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BANGLAPONICS: A SOILLESS CULTIVATION TECHNIQUE FOR TOMATO IN BANGLADESH

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Abstract

The study was carried out to develop an efficient, reproducible method to overcome the drought stress and increasing agriculture field crisis of Bangladesh. Banglaponics, a soilless cultivation technique comprised of traditional agricultural fertilizers in pond water mixed with cow urine has been used to evaluate the efficiency of tomato production. The production rate (237.85 ± 10.87 g/plant) was significantly ($p < 0.05$) higher in the Banglaponics medium than soil medium. Plant height, leaf number, leaf area, root number, root length, and flower number of the studied plant showed significantly ($p < 0.05$) higher in Banglaponics medium than plants grown in soil. Both treatments showed that chlorophyll score and antioxidant activity (DPPH) were almost equal. Banglaponically grown plant leaf, despite having lower Ca concentrations, possessed higher concentrations of Fe and Zn than those of soil-grown. Additionally, Banglaponically grown plant also showed significantly much lower Pb concentrations than that of grown in soil. On the contrary the other two heavy metals Cr and Cd, hold nearly the same value. By appearance, Banglaponically-grown plants were much healthier than that of soil-grown. This technique can be introduced in drought-prone areas of Bangladesh as it requires much less water than soil-grown tomato plants.

Introduction

Bangladesh has a boundless agronomical prosperity, but in this era of urbanization, industrialization, and indiscriminate use of water and fertilizers, the evolution of agriculture has been greatly disturbed. As a consequence of losing fertile land, only 57% of arable lands remain for food production (Nasim *et al.* 2017). According to BADC 2019, 73.44% of agricultural fields are irrigated with groundwater, and 26.56% of cultivated crops are irrigated with surface water during the Rabi season of the country. These irrigated waters are commonly provided through earthen channels that cause 59.06% loss of water used in irrigation all around the country (Hossain *et al.* 2014). The enormous amounts of water lost through irrigation directly affect drinking water requirements.

Hydroponic system has many advantages but there is some inconvenience with this technique. Due to high technology, the technique needs intensive capital, which is the most important drawback for a developing country like Bangladesh. In addition, it is necessary to monitor and balance pH and nutrient levels on a daily basis, and it is essential to use a water or air pump. Thus, the present study was undertaken to overcome the expensive cost and adjust the time and other complexity with an affordable closed hydroponic methodology for usable to all the ramified families based on their income to produce vegetables. The technique of soilless vegetable production by using low-cost medium in Bangladesh i.e., Banglaponic was first used by Jonathon (2021).

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Materials and Methods

Tomato seeds were collected from the Horticulture Centre of Rajshahi, Bangladesh. The sprouted seedling about 5-6 cm in length was used as plant material transplanted to the soilless nutrient solution, whereas the soil-grown plants were potted in same-sized plastic pots. Each kg of soil was mixed with 1kg of semi-dried cow dung, and 1 g of urea, potash, and TSP were added to the soil accordingly. No pesticides or insecticides were used during the period of study.

To prepare a batch of Banglaponic medium from the stock nutrient composition (Table 1) prepared according to Naz *et al.* (2021). Pond water 20l free from plankton and debris, 125g stock and 625ml fresh cow urine were mixed together in a plastic bucket. The pH and electric conductivity (EC) were adjusted to 5-7 and 1-3 µS respectively by adding pond water. The medium was then kept for continuous aeration for up to 48 hrs to protect nitrate (NO_3) from degradation.

Table 1. Composition of the Stock Mixture.

Fertilizers	Amount
Agronourish (Trade name of combination trace elements fertilizer)	1000 g
DAP (Di Ammonium Phosphate)	550 g
Murate of Potash	400 g
Calcium Oxide	400 g
Gypsum	200 g

Tomato seedlings with coir support were transplanted in thumb pots and placed at the centre of foam submerged in one-liter plastic pots containing Banglaponics medium. The new solution was added at 15-day intervals to ensure the optimum nutrient supply. For control, seedings of similar age were placed in the same size pot filled with organic fertilizers and soil. All the plants were kept in a net house with natural light and air circulation.

Plants' morphological development *viz.* plant height, leaf number, leaf length and breadth, root number, and root length number of flower, fruit number and weight was regularly observed in every 3-4 days interval till the plant matured. Plants were harvested after 65 days. Plant productivity was also evaluated at the same time. The experiments were performed randomly with ten replications for each morphological attribute and for physiological and minerals tests the replication number was three.

Soil Plant Analysis Development (SPAD, Minolta, Japan) meter was used to determine the chlorophyll score rapidly in a non-destructive process. (Ling *et al.* 2011). 2,2-diphenyl-1-picrylhydrazyl (DPPH) the non-enzymatic antioxidant activity of leaves and roots was assayed with a slightly modified method described by Martínez-Ávila, *et al.* (2012). The concentrations of minerals (Ca, Fe, and Zn) and heavy metals (Pb, Cd, and Cr) were analyzed based on the methodology of Uddin *et al*. (2016) with slight modification using a flame atomic absorption spectrophotometer (AAS, Perkin Elmer model 2130). The mean value was analysed at 5% significance level by t-test followed by Duncan's Multiple Range Test (DMRT) and Pearson's correlation with treatments using SPSS Statistics 23 software.

Results and Discussion

The germination rate and viability of tomato, lettuce, and pepper seedlings in different low-cost mediums e.g., recyclable plastic bottles, coco coir, foam and semidried *Eichhornia* leaves in soilless medium was studied by Naz *et al*. (2021). Based on the findings the study has been undertaken to observe the effect of low-cost materials used as build-up hydroponics technique for tomato cultivation. Morphological characters are one of the most common features to determine the potentiality of the cultivation methods of the plants. These characteristics are mainly plant height, leaf numbers and area, root number and length, flower number, and yield which are tabulated in Table 2 with the correlation (Table 3) among those phenotypic attributes. The plants cultivated in Banglaponic medium showed significantly ($p < 0.05$) higher value for all the morphological parameters. The root length is much lengthier in Banglaponically-grown tomato plants than the soil grown plants.

Table 2. Morphological traits and plant production rate of tomato.

Characteristics	Banglaponics medium	Soil medium
Plant height (cm)	57.10 ± 1.65^{a}	41.82 ± 2.18^{b}
Leaf number	28.10 ± 2.38^{a}	18.40 ± 1.29^{b}
Leaf area (cm^2)	225.8 ± 26.46^{a}	60.77 ± 4.60^{b}
Root number	$355.7 \pm 32.45^{a`}$	102.4 ± 5.46^{b}
Root length (cm)	29.63 ± 1.06^{a}	28.41 ± 1.31^{a}
Flower number (per plant)	36.50 ± 2.87^{a}	12.10 ± 1.30^{b}
Production (g/plant)	237.85 ± 10.87^{a}	79.83 ± 8.45^{b}

Table 3. Pearson correlation (r) matrix of the morphological attributes of Banglaponically grown tomato.

	Height	Leaf number	Leaf area	Root number	Root length	Flower number	Yield
Height	1						
Leaf number	0.784**	1					
Leaf area	0.876**	0.782**	1				
Root number	0.465	0.555	0.576	1			
Root length	0.832**	0.747*	0.744*	0.462	1		
Flower number	0.905**	0.769**	0.846**	0.382	0.903**	1	
Yield	0.787**	0.588	0.710*	0.295	0.589	0.729*	1

** Correlation is significant at the 0.01 level (2-tailed) * Correlation is significant at the 0.05 level (2-tailed)

The high productivity was correlated with the plant morphological development and in the present study vegetative development showed a positively high correlation (Table 3) with plant yield. This observation is more or less similar to the previous studies where the number of leaves (Logendra *et al*. 2001), and plant height (Mehta and Asati 2008) showed positive effects on plant productivity. Tomato fruits yield is influenced by a fundamental factor like plant height and it has a very positive effect which was reported by Mehta and Asati (2001) and in Banglaponic solution, the plant height showed significantly ($p < 0.05$) 26.76% higher plant height than soil condition (Table 2). The research result of Kaushik *et al.* (2011) finds an average plant height rate for tomato variety and reported that height was 9-12 cm. Generally, plant height depends on different cultivation techniques and the nutritional recipe that is given in hydroponic production by Shah *et al*. (2011).

In terms of other studied morphological characteristics (Table 2), plant produced 34.51% excess leaves with approximately four times higher leaf area in Banglaponic medium than soil cultivated plants, which clarified that both conditions were significantly ($p < 0.05$) different from each other. Additionally, another morphological trait is root formation, like root number, root length is highly emergent and fundamental factor for hydroponic cultivation and generally tomato growth and development rate on the technique much rely on these attributes. Many roots can uptake sufficient nutritional elements abundantly from modified solution and it influenced the growth providing better desirable production. Plants positively correlated morphological attributes and also the plant generative organ e.g., flower development (Table 3). The production rate of flower was almost 3 times higher in Banglaponics medium than soil grown plants (Table 2). This high rate of flower develops fruits at a higher rate which ultimately gives significantly ($p < 0.05$) higher production (237.85 ± 10.87 g/plant) than soil-grown tomatoes weighing 79.83 ± 8.45 g/plant. High productivity and the highest vegetative growth in Banglaponics might be due to sufficient nutritional supply.

There were no significant differences in chlorophyll concentration between the cultivation methodologies although the highest chlorophyll score (44.73 ± 2.15) was found in soilless grown plants whereas soil grown plants showed chlorophyll score of about 43.43 ± 1.99. The observed values are exalted than other studies (Singh and Varshney 2013).

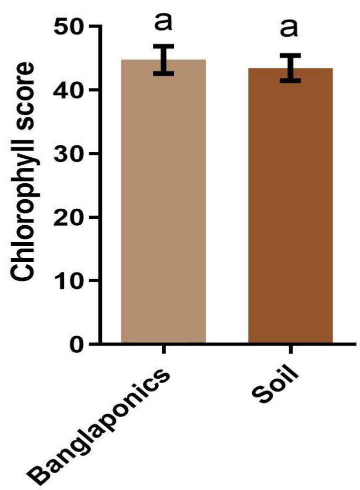

Fig. 1. Chlorophyll score of tomato plants grown in two different cultivation techniques.

The scavenging activity of tomato leaves and roots are shown in Fig.2. Root showed higher 17.74 ± 8.82% antioxidant potency in Banglaponics though has no significant difference with soil grown plant roots that showed 11.89 ± 4.93% scavenging activity. Conversely, soil grown plant leaves possessed higher values (10.53 ± 5.26%) but significantly similar antioxidant activity than Banglaponics (8.87 ± 4.85%).

Minerals (Ca, Fe and Zn) concentration of tomato leaves was evaluated with FAAS and the measured value was tabulated in Table 4. Iron and Zn showed higher (20.30 ± 3.15 mg/100g and 5.96 ± 1.64 mg/100, respectively) concentration on Banglaponically grown tomato leaves than soil grown (15.36 ± 0.77 mg/100g and 4.50 ± 0.97 mg/100 g, respectively) despite having any significant ($p < 0.05$) differences.

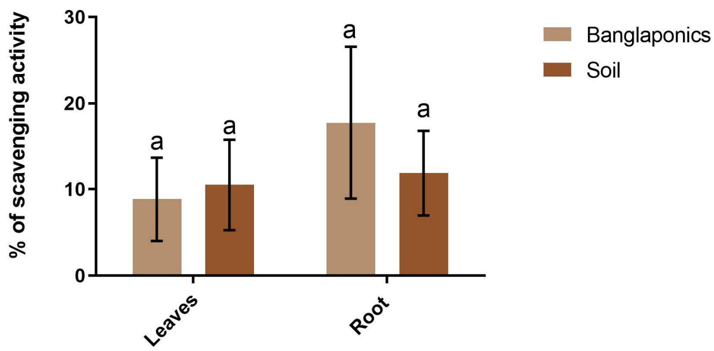

Fig. 2. Non-enzymatic antioxidant (DPPH) activity of tomato plants grown in two different cultivation techniques.

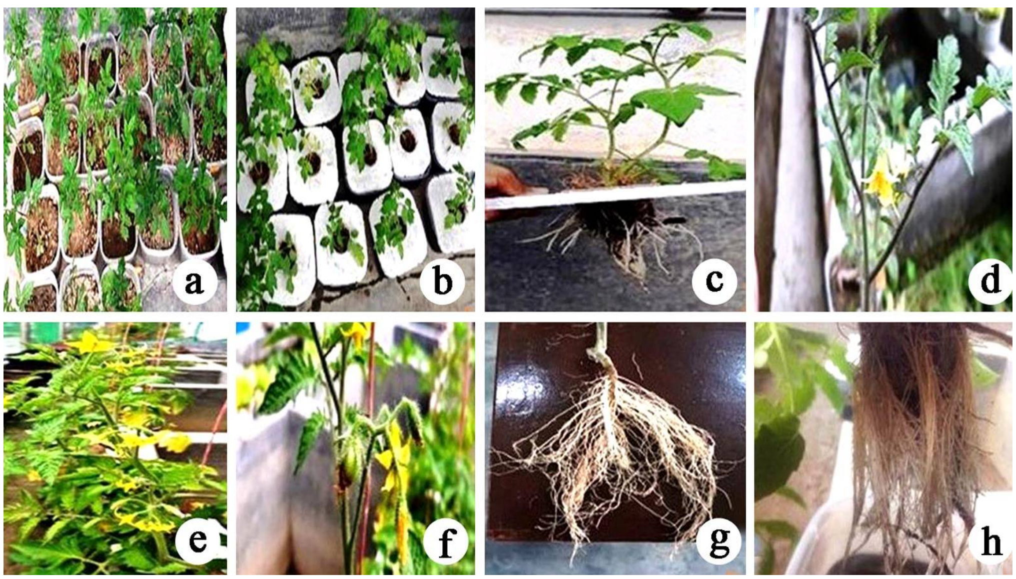

Fig. 3. Tomato cultivation A: Soil medium; B: Banglaponics medium; C: Roots of tomato at the initial stage of transplantation; D: Flowering in soil grown plants; E: Flowering at Banglaponics grown plant; F: Fruiting; G: Hairy roots at the final stage of soil grown plant; H: Hairy roots at the final stage of Banglaponics grown plant.

Among the mineral concentration, Fe and Zn showed higher amount in Banglaponically-grown plant leaves although the soil-grown plant leaves possessed significantly equal amount of the minerals (Table 4). However, Ca content was evaluated lower (537.1 ± 103.6 mg/100 g) in Banglaponics medium than soil grown (569.5 ± 62.23 mg/100g) tomatoes. The recorded values were higher in concentration than the reported results by Sainju *et al*. (2003) and Roosta and Hamidpour (2013) in different growing substances. Cardoso *et al*. (2018) reported almost similar concentrations of Zn in tomato leaves ranging 20 - 120 mg/kg depending on plants density grown hydroponically. However, lower Ca concentration in nutrition might be responsible for lower amount of Ca uptake that ultimately results in lower concentration in plants leaves.

Table 4. Minerals concentration of tomato leaves, grown on two media.

Minerals	Banglaponics medium (mg/100g)	Soil medium (mg/100g)
Ca	537.1 ± 103.6^{a}	569.5 ± 62.23^{a}
Fe	20.30 ± 3.15^{a}	15.36 ± 0.77^{a}
Zn	5.96 ± 1.64^{a}	4.50 ± 0.97^{a}

Heavy metals are not only detrimental for plants growth and development but also cause carcinogenic and non-carcinogenic effects on human health. Therefore, plants heavy metals (Pb, Cd and Cr) concentrations were analysed in plant leaves with AAS and the calculated amount tabulated in Table 5. Banglaponics plant showed lower Cd and Cr concentration without having any significant ($p < 0.05$) differences. Leaves of Banglaponically grown plants were found not to possess any Pb concentration whereas soil-grown leaves showed significantly higher Pb concentration (93.78 ± 15.95 mg/100g). Cadmium and Cr, in addition also showed lower accumulation in Banglaponics medium than soil cultivated plants. Differences between heavy metals concentration in cultivation techniques might be due to plants response to the cultivation environment. The Banglaponic medium have no Pb source which led the plant to grow in Pb-free condition and resulting Pb free roots, leaves, and tomato.

Table 5. Heavy metals concentration of tomato, grown on two media.

Heavy metals	Banglaponics medium (mg/100g)	Soil medium (mg/100g)
Pb	0^{a}	93.78 ± 15.95^{b}
Cd	1.68 ± 0.64^{a}	1.62 ± 0.34^{a}
Cr	8.57 ± 0.98^{a}	9.72 ± 0.10^{a}

Hydroponic is an alternative method for crop production in confined conditions or in open fields with a co-cultivation method. The technique is of high cost therefore, the present study has been undertaken to develop a low-cost- soilless cultivation technique. Banglaponics technique was applied and used to determine the productivity of a common vegetable of the country, the tomato. The technique is cost-effective and easily adaptable for agricultural practice in drought-prone areas of the country. Moreover, this technique has proved applicable as vegetative and generative growth and was found significantly ($p < 0.05$) higher which is positively correlated with the productivity of the plants. Plant photosynthetic pigment, antioxidant activity and mineral components were also found to be higher in the newly developed methods. The nutrient medium also minimized the heavy metal contamination of the plants.

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