of limited effectiveness against mealybugs because of the presence of waxy covering of its body. Therefore, it is needed to determine the damage severity of this pest in Bangladesh and to develop sustainable management practices for this pest. However, a very few scientific and continues research work have been done in Bangladesh to find out the proper biology of *D. mangiferae* and to screen the insecticides from different groups for their efficacy against *D. mangiferae*. The present research was conducted to investigate biology of *D. mangiferae* under laboratory conditions and to determine the efficacy of some chemical insecticides against *D. mangiferae*.

Materials and Methods

Experimental site:

The above experiment was conducted in the entomology laboratory of Sher-e-Bangla Agricultural University, Dhaka.

Insecticides applied in laboratory:

T_1 = Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water
T_2 = Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water
T_3 = Imitaf 20 SL (Imidacloprid) @ 0.5ml/L of water
T_4 = Ripcord 10 EC (Cypermethrin) @1ml/L of water
T_5 = Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water
T_6 = Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @ 1gm/L of water
T_7 = Capture 75 WDG (Imidacloprid 70%+ Emamectin benzoate 5%) @ 0.5gm/L of water

Insect collection:

The adult mealybugs were collected from different mango plants which are not sprayed with any insecticide for last one month. The mango plants were twelve-year-old and situated in the area of Sher-e-Bangla Agricultural University. These insects were brought to the Entomology laboratory and keep in the transparent plastic jars covered with porous white cloth for aeration. Inside the jars, leaves of mango with soft branches were given to the insects for feeding.

Sample size: 20 mealy bugs are used as a sample for biology study in laboratory.

Data collection:

Survival and molt of the crawlers, developmental time of each instar, determination of the pre-reproductive and reproductive periods, fecundity and longevity, mortality rate as affected by different insecticides.

Statistical analysis:

The data collected on different parameters were statistically analyzed using the Statistix 10 computer package. Mean values were ranked and compared by Least Significant Difference (LSD) at 5 % level of significance (Gomez and Gomez, 1984).

Results and Discussion

The observations were recorded on the change in population size at each day up to the end of the generation. The mango mealy bug, *D. mangiferae* (Green) comes under the order Hemiptera, Family Margarodidae (Coccidae).

Measurement of the body size of different life stages of mango mealy bug, *D. mangiferae*

The freshly emerged first instars nymphs were delicate, elliptical and pink in colour. Male and female could not be differentiated at this point. First instar nymph was very active and yellowish color. The length of first instar nymph was recorded as (0.67±0.09 mm) whereas, breadth of first instar nymph was recorded as (0.41±0.05 mm) (Table 1). Miller and Miller (2002) reported that in first instar gender could not be determined and nymph is yellow color which is similar to the present findings. They also reported that the length and breadth of nymph was 0.4 mm and 0.2 mm which is close to the present findings. The present findings are in close conformity with the findings of Rahman and Latif (1944), who reported that 1.31 – 2.23 mm length and 0.70 – 1.19 mm breadth of first instar nymphs of *D. mangiferae*.

The second instar nymph colour was dull, grey brown with black colour. The mean length of second instar nymphs is 0.92±0.04 mm whereas mean width is 0.55±0.05 mm, respectively (Table 1). The above finding corroborates with the reports of Beesan (1941).

Third instar nymphs were greenish in colour and the mean lengths of third instar nymphs is 1.06±0.13 mm whereas mean width is 0.69±0.04 mm, respectively (Table 1).

Our findings are partially supported by Singh *et al*. (2015). They found that the nymphs were greenish in colour and the mean lengths of third instar nymphs ranged from 5.08-7.70 mm whereas; mean width ranged from 2.78 to 3.72 mm.

The above findings are in close conformity with Rahman and Latif (1944). Rahman and Latif (1944) and Chandra *et al.,* (1989) support the present investigation on third instar nymph lengths and breadth of the *D. mangiferae* who reported that the body length varied from 4.55 to 7.7 mm and greatest breadth 2.5 to 3.7 mm.

Adult male bug was observed that it was crimson colored with brownish black fore wings. Body shape was elongated. Hind wings were reduced to small-flattened halters. It was observed that the length and width of adult's male was 1.38±0.10 mm while width was 0.78±0.03 mm, respectively (Table 1). Rahman and Latif (1944) support the present finding.

Adult female bugs are white in colour, elliptical in shape and body is covered with numerous minute hairs. It was evident that length of female bug 2.18±0.28 mm whereas, mean width 1.35±0.15 mm, respectively (Table 1).

Table 1. Measurement of the body size of different life stages of mango mealy bug, *D. mangiferae*

Stage	**Average ± SD**	
	Length (mm)	**Breadth (mm)**
1st instar nymph	0.67±0.09	0.41±0.05
2nd instar nymph	0.92±0.04	0.55±0.05
3rd instar nymph	1.06±0.13	0.69±0.04
Adult male	1.38±0.10	0.78±0.03
Adult female	2.18±0.28	1.35±0.15

Measurement of the longevity of different life stages of mango mealy bug, *D. mangiferae*

First instar stage male and female could not be distinguished. First instar nymph was very active and yellowish color. The longevity of first instar nymph was recorded 49.33±2.52 days was observed (Table 2). Rahman and Latif (1944) and Chandra et al., (1989) support the present investigation on first instar nymph lengths, width and live days.

The longevity of second instar nymphs 23.00±1.73 days was observed (Table 2). Rahman and Latif (1944) and Chandra et al. (1989) support the present investigation on second instar nymph lengths, width and live days.

The longevity of third instar nymphs 13.00±2.00 days was observed (Table 2). Rahman and Latif (1944) and Chandra et al. (1989) support the present investigation on third instar nymph live days who reported that the nymphal period was completed in 10-12 days;

The longevity of adult male 3.33±1.15 days was observed and the adult female bug longevity 14.00±1.36 days (Table 2). Singh et al. (2015) also found similar result close to our findings. They observed that, the longevity of female bug was 9.33 to 53.67 days while adult male bug was 4.33 to 7.0 days.

Table 2. Measurement of the longevity of different life stages of mango mealy bug, *D. mangiferae*

Life stages	**Observations**	**Duration (days) Average±SD**
1st instar nymph	3	49.33±2.52
2nd instar nymph	3	23.00±1.73
3rd instar nymph	3	13.00±2.00
Adult male	3	3.33±1.15
Adult female	3	14.00±1.36

Effect of different treatments on the mortality of mango mealybug

At different hours of insecticides spraying statistically significant variation ($p>0.05$) was recorded for mortality of mealybug due to different insecticides practices (Table 3) at after different hours of insecticides spraying. After 12 hours of insecticides spraying, the lowest number of mortality (0.33) was found from T_0 (Untreated control) which was statistically different (5.67) with T_7 (Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @0.5gm/L of water) and (6.00) with T_6 (Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water) and (7.33) with T_4 (Ripcord 10 EC (Cypermethrin) @1ml/L of water) treatments respectively.

On the other hand, the highest number of mortality was recorded in (14.33) T_2 (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water) which was statistically similar with T_5 (12.33) (Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water) with identically similar from T_1 (12.00) (Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water) and T_3 (10.33) (Imitaf 20 SL (Imidacloprid) @0.5ml/L of water) treatment.

After 24 hours of insecticides spraying, the lowest number of mortality (1.17) was found from T_0 (Untreated control) which was statistically different (7.33) with T_7 (Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @0.5gm/L of water) and (10.00) with T_4 (Ripcord 10 EC (Cypermethrin) @1ml/L of water) and (10.33) with T_6 (Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water) treatments respectively.

On the other hand, the highest number of mortality was recorded in (18.00) T_2 (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water) which was statistically similar from T_5 (16.33) (Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water) with identically similar from T_1 (14.33) (Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water) and T_3 (14.00) (Imitaf 20 SL (Imidacloprid) @0.5ml/L of water) treatment.

Table 3. Effect of different treatments on the mortality of mango mealybug

Treatment	Number of mealybugs died (mortality) after different hours of insecticides spraying				Mean	Increased over control
	12 h	24 h	36 h	72 h		
T_1	12.00 b	14.33 ab	17.67 ab	20.00 a	16.00 bc	92.88
T_2	14.33 a	18.00 a	19.67 a	20.00 a	18.00 a	93.67
T_3	10.33 b	14.00 bc	16.67 a-c	20.00 a	15.25 c	92.52
T_4	7.33 c	10.00 d	14.33 bc	20.00 a	12.92 d	91.18
T_5	12.33 ab	16.33 ab	18.67 a	20.00 a	16.83 ab	93.23
T_6	6.00 c	10.33 cd	14.67 bc	19.00 ab	12.50 d	90.88
T_7	5.67 c	7.33 d	13.33 c	17.33 b	10.92 e	89.56
T_0	0.33 d	1.17 e	1.51 d	1.55 c	1.14 f	--
CV (%)	**7.45**	**10.29**	**7.75**	**3.54**	**3.87**	**--**
LSD $_{(0.05)}$	**2.02**	**3.70**	**3.55**	**1.93**	**1.58**	**--**

[T_1 = Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water, T_2 = Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water, T_3 = Imitaf 20 SL (Imidacloprid) @0.5ml/L of water, T_4 = Ripcord 10 EC (Cypermethrin) @1ml/L of water, T_5= Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water, T_6 = Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water, T_7 = Capture 75 WDG (Imidacloprid 70%+ Emamectin benzoate 5%) @ 0.5gm/L of water, T_0= Untreated control]

After 36 hours of insecticides spraying, the lowest number of mortality (1.51) was found from T_0 (Untreated control) which was statistically different (13.33) with T_7 (Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @ 0.5gm/L of water) and (14.33) with T_4 (Ripcord 10 EC (Cypermethrin) @1ml/L of water) and (14.67) with T_6 (Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water) and treatments respectively.

On the other hand, the highest number of mortality was recorded in (19.67) T_2 (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water) which was statistically similar with T_5 (18.67) (Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water) with identically similar from T_1 (127.67) (Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water) and T_3 (16.67) (Imitaf 20 SL (Imidacloprid) @0.5ml/L of water) treatment.

After 72 hours of insecticides spraying, the lowest number of mortality (1.55) was found from T_0 (Untreated control) which was statistically different (17.33) with T_7 (Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @0.5gm/L of water) and (19.00) with T_6 (Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water) treatments respectively.

On the other hand, the highest number of mortality was recorded in (20.00) T_2 (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water) which was identically similar from T_5 (20.00) Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water) with identically similar from T_1 (20.00) (Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water) and T_3 (20.00) (Imitaf 20 SL (Imidacloprid) @0.5ml/L of water) and (20.00) with T_4 (Ripcord 10 EC (Cypermethrin) @1ml/L of water) treatment.

After 72 hours of insecticides spraying, the lowest number of mean mortality (1.14) was found from T_0 (Untreated control) which was statistically different (10.92) with T_7 (Capture 75 WDG (Imidacloprid 70%+Emamectin benzoate 5%) @0.5gm/L of water) and (12.50) with T_6 (Fame 70 WDG (Imidacloprid 60% + Acetamiprid 10%) @1gm/L of water) and (12.92) with T_4 (Ripcord 10 EC (Cypermethrin) @1ml/L of water) treatments respectively.

On the other hand, the highest number of mortality was recorded in (18.00) T_2 (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water) which was statistically similar with T_5 (16.83) (Voliam Flexi 300 SC (Chlorantraniliprole + Thiamethoxam) @ 0.5 ml/L of water) with identically similar from T_1 (16.00) (Nitro 505 EC (Chlorpyrifos + Cypermethrin) @1ml/L of water) and T_3 (15.25) (Imitaf 20 SL (Imidacloprid) @0.5ml/L of water) treatment.

Number of mortality reduction over control in number was estimated and the highest value was found from the treatment T_2 (93.67%) which was followed by T_5 (93.25%), T_1 (92.88%) and T_3 (92.52%) treatments and the minimum reduction over control from T_7 (89.56%) treatment.

Our research findings are partially supported by Afzal et al. (2018). They found that, methidathion produced significantly higher mortality of 73.57% seven days after treatment while mortality due to bifenthrin was 59.996% four days after treatment but it decreased to 20% seven days after treatment. Profenofos produced higher mortality (58.07%) seven days after treatment but it was significantly less as compared to methidathion. Carbosulfan showed good results four days after treatment with 59.81% mortality

Conclusion

The experiment is concluded with a clear perception of the biology of mango mealybug, which benefited from applyingthe insecticides timely to control this notorious pest. The mealybug mortality data showed how well various insecticides and their combinations worked to reduce the mealybug population. . The longevity of the adult male was 3.33 days, and the adult female bug longevity was recorded at 14.00 days. The first instar, second instar, and third instar nymphal longevity were recorded at 49.33, 23.00 and 13.00 days, respectively, in laboratory conditions. The highest mortality (18.00) was recorded in T_2 treatment (Karate 2.5 EC (Lambda Cyhalothrin) @ 1ml/L of water), and the lowest mortality (1.14) was found in T_0 (untreated control).

Conflict of Interest

The authors declare that there is no conflict of interest.

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IMPACT OF DIFFERENT LIQUID MANURE ON GROWTH AND YIELD OF WATER SPINACH

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Abstract

The experiment was conducted at Horticultural Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period of September to October 2023. The single factor experiment was laid out in randomized complete block design (RCBD) with three replications to study the growth and yield of water spinach. The experiment was consisted of five treatments namely; T_1: Control (only same amount of water spray); T_2: Vermi Tea (VT), T_3: SAU-MLM, T_4: SAU-NLM and T_5: SAU-PLM. Treatments were applied to plants four times every 10 days interval from 7 days after seed germination. A significant variation was found among the parameters. The average tallest plant (42.1 cm), maximum SPAD Value (40.9), maximum leaf area (42.1 sq cm), Root length (12.1 cm) maximum root number (35.0), highest yield per plant (57.0 g) and highest yield per ha (11.1 ton) was found in ($T_{5)}$ application while shortest plant (24.3 cm), minimum SPAD Value (32.8), minimum leaf area (12.8 sq cm), lowest yield per plant (12.0 g) and the lowest yield per ha (4.4 tons) was found in ($T_{1).}$ Therefore, it can be concluded that SAU-PLM is easy and effective liquid manure that has the potential to increase the entire growth and yield of water spinach.

Key words: *Ipomoea aquatica*, Organic production, Safe food, Zero carbon and Liquid manure.

Introduction

Water spinach (*Ipomoea aquatica*) is a semi-aquatic, tropical plant grown as a vegetable for its tender shoots and very popular in Bangladesh. Propagation is either by planting cuttings of the stem shoots, which will root along nodes, or by sowing the seeds from flowers that produce seed pods. Poor soil usually contains low concentrations of soil nutrients, has a low or high pH, and has low soil enzyme activity (Li *et al*., 2017). Such soil has low fertility and yields less food. Huge areas of cultivated fertile soil have degraded into poor soil due to the rapid advancements in industry, agriculture, and population increase (Shu *et al*., 2013). Many recently reclaimed sections of soil, the majority of which are bad soils, have been put to use for plant cultivation. Many studies have shown that soil quality can be improved by applying organic matter (Barzegar *et al*., 2002). The consensus holds that organic matter is a crucial soil component for improving the physical properties of soil and that returning organic matter to soil can increase the content of soil active organic carbon (AOC) and improve soil vitality (Li *et al*., 2017). However, organic matter alone, which lacks adequate available nutrients, exerts slow and variable effects on crop growth (Khaliq *et al*., 2006). Agricultural intensification is believed to cause acidification, loss of organic matter, nutritional value loss, weathering, soil compaction, and xenobiotic accumulation, among other things (Niemiec *et al*., 2020). In addition, 'pollution' has become an issue due to the abuse of chemical growth regulators and fertilizers. For life to persist, there must be a natural balance between property and life (Elayaraja and Vijai, 2020).

The agricultural method known as organic farming emphasizes the well-being of the land, plants, food, and environment over crop productivity. It is believed that organic farming is a more environmentally beneficial alternative because it utilizes only organic fertilizers and natural insecticides, if any (Gong *et al*., 2022). Then Higher prices in fresh markets for organically grown vegetables than for conventionally grown vegetables encourage farmers to grow vegetables organically (AL-Kahtani *et al*., 2018).

Seed germination is excellent with Jeevamrutha, organic liquid manure. It's made with native cow's urine, dung, horse gram, and jaggery, and using cow-based products is a time-honored agricultural tradition (Bharadwaj, 2021). Organic manures improve the soil's physical, biological, and chemical properties, improving fertility, productivity, and water holding capacity (Verma *et al*., 2019). The present objective is to use Jeevamrutha to develop nutritious organic water spinach crops and evaluate its effect on the growth and productivity of the water spinach. In Bangladesh, farmers commonly use synthetic fertilizers for commercial water spinach production and use excess fertilizers to increase yield. As a result, water spinach yields more, but the crop loses flavor and nutritional value, sometimes posing health risks. Excessive fertilizers destroy the health of the soil as well as slowly degrade the environment. Liquid manures rich in nitrogen, phosphorus, and potassium have been found to enhance the

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vegetative growth of water spinach, promoting leaf development and overall plant vigor. Additionally, the organic matter present in these liquid manures contributes to soil fertility and microbial activity. The specific composition of liquid manures, including micronutrients and beneficial microbes, can influence the plant's resistance to diseases and pests, further contributing to improved yields.

Methods and materials

The research work conducted for the evaluation and compare of the performance different treatment and application on Water spinach. The research work on Performance of Liquid Manure on growth and yield of water spinach was undertaken in the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka during the period of September to October 2023. Experiment was laid out in randomized complete block design (RCBD) with three replications. Land that had never been used synthetic fertilizers for crop production were selected for this study. At first the land was prepared by thoroughly plowed and land was dived into 15 small unit plots, and the unit plot size was maintained with 1m X 2.6 m. That one plot was separated from another by wooden frames. Two seeds were sown in a pit with maintaining plant to plant 5cm and row to row 25 cm. spacing. Seeds were germinated within 5 days. After 7 days of seed germination, the experiment was consisted of five treatments namely; T_1: Control; T_2: Vermi Tea; T_3: SAU- MLM; T_4: SAU-NLM and T_5: SAU-PLM. Treatments were applied to plants four times every 10 days from 7 days after seed germination.

Preparation of liquid manure and its method of application:

T_1: Control (no manure, only water application)

T_2: Vermi Tea: (Vermi compost: water 10:**100**), (**Application:** 1:5 V/V): 10 kg of vermicompost was mixed with 100 liters of water and left for 7 days to make vermi-tea. The solution was stirred with a stick once in a day to prepare the vermi tea well. One-part vermi tea mixed with 5 parts water was used when it was used as the treatment.

T_3: SAU- MLM (Vermi compost: Oil cake: bone meal: water=10:1:1:**100**) (**Application:** 1:5= MLM: water, V/V (Mix Liquid Manure): The SAU-MLM liquid manure was prepared by mixing 10 parts vermicompost with one part of mustard oil cake and one part of bone meal in 100 liters of water. The solution was stirred with a stick once in a day to prepare the SAU-MLM well. One-part MLM mixed with 5 parts water was used when it was used as the treatment.

T_4: SAU-NLM (Fresh Cow dung: Fresh Urine: Jaggery: Water=10:10:1:**100**) (**Application:** 1:5; NLM: Water, V/V) (Natural Liquid Manure); SAU-NLM liquid manure was prepared by mixing 10 parts of fresh cowdung mixed with 10 parts of urine and 1 part of molasse and the mixture was mixed well with 100 liters of water. The solution was stirred with a stick once in a day to prepare the SAU-NLM well. One-part NLM mixed with 5 parts water was used when it was used as the treatment.

T_5: SAU-PLM (Fresh Cow dung: Urine: Jaggery: Chick pea/ Gram Besan: Soil: Water=10:10:1: 1:1:**100**) (**Application:** 1:5; PLM: Water, V/V) (Probiotic Liquid Manure): To prepare the SAU-PLM; 10 parts of cow dung mixed with 10 parts of urine mixed with 1-part molasses and 1 part of besan flour. This mixture mixed well with 100 liters of water. The solution was stirred with a stick once in a day to prepare the SAU-PLM well. One-part NLM mixed with 5 parts water was used when it was used as the treatment.

The research plot was kept under close observation. Weeding and irrigation were done when it was required. Light trap and yellow sticky traps were used to control insect infestation. In order to understand the effect of liquid manure, data were taken on plant height, number of leaves, leaf area, SPAD value, number of roots, fresh weight of single plant and yield per plot. Yield per hectare was calculated from the yield of each plot and express in tons per hectare.

Data analysis: The statistical analyses were conducted using the STATISTIX 10 statistical program. The analysis of variance (ANOVA) was conducted to assess the differences between treatments. The Least Significance Difference (LSD) test, as Gomez and Gomez (1984) proposed, was employed at a significance level of 5%.

Results and Discussion

Plant height: A significant variation was found on plant height with different treatments at different days after sowing. It was found tallest plant height (42.1 cm) at final harvest (40 DAS) with T_5, whereas the lowest plant height (28.8 cm) with T_1 (Fig.1). All the organic manure treatments showed positive effects through growth and yield characteristics. The chlorophyll content in the leaves might have been significantly improved with the application of organic sources of nutrients. Similar findings reported by Premsekhar and Rajashree 2009. The fermented liquid organic manures also contain microbial load and plant growth promoting substances in addition to nutrients that help in improving plant growth, metabolic activities and resistance to pest and diseases (Muthuvel *et al*., 2002).

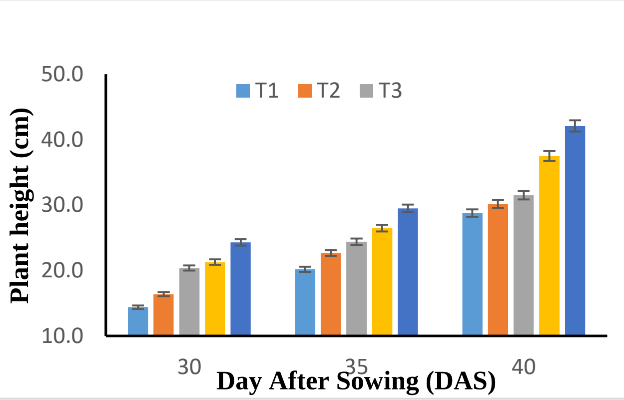

Fig. 1. Influence of Liquid Manure on Plant height (T_1: Control; T_2: Vermi Tea; T_3: SAU- MLM; T_4: SAU-NLM and T_5: SAU-PLM)

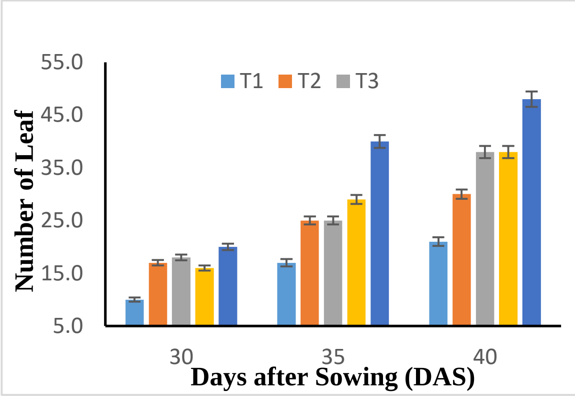

Fig. 2. Influence of Liquid Manure on Number of Leaf (T_1: Control; T_2: Vermi Tea; T_3: SAU- MLM; T_4: SAU-NLM and T_5: SAU-PLM)

Number of leaves: A significant variation was observed in the Leaf number of water Spinach at the days after sowing DAS time. The significant maximum Leaf number from graph is T_5 (48.0) in 40 days, the significant minimum Leaf number value is T_1 (21.1). The presence of nitrogen in cow urine may have aided the plant's production of chlorophyll, which promotes lustrous, healthy, and darker-colored leaves (Bohra and Nautiyal, 2019; Praveen *et al.*, 2021).

Table 1. Influence of Liquid Manure on root length, number of roots, leaf area and SPAD value of water spinach

Treatments	Root length (cm)	Number of roots	Leaf area (sq. cm)	SPAD value	Single Plant wt. (g)	Yield (kg/plot)	Yield (t/ha)
T_1	6.9 b	13.0 d	12.8 d	32.8 b	12.0 d	1.1 d	4.4 d
T_2	10.3 a	17.0 c	23.6 c	35.1 b	12.6 d	1.5 c	5.8 cd
T_3	10.2 a	18.0 c	22.8 c	37.7 ab	24.3 c	2.2 b	8.5 b
T_4	12.1 a	35.0 a	34.8 b	40.9 a	34.4 b	1.6 c	7.3 bc
T_5	11.0 a	29.0 b	42.1 a	37.8 ab	57.0 a	2.6 a	11.1 a
CV%	8.7	3.3	1.6	5.4	4.5	4.5	10.3
LSD	2.4	2.1	1.2	5.6	3.5	0.2	2.1

Here, T_1: Control; T_2: Vermi Tea; T_3: SAU- MLM; T_4: SAU-NLM and T_5: SAU-PLM

According to the 0.05 threshold of provability, means in a column with similar letters are statistically the same, whereas those with differing latter differ significantly

Root length: Significant variations was found in root length due to the different treatments. The highest root length (12.1cm) at final harvest with T_4 treatment, whereas the lowest value of root weight (6.9) in T_1 treatment (Table 1).

Number of roots: Significant variations was observed in root number due to the different treatments. The highest number of root (35.0) at final harvest with T_4 treatment, whereas the measly value of root number (13.0) in T_1 treatment (Table 1).

Leaf area: A significant variation was found in the leaf area with different treatments. Highest leaf area was measured (42.1 sq. cm) at final harvest with T_5 application, whereas the lowest value of leaf area (12.8 sq.cm.) in T_1 application (Table 1). The nutrient intake of mineral nutrients strongly influences the formation and growth of leafy plants (Hartatik and Setyorini 2009).

SPAD value: A significant variation was found among the treatments. The highest recorded SPAD value (40.9) in T_4, and the lowest value (32.8) in T_1 application (Table 1). The content was measured one time from three distinct leaves for evaluation, with the average being used for analysis. The SPAD meter readings correlate with the amount of green in the leaf. The application of liquid manure increased the amount of chlorophyll because it added vital plant nutrients, such as calcium, which both reduced and enhanced the uptake of nitrogen in the form of nitrate (Banijamali *et al.*, 2008) and encouraged guard-cell energy and stomata aperture leading to proper photosynthesis (Mansfield *et al.*, 1990).

Single plant weight: The significant variation is noted by the application of treatments where, highest weight per plant (57.0 g) was recorded in T_5 application (Table 1), while T_4 performed well and weight per plant was recorded (34.4 g) (plate 1). Organic manure, as well as liquid manure like Jeevamrutha, results in significantly increased crop growth, yield, and quality (Hameedi *et al.*, 2018).

a)

b)

Plate 1. a) Liquid manure preparation, **b)** plant growth with different liquid manure

Yield per plot: Significant difference of water hyacinth yield per plot was found among the different treatments. The highest yield (2.6 kg) was found with SAU-PLM (T_5) and lowest yield (1.1kg) found in T_1 (Table1).

Calculated yield: The significantly highest plant yield was recorded in the T_5 (11.1 t/ha) treatment and T_1 (4.4 t/ha) was recorded significantly the lowest yield (Table 1). In particular the use of liquid organic manures not only helps to achieve higher yield but also a low-cost production approach, thus helps to realize higher returns by the farmers (Deva kumar *et al*., 2014).

Conclusion

Improved water spinach growth and yield-attributing characteristics were the outcomes of using SAU-PLM. The slower release of nutrients during the crop's growing season and the improved physical, chemical, and mineralogical characteristics of the soil, which raised its fertility status, were the main causes of the higher yield. SAU-PLM has the ability to compete with traditional fertilizers on a broad scale. It is clear from the investigation's findings that SAU-PLM can be successfully applied to the growth of high-quality water spinach.

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POT SIZE ON COLE CROPS PRODUCTIVITY IN ROOFTOP GARDENING

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Abstract

The experiment was conducted during the rabi season of 2020–21 on rooftop of On-Farm Research Division (OFRD), Bangladesh Agricultural Research Institute (BARI), Bandarban station, to find out the influence of pot size for cultivating three popular cole crops in Bangladesh (broccoli, cauliflower, and cabbage). Four pot sizes (8, 10, 12, and 14 inches) were used as treatments in this experiment, which followed a completely randomized design (CRD) with three replications. The results showed a significant relationship between pot size and crop yield. Among all the pot sizes, the highest marketable yield of broccoli, cauliflower, and cabbage was found from 14-inch pots (261.33 g, 925.33 g, and 1105 g), while 8-inch pots yielded the lowest for all three crops (74.67 g, 330.67 g, and 300 g) respectively. Interestingly, the cauliflower plants in the largest pots (14 inches) took the longest time to mature (61.33 days), while delayed curd formation in broccoli (54.67 days) and head formation in cabbage (66.33 days) was found in 8-inch pots. Overall, cole crops like broccoli, cauliflower, and cabbage yielded more in larger pots (14-inch) compared to smaller pots.

Key words: Pot size, Rooftop Garden, Broccoli, Cauliflower, Cabbage.

Introduction

Rooftop gardens are more than just spaces for cultivation; they are realms of fantasy and imagination. They serve a dual purpose - growing vegetables that provide fresh, chemical-free food to the family and acting as a green lung in urban areas, purifying the polluted air. They contribute to biodiversity enhancement, reducing pollution, absorbing CO_2 emissions, controlling urban heat, and mitigating sound pollution by absorbing sound waves outside buildings and preventing inward transmission (Dunnet & Kingsbury, 2004).

About 2.57% of Bangladesh's total land area is used for vegetable production, yielding 3.73 million tons of vegetables (BBS, 2022) with an average national per capita consumption of 23 g of leafy vegetables, 89 g of non-leafy vegetables, the average Bangladeshi eats a total of 112 g of vegetables daily (FAO, 2003). This is far below the minimum daily consumption of 400 g of vegetables and fruit recommended by FAO and the World Health Organization (WHO). In the face of an increasing population and shrinking agricultural land, rooftop farming has emerged as an innovative and economically viable solution in Bangladesh. This practice of cultivating organic produce for family consumption and surplus sale to agribusinesses ensures food security and creates employment opportunities (Wardard, 2014). In Bangladesh, approximately 70% of vegetables like tomatoes, brinjal, and cole crops are grown during winter (Akter et al., 2016), providing a risk-free environment for vegetable cultivation (Busch et al., 2017).

Cole crops, such as broccoli (*Brassica oleracea* var. italica), cabbage (*Brassica oleracea* var. capitata), and cauliflower (*Brassica oleracea* var. botrytis), are essential members of the Cruciferae family (Fahey, 2016). They are popular vegetables in Bangladesh and in many other countries. These crops contain important nutrients; broccoli is a compact powerhouse of fiber, vitamins A, C, and K, minerals, and antioxidants (Syed *et al*., 2023). Cabbage is a good source of vitamins C, B, E, tryptophan, potassium, and calcium (Rashid, 1993). Cauliflower contains carbohydrates, protein, carotene, vitamins B1 and B2, vitamin C, calcium, and iron (Rashid, 1999). Broccoli, cabbage, and cauliflower are well suited to the climate of Bangladesh. As a result, during the rabi season of 2020-2021, cauliflower was grown over an area of 22,674.16 hectares, producing a significant 294,684.11 metric tons, as cabbage was cultivated across 22,339.27 hectares, yielding 380,259.38 metric tons in Bangladesh (BBS, 2022). They do not require much space to grow, making them ideal for rooftop gardens. This highlights their potential as a sustainable food source and a space-efficient solution for space-limited urban landscapes.

Urban rooftop farming typically involves container gardens, hydroponics, organic farming, aeroponics, and green roofs (Asad & Roy, 2014). The choice of containers is primarily determined by their availability, the gardener's preferences, and the characteristics of the plants being grown. According to Rahman et al. (2013), 77% of rooftop gardeners use earthen containers, while others use cement beds, drums, brass pots, and other containers. For

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vegetable growers, the size of the container is a critical consideration. Smaller containers are becoming popular among commercial transplant producers as they enhance plant productivity without requiring additional space for transplant production (Vavrina, 1995). This trend also lowers costs per plant because production costs are strongly correlated with the size and type of containers (Marsh & Paul, 1988). However, gardeners lack knowledge about the appropriate size of containers for their gardens, especially for growing different cole crops during the rabi and kharif seasons. This has led to the initiation of this experiment to determine the influence of pot size for the three most demanded rabi season cole crops for rooftop gardens.

Materials and methods

Experimental site: The experiment was carried out at the rooftop of OFRD, BARI, Bandarban station during the rabi season of 2020-21. The highest temperature during the experimental period was approximately 35.3°C, and the lowest was 13.9°C. Total precipitation of approximately 23 mm and average humidity of 84% was recorded during the growing season from November 2020 to April 2021.

Designs and treatments: The experiment was laid out in a Completely Randomized Design (CRD) with three replications. Plastic pots of different sizes were used for this experiment. Four pot sizes, 8-inch, 10-inch, 12-inch, and 14-inch were used as treatments of the three (03) rabi crops, viz. broccoli, cauliflower, and cabbage, during 2020-21.

Experimental pot preparation: Volume for 8-inch, 10-inch, 12-inch and 14-inch plastic pots were 159.13 $inch^3$, 250.54 $inch^3$, 369.29 $inch^3$, and 502.83 $inch^3$ respectively. The lower part of 1-1.5 inches of each pot was filled with gravel and dry leaves to facilitate drainage through the container hole. The potting mix was sincerely prepared with 30% cocopeat, 30% soil, 30% compost, and 10% sand. The potting mixture was then filled into each pot/container. The potting mixture required for 8-inch, 10-inch, 12-inch, and 14-inch plastic pots was 2.59 kg, 5.14 kg, 9.32 kg, and 15.14 kg, respectively (Figure 1).

Figure 1. Different pot sizes and their volumes with potting mixture and required mixture/pot

Transplanting and fertilization: The rabi vegetable seedlings were transplanted on 18 November 2020. Fertilizers were used as the recommended dose for each pot (BARC, 2018) when necessary, using the ring method at each vegetable's peripheral portion of the pot.

Data analysis: The statistical analyses were conducted using the STATISTIX 10 statistical program. The analysis of variance (ANOVA) was conducted to assess the differences between treatments. The Least Significance Difference (LSD) test, as Gomez and Gomez (1984) proposed, was employed at a 5% level of significance.

Result and Discussions

Broccoli: This experiment revealed significant variations in yield-attributing characters based on pot size. Compared to the other pot sizes, the 14-inch pots demonstrated the quickest curd formation and harvesting times for broccoli (47 and 62 DAT, respectively). These findings are similar to Thakur et al. (1991) research on broccoli (var. calabrese), where initial curd formation and first harvest occurred at 45.13 and 55.81 days, respectively. Regarding physical attributes, the 14-inch pots produced the longest (16 cm) and widest curds (16 cm), significantly outperforming the 8,10 and 12-inch pots. Hossain et al. (2011) reported a broccoli diameter range of 16.2 cm to 22.9 cm in his study.

In terms of yield, the 14-inch pots again showed the highest single curd weight (196.67 g) and marketable yield per pot (261.33 g), followed by the 12-inch pots with a single curd weight of 116.33 g and a marketable yield of 150.33 g per pot. The 10-inch and 8-inch pots yielded less. Kandil, H., & Gad, N. (2009) reported higher curd weights for broccoli (ranging from 133.50 g to 278.60 g) when using a combination of organic and inorganic fertilizers. `

Table 1. Yield and yield contributing characters of broccoli in different sizes of pots on the rooftop garden

Treatments	Days to first curd formation	Days to first harvest	Curd length (cm)	Curd diameter (cm)	Curd weight (g)	Marketable Yield/ pot (g)
T_1	54.67	70.33	10.67	8.67	51.33	74.67
T_2	50.33	62.67	11.83	11.00	83.67	122.67
T_3	50.33	63.33	12.50	12.50	116.33	150.33
T_4	47.00	62.00	16.00	16.00	196.67	261.33
CV (%)	4.08	4.65	6.40	6.67	6.03	4.71
LSD (0.05)	3.88	5.65	1.54	1.51	12.71	13.49

T_1: 8-inch pot, T_2: 10-inch pot, T_3: 12-inch pot, and T_4: 14-inch pot

Cauliflower: The pot size significantly affected cauliflower's growth and yield. Although the 14-inch pots took longer to form curd (41.67 DAT) and harvest (61.33 DAT), they outperformed the 8 & 10-inch pots in terms of curd length and diameter. The curd length of 14-inch pots was 10.50 cm, which is significantly higher than the smaller pots. Similarly, the curd diameter was highest in the 14-inch pots (17.50 cm), followed by the 12-inch pots (16.50 cm), and lowest in the 8-inch pots (11.83 cm). These findings align with Akter *et al.* (2023), who reported a slightly better curd height (highest 17.18 cm at 60 DAT) per plant and a similar range of curd diameters (12.02 cm to 15.25 cm at 60 DAT) in a rooftop cauliflower gardening experiment. The 14-inch pots also yielded the highest single curd weight and yield per pot (732.67 g and 925.33 g, respectively), which is statistically higher than all other pot sizes. Akter *et al.* (2023) recorded the maximum curd weight per plant (551.60 g) in their study.

Table 2. Yield and yield contributing characters of cauliflower in different sizes of pots on the rooftop garden

Treatment	Days to first curd formation	Days to first harvest	Curd length (cm)	Curd diameter (cm)	Curd weight (g)	Marketable Yield/pot (g)
T_1	35.67	59.00	6.17	11.83	284.3	330.67
T_2	35.00	59.00	8.00	12.67	491.33	589.33
T_3	40.00	58.00	8.83	16.50	509.33	677.33
T_4	41.67	61.33	10.50	17.50	732.67	925.33
CV (%)	8.16	4.49	7.11	5.58	5.79	6.03
LSD (0.05)	5.85	5.01	1.12	2.03	54.98	71.60

T_1: 8-inch pot, T_2: 10-inch pot, T_3: 12-inch pot and T_4: 14-inch pot

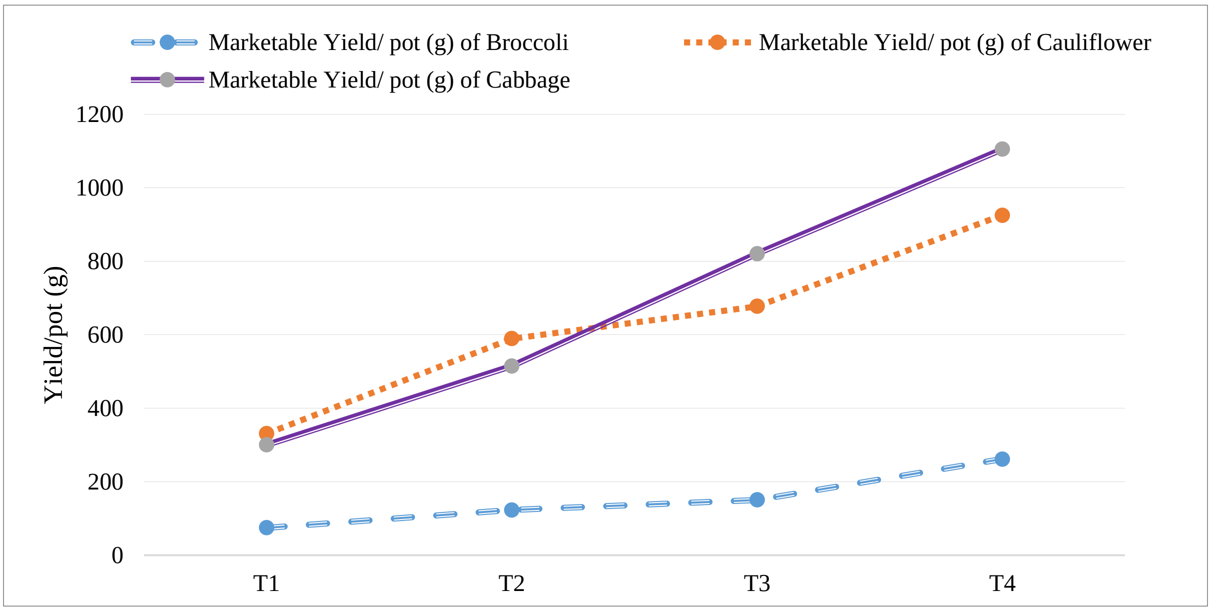
Cabbage: Considering the growth of cabbage in the following rooftop experiment, first head formation (52.67 DAT) and late harvest (97.67 DAT) were observed in 14-inch pots where the smaller 8-inch pots showed the reverse result, 66.33 DAT for head formation and 95.00 DAT to harvest. Head length and diameter reduced with decreased pot size; 14-inch pots (23.33 cm and 13.33 cm) followed by 12-inch pots (21.00 cm and 11.33 cm), 10-inch pots (19.33 cm and 11.00 cm) and 8-inch pots produced the smallest head (10.00cm and 10.67cm). Significant variation was observed in head weight and pot yield. The highest single head weight and yield per pot was found in 14-inch pots (965.33 g and 1105 g) followed by 12-inch pots (668.33 g and 820.70 g), 10-inch pots (373.33 g and 515 g), and the lowest was found from 8-inch pots (203.33 g and 300 g) (Table 3). Results obtained by Ahmed *et al.* (2017) indicated that increasing pot volume from 4 liters to 8 liters of substrate led to an increase in the vegetative yield of celery and red cabbage.

Table 3. Yield and yield contributing characters of cabbage in different sizes of pots on the rooftop garden

Treatment	Days to first head formation	Days to first harvest	Head length (cm)	Head diameter (cm)	Head weight (g)	Marketable Yield/ pot (g)
T_1	66.33	95.00	10.00	10.67	203.33	300.00
T_2	61.33	96.00	19.33	11.00	373.33	515.00
T_3	53.00	96.67	21.00	11.33	668.33	820.67
T_4	52.67	97.67	23.33	13.33	965.33	1105.00
CV (%)	0.86	0.42	5.86	11.42	7.41	6.38
LSD (0.05)	0.49	0.33	2.03	2.49	77.15	82.32

T_1: 8-inch pot, T_2: 10-inch pot, T_3: 112-inch pot and T_4: 14-inch pot

It was found from the experiment that, when considering all the chosen cole crops, the 14-inch pot size made a substantial difference in yield (figure 2).



T_1: 8-inch pot, T_2: 10-inch pot, T_3: 12-inch pot and T_4: 14-inch pot

Figure 2. Marketable Yield of broccoli, cauliflower, and cabbage in different sizes of pots at the rooftop garden of Bandarban, 2020-2021

Limitations of the study

While this experiment provides valuable insights into optimizing pot size for cole crops in rooftop gardening, it has certain limitations that should be acknowledged. The most significant limitation is the restriction on pot size. This experiment did not use pots larger than 14 inches in diameter, which could limit the findings' applicability to larger pots. The focus was on three cole crops - broccoli, cabbage, and cauliflower, limiting its relevance to other vegetables commonly grown in rooftop gardens. This experiment was conducted in Bangladesh during the rabi season, so the region's specific climatic and environmental conditions influenced the findings, and it might not directly apply to rooftop gardens in other geographical locations or to other seasons due to climatic variations.

Conclusion

The study found that larger pots (14-inch) resulted in higher broccoli, cauliflower, and cabbage yields, likely due to more space for root growth. Conversely, smaller pots (8-inch) yielded less, possibly due to restricted root expansion slowing plant development. Repeating the experiment for several years could produce concrete recommendations.

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INVESTIGATION OF ANTIOXIDANT ACTIVITIES OF *Cenchrus purpureus* EXTRACTS USING *In Vitro* ASSAY

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Abstract

This in vitro study evaluated *Cenchrus purpureus* (also called as Napier grass, elephant grass) extract's antioxidant capacity and Phytoactive compounds. At present various parts of plant materials are becoming more popular for their health advantages as well as natural antioxidants. Ethanolic, methanolic, and aqueous extracts were examined to find out the total phenolic compound (TPC) (138.54±1.66, 77.5±1.73, 53.63±2.05 mg GAE/g), total flavonoids compound (TFC) (34.49±1.57, 28.24±3.35, 16.58±1.41 mg QE/g) of dry extract respectively, as well as antioxidant activity assay including DPPH scavenging capacity using *C. purpureus* extract. The ethanol extract of the three had an IC50 value of 39.41 µg/mL, similar to conventional ascorbic acid (31.46 µg/mL), suggesting its potential as a natural antioxidant. The study highlights the importance of examining diverse plant species to discover bioactive compounds that can be used to create innovative antioxidant agents for pharmaceuticals and functional foods product.

Key words: Antioxidant, Phytoactive, Ethanolic, Methanolic, and Aqueous Extracts.

Introduction

Plants that are used for medicinal purposes are an important part of human society since they are employed for the treatment and prevention of various ailments. Numerous studies have demonstrated that these plants play a beneficial role in the field of medicine and are an essential component of traditional treatments. The collection of knowledge, practices, and abilities that are founded on the theories, experiences, and beliefs of indigenous cultures are collectively referred to as traditional medicine. For the purpose of diagnosing, preventing, improving, or treating mental and physical disorders, as well as maintaining good health, it is utilized. Traditional medicines make use of a wide variety of plant parts, including stems, leaves, and roots, in order to treat a wide range of illnesses.

Plants contain a significant quantity of bioactive chemicals that exhibit a high level of antioxidant activity. It is possible that research aimed at determining the antioxidant activity of various plant species could help to the discovery of the utility of these plant species as a source of new antioxidant molecules. The quantification of antioxidant activity can be accomplished using a wide range of in vitro techniques, and it is essential to choose the appropriate technique in order to ascertain which species exhibit the highest levels of antioxidant activity. The majority of the global population, approximately 80%, relies on medicinal plants as a primary source of therapeutic substances for healthcare (Oliveira et al., 2012). The growing interest in organic substances as potential alternatives for synthetic compounds in food or medicine is driven by concerns about the adverse consequences of those substances (Kaur et al., 2014). Peoples are progressively relying on therapeutic herbs due to their boosting antioxidant potency. These natural sources provide a reliable and effective way for dealing with free radicals and safeguarding against diseases, rendering them potential replacements for conventional medicine (Carrera-Juliá et al., 2020). *Cenchrus purpureus, a* medicinal plant from the Poaceae family, has a broad global range and thrives in many tropical and temperate regions. The traditional use of *C. purpureus* as a therapy for diabetes mellitus has been documented (Brantley et al., 2015). *C. purpureus* has been found to possess potent antioxidant and hypoglycemic properties, as reported by Tsai et al. (2008), Okaraonye and Ikewuchi (2009), Olorunsanya et al. (2011), Akuru et al. (2015), and Tjeck et al. (2017). The main objective of the present investigation was to investigate the antioxidant properties of leaf extracts from *C.purpureus.* More specifically, the study aimed to examine the extract's capacity to neutralize free radicals, which could potentially result in improved health outcomes or enhanced oxidative stress management. As, it is one kind of widely popular cow, sheep and goat food in all over the world, specially south Asian region. So, this research is might validate as an effective technique for organically derived antioxidant supplementation or as a natural source of antioxidants in the field of agriculture.

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Material and Methods

Materials

All chemicals were used of analytical grade that purchased from Sigma-Aldrich Ltd. (Germany). All absorbance measurements for determination of total phenolic content, total flavonoids content and antioxidant capacity were conducted using a double beam UV spectrophotometer (U-2900, Hitachi, Japan)

Plant Collection.

C. purpureus was collected during September 2023 from west side of Islamic University, Kushtia, Bangladesh. The leaves with stem of the plant were washed, dried at room temperature from 48 to 92 hour, ground into powder and then preserved in glass amber bottles protecting from light and moisture until use.

Preparation of Plant Extract.

The dehydrated and powdered sample of *C. purpureus* was subjected to extraction of phytochemicals using three different solvents: ethanol, methanol, and distilled water, using a shaking incubator (Lab Tech-LSI-3016R). Approximately 10 grams of powdered sample were precisely measured and poured into three different amber bottles, to which 100 ml of each solvent (ethanol, methanol, and distilled water) were separately added. The extraction procedure was carried out at a temperature of 37°C for 96 hours. Afterwards, the liquid extracts were dehydrated using an air performance incubator adjusted at a temperature of 45°C. The crude extracts' percentage yield (w/w) was determined and subsequently stored in a refrigerator at a temperature of 5°C until the extracts were required for analysis.

Phytochemical screening

The ethanol, methanol, and aqueous extracts (1 gram) were fully diluted in 100 mL of their respective solvents to prepare the stock solution. The stock solutions were analyzed for phytochemical content using established procedures (Harborne et al., 1998; Subba et al., 2016).

Determination of total phenolic content (TPC)

The quantification of the overall phenolic content was conducted using the Fiolin-Ciocalteu reagent, following the methodology established by Singleton et al., 1965. A standard curve was created using gallic acid as the standard compound. Various quantities of gallic acid were prepared using distilled water, and the absorbance values were measured at a wavelength of 765 nm. For the sample measurements, 5 mL of Folin Ciocalteu phenol reagent (diluted at a ratio of 1:10 with distilled water) and 900 µL of distilled water were added with 100 µL of plant extract. After 5 minutes, samples were combined with 4 ml of 15% sodium carbonate (Na2CO3) and incubated for 120 minutes. The measurement of absorbance at a wavelength of 765 nm was carried out. The data is displayed as the mean values of three measurements for each sample.

Determination of total flavonoid content (TFC)

The quantification of the flavonoid content in *C. purpureus* extracts was conducted using the procedure outlined by Dewanto (Dewanto et al., 2002), using aluminum chloride (AlCl3) as the reagent. The standard curve was created using catechin, and the results were presented as the amount of catechin equivalent per gram of extract dry weight (mg CE/g dw).

Determination of antioxidant activity DPPH radical scavenging activity assay

The free radical scavenging activity was measured in vitro using 1,1-diphenyl-2- picrylhydrazyl assay (DPPH) according to the method described by Brand-Williams (Brand-Williams et al.,1995) with some slight modification. In glass bottles, 2.5 mL of various quantities of each extract were placed, followed by the addition of 0.5 mL of a freshly made methanol solution containing DPPH (0.2 mM of DPPH dissolved in methanol). The mixture is vigorously agitated using a vortex mixer and then placed in a dark environment at room temperature for 30 minutes. Subsequently, the spectrophotometer was used to measure the absorbance of the mixture at a wavelength of 517 nm. Scavenging activity is expressed as the inhibition percentage calculated using the following equation:

Anti-radical activity (%) = {(control absorbance – sample absorbance) / control absorbance} × 100

Each determination was carried out in triplicate. The IC 50 values for the concentration required for 50% scavenging activity were calculated from linear regression equation.

Results and Discussion

Extraction yields calculation:

The yields of ethanol, methanol, and aqueous extracts of *C. purpureus* were 4.5%, 12.50%, 20.25% respectively. The percentage yield of extract increases with the increase of the polarity of the solvent. The study of the three different extracts revealed the existence of several phytochemical components. All extracts contain polyphenols, flavonoids and terpenoids. The ethanol and methanol extracts contained alkaloids, flavonoids, polyphenols, tannins, and steroids. Proteins were exclusively detected in the ethanol extract (Table 1). The existence of these metabolites in the plant demonstrates its antioxidant efficacy and other biological characteristics (Rice-Evans et al., 1996).

Table 1: Phytochemical screening of different extracts of *C. purpureus*

Phytochemicals	Ethanol Extract	Methanol Extract	Aqueous Extract
Alkaloids	+	+	-
Flavonoids	++	+	+
Cardiac glycosides	-	-	-
Glycosides	+	-	-
Polyphenols	++	+	+
Terpenoids	+	+	+
Steroids	+	+	-
Proteins	-	-	+
Quinones	-	-	+
Tannins	++	+	-
Reducing sugar	-	-	-

Key: + = Present - = Absent

Total phenolic content (TPC) and total flavonoid content (TFC)

The current investigation involved the determination of the overall phenolic and flavonoid compounds (table-2 and figure 1) in three distinct extracts of *C. purpureus*. The total phenolic content (TPC) and total flavonoid content (TFC) were determined by extrapolating values from the calibration curve obtained using gallic acid and catechin concentrations as a standard, respectively.

Table 2: Total phenolic and total flavonoid contents of different extracts *C. purpureus*

	Polyphenolic content (mg of GAE/g of extract)	Flavonoid content (mg of CE/g of extract)
EE	138.54±1.66	34.49±1.57
ME	77.5±1.37	28.24±3.35
AE	53.63±2.05	16.58±1.41

(Values are expressed as mean ± SD (n=3). Here, EE: Ethanolic extract; ME: Methanolic extract; and, AE: aqueous extract; GAE: gallic acid equivalent; CE: catechin equivalent)

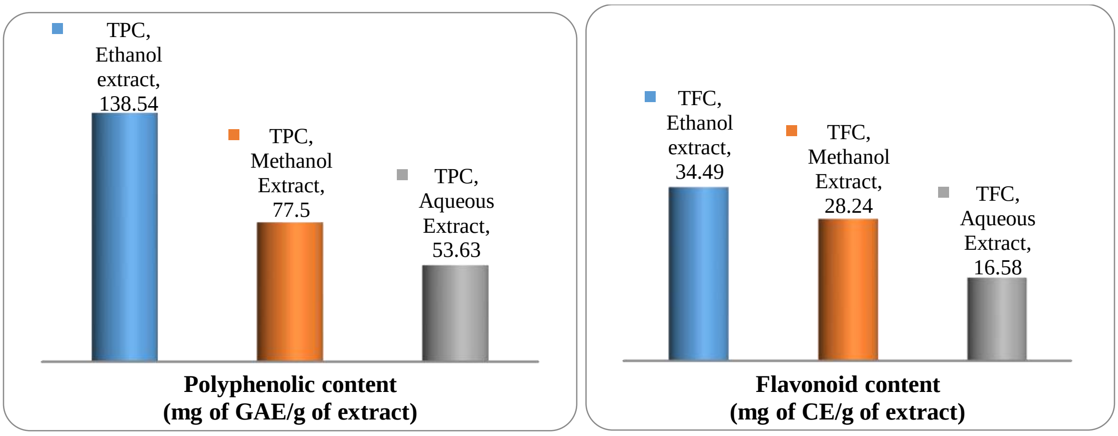

Figure 1. TPC and TFC of different extracts of *C. purpureus*

The analysis revealed a substantial amount of total phenolic and flavonoid compounds present in the plant extracts. The total phenolic content in the Ethanol extract of *C. purpureus* was found to be significantly high, measuring 138.54±1.66 mg GAE/g. The study revealed that the ethanol extract had the highest total flavonoid concentration (34.49±1.57mg QE/g), followed by the methanol and aqueous extracts. The polarity of the solvents can influence the levels of TPC and TFC. The plant has a significant amount of phenolic and flavonoid components, which can efficiently remove free radicals and act as antioxidants (Lien et al., 1999; Rice-Evans et al., 1996).

DPPH radical scavenging activity

The antioxidant activity of the plant was analyzed using the DPPH assay, using ascorbic acid being as the standard. This experiment involved incubating various quantities of different extract solutions and ascorbic acid solutions at room temperature, then measuring their absorbance using a spectrophotometer. The percentage of scavenging free radicals at various concentrations and the IC50 values of each extract and ascorbic acid were calculated. The findings are displayed in table 3. The given figure suggests that the extracts of *C. purpureus* exhibited a percentage inhibition of DPPH free radicals that was similar to that of ascorbic acid, which served as a standard. Among the three different extracts, the ethanol extract exhibited an IC50 value of 39.41 μg/mL, which is very close to the standard ascorbic acid value of 31.46 μg/mL. The antioxidant activity of the ethanol extract of *C. purpureus* is higher in potency. Additionally, it possesses the greatest amount of TPC (138.54±1.66 mg GAE/g of dry extract) and TFC (34.49±1.57mg QE/g of dry extract). The ethanol extract showed significant antioxidant activity that can be attributed to the presence of phytochemicals, including flavonoids, polyphenols, and tannins. Previous studies additionally support that flavonoids, polyphenols, and tannins present in plants exhibit notable antioxidant properties (Guleria et al., 2013; Kaur et al., 2014). The results indicate that the extracts *C. purpureus* have significant potential in the field of medicine due to their strong antioxidant properties in natural product chemistry.

Table 3. Percent radical scavenging activity of *C. purpureus* Extracts and Ascorbic acid on DPPH

Concentration (µg/ml)	% free radical scavenging activity test using DPPH			
	Ethanol Extract	Methanol Extract	Aqueous Extract	Ascorbic Acid
5	0.00	0.00	0.00	0.00
10	38.28	27.36	5.71	54.21
20	55.36	31.42	20.36	57.14
40	63.96	43.36	31.23	67.32
60	68.36	47.35	42.36	69.24
80	72.36	56.36	49.37	74.68
100	74.36	59.22	56.36	79.26
IC50 value(µg/mL)	**39.41**	**69.24**	**80.71**	**31.46**

Conclusion

In the present investigation, extractions from *C. purpureus* has been carried in ethanol, methanol and aqueous solvents. Phytochemical screening of the extracts revealed the presence of alkaloids, flavonoids, glycosides, polyphenols, terpenoids, tannins and steroids. The plant possesses a high amount of total phenolic and total flavonoid contents. DPPH scavenging activity showed that the plant possesses high antioxidant properties. Among all three extracts, the IC50 value of ethanol extract was the lowest and closest (39.41 µg/mL) to that of standard ascorbic acid (31.46 µg/ mL). The significant potency of the extracts of *C. purpureus* as antioxidant agents may be due to the presence of high phenolic and flavonoid contents that may play important role in the field of medical and agriculture science.

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