



Yield and Nutritional Quality of Tomato as Affected by Chemical Fertilizer and Biogas Plant Residues

M. G. Kibria¹, M. Islam¹ and M. Alamgir^{1*}

¹Department of Soil Science, University of Chittagong, Chittagong- 4331, Bangladesh.

Authors' contributions

This work was carried out in collaboration between all authors. Author MGK designed the study and wrote the manuscript. Author MI collected samples, managed the analyses of the study and recorded data. Author MA performed the statistical analysis and data interpretation and evaluated the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/29434

Editor(s):

- (1) Marco Trevisan, Institute of Agricultural Chemistry and Environmental Research Centre BIOMASS, Faculty of Agriculture, Catholic University of the Sacred Heart, Italy.
(2) L. S. Ayeni, Adeyemi College of Education, Ondo State, Nigeria.
(3) Susana Rodriguez-Couto, Unit of Environmental Engineering, Paseo Manuel Lardizabal, Donostia-San Sebastián, Spain.

Reviewers:

- (1) Godsteven Peter Maro, Tanzania Coffee Research Institute, Tanzania.
(2) Mtaita Tuarira, Africa University, Zimbabwe.

Complete Peer review History: <http://www.sciencedomain.org/review-history/16663>

Original Research Article

Received 10th September 2016
Accepted 21st October 2016
Published 25th October 2016

ABSTRACT

A field experiment was conducted to study the effects of biogas plant residues (BPR) and NPK fertilizer on growth, yield and quality of tomato (*Lycopersicon esculentum*). The treatments were arranged in randomized block design with three replications. The results showed that application of BPR and NPK fertilizers significantly influenced the growth and yield of tomato compared to control treatment. BPR @ 50 t/ha produced the highest shoot and root dry weight and plant height at 30 and 45 days after transplantation (DAT). The highest number of fruits per plant, weight of fruits per plant and yield (t/ha) were also found with the same treatment. Application of inorganic fertilizer produced statistically similar number fruits per plant, weight of fruits per plant and yield (t/ha) to those found with BPR from 10 to 40 t/ha. There was no significant variation in single fruit of tomato among the treatments. Mineral nutrient content of tomato were not significantly affected by application of fertilizer and BPR except nitrogen in the fruit tissues. Protein content was decreased but lycopene content was increased by higher rates of BPR compared to control. BPR @ 20 t/ha has been suggested as an alternative to recommended level of chemical fertilizer in ensuring good performance in terms of yield and quality of tomato compared to other treatments in valley soils of Chittagong University campus in Bangladesh.

*Corresponding author: E-mail: mdalamgir@cu.ac.bd;

Keywords: Tomato quality; biogas residues; lycopene; protein.

1. INTRODUCTION

The low fertility status is one of the major constraints to crop production in most of the soils of the tropics [1,2]. Vast areas of tropical lands that were once fertile have been rendered unproductive due to continuous cultivation and erosion which caused physical degradation, loss of soils organic matter and decreased cation exchange capacity (CEC) and as well as increased Al and Mn toxicity [3]. The problem of low fertility status of most tropical soils has necessitated growing search for many soil fertility improvement techniques, such as adoption of appropriate and adequate fertilizer packages, involving the use of organic and / or inorganic fertilizers [4].

Bangladesh is an agricultural country and its soil is of great importance as a natural resource. Continuous mining of nutrients from the soil system of Bangladesh is going on by forcing the limited cultivable land to maximize crop yields per unit area through the use of land and soil resources. The illiterate and poor farmers of Bangladesh have tended to only exploiting the soils rather than maintaining them in a healthy fertile state. Intensive cultivation of high yielding crop varieties using only inorganic fertilizers and almost no recycling of organic residues have reduced soil organic carbon as well as other plant nutrients, especially N, which leads to severe land degradation in Bangladesh [5]. Under such situation to increase soil fertility and sustain crop productivity, there is no alternative besides to add organic fertilizer into the soil. Organic fertilizer can serve as a substitute to mineral fertilizers. Despite the large quantities of plant nutrients contained in inorganic fertilizers as compared to organic nutrients, the presence of growth promoting agents in organic fertilizers make them important for enhancement of soil fertility and productivity [6]. Due to high cost and scarcity of mineral fertilizer, most farmers cannot afford the use of chemical fertilizer. This necessitates research into organic wastes that are cheap, readily available and environmentally friendly that can be used as fertilizer.

The residues generated during the production of biogas through anaerobic digestion of organic wastes are known as digestate that can represent a valuable resource to sustain and improve soil fertility and to increase soil organic matter content. It may be considered as an

effective source of organic fertilizer as it contains considerable amounts of nutrients and organic matter [7,8]. Biogas technology is becoming popular in rural Bangladesh in view of escalating costs of fuels as well as soaring prices of chemical fertilizers which our farmers find difficult to buy for their sustainable crop production. The biogas plant technology uses cowdung, poultry litter, water hyacinth and other biomass wastes to produce biogas thereby ensuring a smoke-free, odor free, clean and healthy cooking environment for rural women.

Tomato is one of the most popular, important and widely used vegetable crops as ranked number two vegetable of the world after potato [9,10]. Tomatoes and tomato-based foods are considered healthy foods as they are low in fat and calories, cholesterol free, and a good source of fiber and protein. Since tomato plays an important role in human diet, its nutritional quality is of particular concern to consumers throughout the world [11]. The nutritional value of tomato consists essentially of carotene (provitamin A), lycopene, vitamin C and mineral nutrients. Lycopene is considered to be important contributors of carotenoids to the human diet. Increasing clinical evidence supports the role of lycopene as a micronutrient with important health benefits, because it appears to provide protection against a broad range of epithelial cancers [12]. The amount of lycopene in fresh tomato fruits depends on variety, maturity, and the environmental conditions under which the fruit matured. The composition and structure of the food also have an impact on the bioavailability of lycopene and may affect the release of lycopene from the tomato tissue matrix [13]. Minerals are essential regulators of physiological processes in humans but they cannot be synthesized by the body, and therefore, must be obtained through the diet. More than a third of all human proteins require metal ions to function. The absence of these ions can be harmful to human health [14,15,16]. Most research indicates that fruit quality is affected not only by adequate amounts of N, P, and K, but also by the balance between the levels of these nutrients [17].

Consumers recognize that organic production is safe and present high biological value [18]. Many studies on the quality of organic vegetables indicate a higher nutritional value and a higher content of biologically active compounds in agricultural crops from organic

farming [18,19,20]. Yield responses of vegetable crops to bio-slurry manure application have been reported in different crops including okra [21] maize and cabbage [22]. However, research information is scarce on response of tomato, nutrient composition and yield to application of biogas plant residues (BPR) especially in valley soils of Chittagong University campus. With these views in mind the objective of this study was to determine the optimum rate of biogas plant residues and its effect on growth characteristics, yield and quality of tomato relative to the recommended level of NPK fertilizer in the Chittagong University campus.

2. MATERIALS AND METHODS

2.1 Field Experiment

A field experiment was conducted to study the effects of biogas plant residues on growth and yield of tomato in the Crop Field of the Department of Soil Science, University of Chittagong. There were seven plots in each block for the seven treatments comprising of biogas plant residues and NPK fertilizers as follows-

T1 = Control (No fertilizer + No biogas plant residues),

T2 = Recommended NPK fertilizer @ 120 kg N/ha, 60 kg P/ha and 80 kg K/ha

T3 = Biogas plant residues (BPR) @ 10 t/ha

T4 = Biogas plant residues (BPR) @ 20 t/ha

T5 = Biogas plant residues (BPR) @ 30 t/ha

T6 = Biogas plant residues (BPR) @ 40 t/ha

T7 = Biogas plant residues (BPR) @ 50 t/ha

The experiment was laid out in a randomized complete block design with three replication of each treatment. The unit plots were 1 m×1 m size separated by 0.5 m margin. About thirty days old seedlings of a local tomato variety ruma were collected from a local market. Four seedlings were transplanted in four corner of each plot maintaining 75 cm spacing between seedlings to seedling. For the study, biogas plant residues were collected from a biogas plant at Jubra village situated nearby Chittagong

University. All of biogas plant residues were applied as basal during soil preparation and soils mixed with biogas plant residues were allowed to equilibrate for 4 weeks prior to planting seedlings. According to the recommendation of Bangladesh Agricultural Research Council [23], nitrogen and potassium was applied in two equal installments at 15 and 35 days after transplanting as ring method around the plants followed by irrigation. Full phosphorus was broadcast and incorporated during final land preparation.

2.2 Determination of Soil Properties

Surface soil sample was collected before conducting the experiment from the experimental site. The particle size distribution and textural class of the soil were determined by hydrometer method [24]. Soil pH was measured in a 1:2.5 soil water suspension with glass electrode pH meter (Mettler Toledo Seven Compact pH meter). Electrical conductivity (Ec) of the soil was measured by Ec 214 Conductivity Meter. The potassium dichromate wet-oxidation method of Walkley & Black [25] was used for the determination of organic carbon followed by multiplying the values with 1.724 to calculate the organic matter content. Total nitrogen was determined by micro - Kjeldahl method as described by Jackson [26]. Soil samples were digested with nitric acid and perchloric acid as described by Olsen and Sommers [27] for the determination of P and K in soil. Phosphorus was determined by ascorbic acid blue-color method by Murphy and Relay [28]. The potassium in the digest was measured by Atomic Absorption Spectrophotometer (Agilent Technologies 240AA). The pH of the soil was 6.8, texture was clay loam, organic matter content was 1.32%; electrical conductivity was (Ec) 28.3 μ S/m. Total nitrogen, phosphorus and potassium content of the soil were 0.09%, 0.01% and 1.23% respectively.

2.3 Characterization of Biogas Plant Residues

Biogas plant residues (BPR) were collected from a biogas plant at Jubra village nearby Chittagong University. Biogas plant residues were analyzed for chemical constituents following the same methods used in soil. The pH of the biogas plant residues was 6.0. Organic carbon content of the BPR was 6.67% and total nitrogen, phosphorus and potassium contents were 0.78%, .02% and 1.35% respectively.

2.4 Growth and Yield Components

Plant height was recorded after 30 and 45 days after transplanting seedlings to assess the plant growth. The fruits were harvested at 4 to 5 days interval when matured and ripened. The number of fruits per plant, weight of fruits per plant and yield were recorded during harvest. The shoot and root of tomato plants were collected after completion of the harvesting; washed thoroughly with tap water first to remove adhering soil and dust from the roots and shoots and then with distilled water. They were air dried first and then their oven dry weights were recorded.

2.5 Determination of Quality of Tomato

Oven dried (65°C constant weights) and ground ripe fruit samples were digested with a mixture of H₂SO₄, H₂O₂ and lithium sulfate for the determination of mineral nutrient N, P, K, Ca and Mg in the fruit tissues [29]. Micro- Kjeldahl method as described by Jackson [26] was used for the determination of nitrogen. Phosphorus was determined by vanadomolybdo phosphoric yellow colour method in nitric acid system according to Jackson [26]. The concentrations of K, Ca and Mg in the digest were measured by atomic absorption spectrophotometer (Agilent Technologies 240AA).

Lycopene in the tomato samples was extracted by hexane: Acetate: ethanol (2:1:1, v. v. v) mixture following the method of Sharma and Le Maguer [30]. The absorbance of hexane solution containing lycopene was measured at 472 nm on a spectrophotometer using hexane as a blank. The lycopene concentration was calculated using its specific extinction coefficient (E1%, 1 cm) of

3450 in hexane at 472 nm [31]. Protein content of plant material was obtained by multiplying the nitrogen value by 6.25. These parameters were measured as they are considered as indicators of tomato nutritional quality [17,32,33].

2.6 Statistical Analysis

The significance of differences between the means of the treatments was evaluated by one way analysis of variance followed by Duncan's Multiple Range Test (DMRT) at the significance level of 5%. The statistical software Excel [34] and SPSS version 12 [35] were used for these analyses.

3. RESULTS AND DISCUSSION

3.1 Plant Height

Plant height is one of the most important characteristics of tomato plant. The plant height of tomato was measured after 30 and 45 days after transplantation (DAT) of tomato seedlings and the results are presented in the (Table 1). The range of plant height varied from 37.00 to 75.33 at 30 DAT and 50.33 to 94.33 cm at 45 DAT. The results of the study indicated that there were significant variations in plant height among the treatments. The plant height was the minimum in T1 (control) treatment and the maximum in T7 (BPR @ 50 t/ha) treatment at both 30 and 45 DAT. Addition of biogas plant residues and inorganic fertilizers significantly increased plant height than that of the control except BPR @ 10 t/ha. Application of inorganic fertilizer (T2) and BPR @ 20 t/ha (T4) showed similar results in producing plant height of tomato. There was no significant difference in plant height between T4 and T5.

Table 1. Effects of biogas plant residues on plant height of tomato

Treatment	Plant height (cm)		Dry weight (g)	
	30 DAT	45 DAT	Shoot	Root
T1	37.00 d	50.33 d	9.61 d	3.43 c
T2	51.67c	69.67 c	30.73 c	9.35 b
T3	40.33 d	55.67 d	36.29 bc	9.53 b
T4	54.33 c	67.67 c	32.84 bc	12.21 ab
T5	65.00 b	78.67 b	52.94 ab	11.89 ab
T6	66.67 b	81.00 b	40.71 bc	11.99 ab
T7	75.33 a	94.33 a	64.53 a	14.86 a
Significance of F value	0.001	0.001	0.001	0.01

Mean values in a column followed by the same letter(s) are not significantly different by DMRT ($p < 0.05$)

3.2 Dry Weight of Shoot and Root

Data on the dry weight of shoot and root of tomato plants are presented Table 1. Shoot dry weight ranged from 9.61 to 64.53 g and root dry weight ranged from 3.43 to 14.86 g. The highest dry weight of both shoot and root was found with BPR @50 t/ha (T7) and the lowest dry weight of shoot and root were found with the control treatment T1. Application of inorganic fertilizer and biogas plant residues significantly increased shoot and root dry weight of tomato compared to the control. Shoot dry weight found with BPR in treatment T3 (36.29 g; 10 t/ha), T4 (32.84 g; 20 t/ha) and T6 (40.71g; 40 t/ha) were similar to that with recommended inorganic fertilizer in treatment T2 (30.73 g). The treatment T5 (52.94 g) and T7 (64.53 g) were also not significantly different in producing shoot dry weight. Application of inorganic fertilizer (T2) and BPR up to 40 t/ha (T3, T4, T5 and T6) showed similar results in producing root dry weights of tomato. There was no significant difference in root dry weight with BPR between 40 (T5) and 50 (T6) t/ha.

3.3 Number of Fruits

Number of fruits plant⁻¹ is the most important yield attributing character of tomato plant. The results found in this study are presented in Table 2. The value of total number of fruits per plant ranged from 4.75 to 23.75. The highest number of fruits per plant was observed in treatment T7 where biogas plant residues @ 50 t/ha were applied. The lowest number of fruits per plant was observed in control treatment T1 where no fertilizer and biogas plant residues were applied. Application of inorganic fertilizers significantly increased the number of fruits per plant from that of the control. Biogas plant residues @ 10 t/ha (T3) did not show any

significant difference in the number of fruits per plant from that with the control. But biogas plant residues @ 20 t/ha (T4) and above in treatment T5 (30 t/ha), T6 (40 t/ha) and T7 (40 t/ha) showed significantly higher number of fruits per plant compared to control treatment (T1). However, the number of fruits per plant found with the treatments T4, T5 and T6 were statistically similar with each other.

3.4 Single Fruit Weight

The single fruit weight of tomato varied from 37.86 g to 51.21 g (Table 2). Single fruit weight of tomato showed no significant difference among the treatments. However, the highest single fruit weight was found in treatment T5 where biogas plant residues @ 10 t/ha was applied and the lowest single fruit weight was found with the addition of biogas plant residues @ 50 t/ha in treatment T7.

3.5 Weight of Fruits per Plot

Weight of fruits per plot varied from 0.90 kg in treatment T1 (control) to 3.59 kg in treatment T7 where 50 t/ha biogas plant residues was applied (Table 2). Addition of inorganic fertilizers @ 120 kg N/ha, 60 kg P/ha and 80 kg K/ha (T2) significantly increased the weight of fruits per plot from that with the control. Application of biogas plant residues @ 10 t/ha (T3) did not show any significant difference in weight of fruits per plot from that with the control. But biogas plant residues @ 20 t/ha (T4) and above in treatment T5 (30 t/ha), T6 (40 t/ha) and T7 (40 t/ha) significantly increased the weight of fruits per plot compared to control treatment (T1). There were no significant differences in producing weight of fruits plot⁻¹ among inorganic fertilizer (T2) and biogas plant residues up to 40 t/ha (T3, T4, T5 and T6).

Table 2. Effects of biogas plant residues on number and weight of fruits of tomato

Treatment	Number of fruits per plant	Single fruit weight (g)	Wt. of fruits per plot (kg)	Yield (t/ha)	Yield increase (%)
T1	4.75 d	50.05 a	0.90 c	8.50 c	0.00 c
T2	10.33 bc	49.65 a	2.08 b	20.81 b	144.86 b
T3	7.50 cd	51.21 a	1.55 bc	15.53 bc	82.75 bc
T4	12.50 bc	49.41 a	2.48 b	24.80 b	191.73 b
T5	12.83 bc	45.24 a	2.34 b	23.40 b	175.33 b
T6	14.83 b	43.60 a	2.55 b	25.48 b	199.76 b
T7	23.75 a	37.86 a	3.59 a	35.92 a	332.58 a
Sig. of F value	0.001	NS	0.001	0.001	0.001

Mean values in a column followed by the same letter(s) are not significantly different by DMRT ($p < 0.05$)

3.6 Yield of Tomato

Yield is the most important characteristics for the justification of evaluation of tomato genotypes and varieties. It was observed that yield of tomato varied from 8.50 t/ha to 35.92 t/ha among the treatments in the present study (Table 2). The highest yield was obtained with application of biogas plant residues @ 50 t/ha in treatment T7 and the lowest yield was obtained with control treatment T1 where no fertilizer or biogas plant residues were applied. Tomato yield found with the addition of inorganic fertilizer @ 120 kg N/ha, 60 kg P/ha and 80 kg K/ha (T2) was significantly higher than that with the control treatment T1. There was no significant difference between treatments T1 (control) and T3 (biogas plant residues @10 t/ha) in producing yield of tomato in the present study. But biogas plant residues @ 20 t/ha (T4) and above (T5, 30 t/ha; T6, 40 t/ha and T7, 50 t/ha) produced higher yield compared to control treatment (T1). However, the treatments T4, T5 and T6 were statistically similar with each other in producing yield of tomato. Although the single fruit weight of tomato was statistically similar among the treatments, the highest yield of tomato was found in treatment T7 (50 t/ha biogas plant residues) due to the largest number of fruits plant⁻¹ with this treatment.

3.7 Yield Increase

Yield increase of tomato by application of biogas plant residues and inorganic fertilizers over control was in the range from 82.75% in treatment T3 (biogas plant residues @ 10 t/ha) to 332.58% in treatment T7 (50 t/ha biogas plant residues) (Table 2). Yield increase in treatment T3 over control was not significant. Yield increase in treatment T2 (144.86%; NPK @ 120 kg N/ha, 60 kg P/ha and 80 kg K/ha), T4 (191.73%; 20 t/ha biogas plant residues), T5 (175.33%; 30 t/ha biogas plant residues) and T6 (199.76%; 40 t/ha biogas plant residues) were statistically similar with each other but were significantly lower than that in treatment T7 (332.58%; 50 t/ha biogas plant residues) over control.

3.8 Mineral Nutrient Content of Tomato

Mineral elements content in the fruits have been characteristically been used as an indicator of the nutritional quality of the fruits. The mineral nutrient content of tomato is shown in Table 3.

Nitrogen concentration in tomato fruit varied significantly from 3.72% to 4.80% among the treatments. The highest concentration of nitrogen was found in treatment T1 (control) and the lowest concentration of nitrogen was observed in treatment T7 where biogas plant residues were applied @ 50 t/ha. The treatments T2, T3 and T4 showed statistically similar result compared with control. Application of biogas plant residues above 20 t/ha significantly decreased nitrogen concentration in tomato fruit from that of the control. However, the treatments T5, T6 and T7 were statistically similar with each other in producing nitrogen concentration in tomato fruit.

The phosphorus concentration in tomato under the various treatments of the study was in the range between 0.60 and 0.77% (Table 3). There were no significant differences in phosphorus concentration among the treatments of the study. However, the highest concentration of phosphorus was found in control treatment T1 and the lowest concentration of phosphorus was found in both the treatments T3 and T4. Potassium content in tomato fruits analyzed in this work was found to vary from 1.01 to 1.08% (Table 3). The treatments of the present study did not show significant differences in potassium concentration of tomato fruits. However, the maximum K concentration was found in treatment T3 and the minimum K concentration was found in control treatment T1. Calcium content of tomato ranged from 0.05 to 0.06% (Table 3). There was no significant difference in Ca content of tomato among the treatments. However, the highest value of Ca was observed in treatment T2, T5 and T6 and the lowest value was found with T1, T3, T4 and T7 treatment. Magnesium concentration in tomato fruits of the present study varied from 0.13 to 0.14% (Table 3). The treatments of the present study did not show significant difference in Mg concentration of tomato. The higher value of Mg (0.14) concentration was found in treatments T1, T2 and T4 and the lower Mg value (0.13%) was found in treatments T3, T5, T6 and T7.

3.9 Lycopene Content of Tomato

Levels of lycopene in tomato ranged from 73.37 to 118.65 mg/kg (Table 3). The highest level of lycopene content of tomato was found with 50 t/ha biogas plant residues (T7) and the lowest level of lycopene was observed in control treatment T1. Application of NPK fertilizers did not affect the level of lycopene in tomato compared to that with control. Similar results

were found with the addition of biogas plant residues @ 10 and 20 t/ha (T3 and T4). Biogas plant residues @ 30, 40 and 50 t/ha (T5, T6 and T7) produced significantly higher amount of lycopene in tomato compared to control treatment T1. The level of lycopene in tomato was not significantly different between T5 and T6 and between T6 and T7.

3.10 Protein Content of Tomato

Protein content of tomato varied significantly from 23.25% to 30.02% (Table 3). Application of NPK fertilizers produced similar amount of protein in tomato compared with control treatment T1. Biogas plant residues @ 10 and 20 t/ha (T3 and T4) also produced the statistically similar amount of protein in tomato compared to control. Protein content of tomato found with the treatments T5, T6 and T7 were significantly lower than that with the control treatment T1 but were statistically similar with each other.

The results of the present study indicated that the experimental soil is not feasible for profitable crop growing without fertilizer application because of its very poor fertility. Almost all the fertilizer treatments improved growth and yield as indicated by plant height, shoot and root dry weight, number of fruits per plant, and weight of fruits per plant and yield (t/ha). But there were significant differences among the fertilizer treatments. For example, the highest plant height (75.33 cm at 30 DAT and 94.33 at 45 DAT) and yield (35.92 t/ha) was obtained in the treatment with 50 t/ha biogas plant residues. This treatment increased yield of tomato by 332.58 percent over the control (no fertilizer). Addition of recommended doses of NPK (120 kg N/ha, 60 kg P/ha, 80 kg K/ha) also increased tomato yields

but by 144.86 percent. Yield increases by biogas plant residues application @ 20, 30 and 40 t/ha were statistically similar with that of recommended NPK fertilizer but significantly higher than that with control treatment.

Several studies confirm the beneficial effects of compost on shoot and root development of horticultural and economical species growing in substrates with different soil/ compost ratio [36,37,38]. A significant increase in length and height of shoot, leaf number and length of inflorescence, in *Solanum melongena*, *Cyamopsis tetragonoloba*, *Capsicum annuum* and *S. lycopersicum* harvested after growth in soil/compost substrate was observed [39]. The observation of the present study is corroborated with the findings of Grammeen Shakti [40] that in a field trial to study the effects of cow dung and poultry litter biogas residues on cabbage, brinjal and tomato found that biogas residues had favourable influences in increasing the yields of the crops. Application of 50% recommended dose inorganic fertilizer +2 t/ha cow dung biogas residues increased the yield of cabbage, brinjal and tomato by 480, 336 and 284% respectively compared to control. The yield responses were comparable with those of 100% recommended fertilizer doses. Bangladesh Agricultural Research Institute [41] recorded about 371% yield increase of cabbage over native fertility by 5 t/ha cow dung slurry with integrated plant nutrient system (IPNS) base inorganic fertilizer. Yield increase due to application of 3 t/ha poultry manure slurry with IPNS base inorganic fertilizer was 394% [41]. The cob yield of maize was increased by application of biogas slurry [42]. The production of largest head of Sunflower was reported by Jaykumar and Elangoven [43] with the biogas slurry @ 300 g per pot.

Table 3. Effects of biogas plant residues on mineral nutrients, lycopene and protein content of tomato

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Lycopene (mg kg ⁻¹)	Protein (%)
T1	4.80 a	0.77 a	1.01 a	0.05 a	0.14 a	73.37 d	30.02 a
T2	4.47 ab	0.63 a	1.03 a	0.06 a	0.14 a	82.89 cd	27.92 ab
T3	4.23 abc	0.60 a	1.08 a	0.05 a	0.13 a	85.19 bcd	26.46 abc
T4	4.58 ab	0.60 a	1.02 a	0.05 a	0.14 a	79.05 cd	28.63 ab
T5	3.99 bc	0.64 a	1.02 a	0.06 a	0.13 a	93.94 bc	24.94 bc
T6	3.73 c	0.68 a	1.04 a	0.06 a	0.13 a	102.86 ab	23.33 c
T7	3.72 c	0.76 a	1.02 a	0.05 a	0.13 a	118.65 a	23.25 c
Sig. of F Value	0.01	NS	NS	NS	NS	0.001	0.01

Mean values in a column followed by the same letter(s) are not significantly different by DMRT ($p < 0.05$)

Nutrition treatment was found to have a significant positive effect on tomato quality, color and acceptability. Potassium and phosphorus nutrition has a positive effect on sugar and acid content of tomato [44]. Experiments conducted by Islam [45] and Nasir et al. [46] showed that bio-slurry is an excellent organic fertilizer and a good source of plant macro and micro nutrients. In the present study nutrient content of tomato did not significantly affected by the addition of BPR or recommended dose of chemical fertilizers except nitrogen. It has also become increasingly evident that, while crops respond favourably to N and P in some soils (so-called “responsive soils”), they do not respond to fertilizer application in any significant manner in other soils (the so-called non-responsive soils) [47].

Lycopene is the most abundant carotenoid present in red tomatoes, comprising up to 90% of the total carotenoids present. Normally, tomatoes contain about 3 to 5 mg lycopene per 100 g of raw material [13]. Carotenoid accumulation in plant tissue appears to be shaped by the physiological, genetic, and biochemical attributes of a plant species, as well as by environmental growth factors such as light, temperature, and fertility [48]. Changes in nutritional fertility affect plant carotenoid accumulations. Nitrogen fertilization seems to improve carotene accumulation. In fact, increasing N in the nutrient solution increased lutein–zeaxanthin, b–carotene content in parsley (*Petroselinum crispum* Nym.) [49]. Lycopene content of tomato was significantly increased by biogas plant residues @ 30, 40 and 50 t/ha compared to control. Similar increase in lycopene in organically grown tomato was reported by Lumpkin [50]. In agreement with the present study, Adeniyi and Ademoyegun [51] also reported the more influence of organic fertilizers than inorganic fertilizer on the level of lycopene content of tomato.

4. CONCLUSION

This work shows that both inorganic fertilizer and BPR application significantly affected the yield, protein and lycopene content of tomatoes. Application of 50 t/ha BPR resulted the highest growth and yield (t/ha) and lycopene content of tomato. Compared to recommended dose of inorganic fertilizer, application of 20 - 40 t/ha BPR had almost similar effects on tomato yield and quality. Considering the price of BPR, transportation cost and market value of tomato,

use of the highest amount of biogas plant residues used in this study may not be economical. Therefore, application of 20 t/ha BPR has been suggested as an alternative to recommended level of chemical fertilizer in ensuring good performance in terms of yield and quality of tomato in valley soils of Chittagong University campus. In conclusion, BPRs have the potential to be a useful agricultural tool for producing high-quality lycopene products which will offer probable benefits to the food industry and sustainable agroecosystem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. de Ridder N, van Keulen H. Some aspects of the role of organic matter in sustainable intensified arable farming systems in the West African semi – arid tropics. *Fertil. Res.* 1990;26:29–31.
2. Gazel GOT. The role of organic wastes in maintaining soil fertility under continuous cropping. *Adv. J. Soil Sci.* 2005;6(3):553–559.
3. Mba CN. Influence of organic wastes on plant growth parameters and nutrient uptake by maize (*Zea mays* L). *Nig. J. Soil Sci.* 2006;16:104-108.
4. Tankou JFT. The role of organic and inorganic fertilizers in soil fertility maintenance and crop production. *Soil Sci. Res.* 2004;6(4):751–757.
5. Karim Z, Miah MMU, Razia S. Fertilizer in the national economy and sustainable environmental development. *Asia Pacific. Journal of Environment and Development.* 1994;2:48-67.
6. Sanwal SK, Lakminarayana K, Yadav RK, Rai N, Yadav DS, Mousumi B. Effect of organic manures on soil fertility, growth, physiology, yield and quality of turmeric. *Ind. J. Hort.* 2007;64(4):444-449.
7. Bachmann S, Wentzel S, Eichler-Löbermann B. Codigested dairy slurry as a phosphorus and nitrogen source for *Zea mays* L. and *Amaranthus cruentus* L. *J. Soil Sci. Plant Nutr.* 2011;174:908–915.
8. Lošák T, Musilová L, Zatloukalová A, Szostková M, Hlušek J, Fryč J, Vítěz T, Haitl M, Bennewitz E, Martensson A. Digestate is equal or a better alternative to mineral fertilization of kohlrabi. *Acta*

- Universitatis Agriculturae et Silviculturae Mendelae Brunensis. 2012;60:91–96.
9. Dorais M, Ehret DL, Papadopoulos AP. Tomato (*Solanum lycopersicum*) health components: from the seed to the consumer. *Phytochem. Rev.* 2008;7:231-250.
 10. Olaniyi J, Akanbi W, Adejumo T, Ak O. Growth, fruit yield and nutritional quality of tomato varieties. *African J. Food Sci.* 2010;4:398-402.
 11. Chapagain BP, Wiesman Z. Effect of Nutri-Vant-PeaK foliar spray on plant development, yield, and fruit quality in greenhouse tomatoes. *Sci Hortic.* 2004;102:177–188.
 12. Shi J, Maguer ML. Lycopene in tomatoes: Chemical and physical properties affected by food processing. *Crit. Rev. Food Sci. Nutr.* 2000;40:1-42.
 13. Hart DJ, Scott KJ. Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. *Food Chem.* 1995;54:101–111.
 14. Bertini I, Sigel A, Sigel H. Handbook on metalloproteins. New York: Marcel Dekker; 2001.
 15. Odhav B, Beekrum S, Akula US, Baijnath HJ. Preliminary assessment of nutritional value of traditional leafy vegetables in KwaZulu-Natal, South Africa. *J. Food Comp. Anal.* 2007;20(5):430-435.
 16. Pereira MC, Boschetti W, Rampazzo R, Celso PG, Hertz PF, Rios ADO, Vizzotto M, Flores SH. Mineral characterization of native fruits from the southern region of Brazil. *Food Sci. Tech.* 2014;34:258-266.
 17. Varis S, George RAT. The influence of mineral nutrition on fruit yield and quality in tomato. *J. Hort Sci.* 1985;60:373-376.
 18. Hallmann E. The influence of organic and conventional cultivation systems on the nutritional value and content of bioactive compounds in selected tomato types. *J. Sci. Food Agric.* 2012;92:2840–2848.
 19. Brandt K, Mølgaard JP. Organic agriculture: Does it enhance or reduce the nutritional value of plant foods? *J Sci Food Agric.* 2001;81:924–931.
 20. Chassy AW, Bui L, Renaud ENC, van Horn M, Mitchell AE. Three year comparison of the content of antioxidant micro-constituents and several quality characteristics in organic and conventionally managed tomatoes and bell peppers. *J Agric Food Chem.* 2006;54: 8244–8252.
 21. Shahabz M. Potential of bio-slurry and compost at different levels of inorganic nitrogen to improve growth and yield of okra (*Hibiscus esculetus* L.). M. Sc. Thesis, University of Agriculture Faisalabad, Pakistan; 2011.
 22. Karki KB. Response to bio-slurry application on maize and cabbage in Lalipur District. Final Field Research Report Submitted to Alternative Energy Promotion Centre of Ministry of Science and Technology. Pulchok, Nepal; 2001.
 23. Bangladesh Agricultural Research Council (BARC). Fertilizer Recommendation Guide. BARC Soils Publications No 45; 2005.
 24. Day PR. Particle fractionation and particle size analysis. In: *Methods of soil analysis*. Editor. Black CA. Part I. Agronomy Monograph, Academic Press, New York. 1965;545-567.
 25. Walkley A, Black IA. An examination of the Degtjareff method for determining organic carbon in soils: Effect of variations in digestion conditions and of inorganic soil constituents. *Soil Sci.* 1934;63:251-263.
 26. Jackson ML. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi, India; 1973.
 27. Olsen Sand Sommers L. Phosphorus, In: *Methods of soil analysis*. Editors. Page AL, Miller RH and Keeney DR, Agronomy Monogram. No. 9, ASA, CSSA and SSSA, Madison, WI, USA. 1982;403-430.
 28. Murphy J, Riley JP. A modified single solution for the determination of phosphorus in natural water. *Anal. Chem. Acta.* 1962;27:31-36.
 29. Allen SE, Grimshaw HM, Rowland AP. Chemical analysis. In: *Methods in plant ecology*. 2nd Ed. editors. Moore PD and Chapman SB. Blackwell Scientific Publications, Oxford. 1986;285-344.
 30. Sharma SK, Le Maguer M. Lycopene in tomatoes and tomato pulp fractions. *Italian J. Food Sci.* 1996;8(2):107-113.
 31. Toor RK. Influence of different types of fertilizers on the major antioxidant components of tomatoes. *J. Food Comp. Anal.* 2006;19:20-27.
 32. Valverde IM, Periago MJ, Provan G, Chesson A. Phenolic compounds, lycopene and antioxidant activity in commercial varieties of tomato

- (*Lycopersicum esculentum*). J. Sci. Food Agric. 2002;82:323-330.
33. Pieper JR, Barrett DM. Effects of organic and conventional production systems on quality and nutritional parameters of processing tomatoes. J. Sci. Food Agric. 2009;89:177–194.
 34. Excel Inc. Microsoft Excel for Windows, Microsoft Corporation, USA; 2003.
 35. SPSS Inc. Statistics, Chicago, USA; 2003.
 36. Valdrighi MM, Pera A, Agnolucci M, Frassinetti S, Lunardi D, Vallini G. Effects of compost-derived humic acids on vegetable biomass production and microbial growth within a plant (*Cichorium intybus*) – soil system: A comparative study. Agr Ecosyst Environ. 1996;58:133–144.
 37. Atiyeh RM, Subler S, Edwards CA, Bachman G, Metzger JD, Shuster W. Effects of vermicomposts and composts on plant growth in horticultural container media and soil. Pedobiologia. 2000;44: 579–590.
 38. Cooperband L, Bollero G, Coale F. Effect of poultry litter and composts on soil nitrogen and phosphorus availability and corn production. Nutr. Cycl. Agroecosyst. 2002;62:185–194.
 39. Gajalakshmi S, Abbasi SA. Effect of the application of water hyacinth compost/ vermicompost on the growth and flowering of *Crossandra undulaefolia*, and on several vegetables. Bioresour Technol. 2002;85: 197–199.
 40. Grameen Shakti. Field Research Report, Grameen Bank Bhaban, Mirpur, Bangladesh; 2006.
 41. Bangladesh Agricultural Research Institute (BARI). Project Report on Bio-slurry management and its effect on soil fertility and crop production. Soil Science Division & On –Farm Research Division, Gazipur, 1701, Bangladesh; 2008.
 42. Manna MC, Hazra JN. Comparative performance of cowdung slurry, microbial inoculum and inorganic fertilizers on maize. J. Ind. Soc. Soil Sci. 1996;44:526-528.
 43. Jaykumar M, Eyini M, Elanogoven R. Effect of biogas slurry on salinity induced changes in growth and yield of sunflower. Ind. J. Agri. Sci. 1993;63(10):655-657.
 44. Mikkelsen RL. Tomato flavor and plant nutrition: A brief review. Better Crops. 2005;89(2).
 45. Islam MS. Use of bio-slurry as organic fertilizer in Bangladesh agriculture. Bangkok, Thailand. 2006;27-28.
 46. Nasir A, Khalid MU, Anwar S, Arslan C, Akhtar MJ, Sultan M. Evaluation of bio-fertilizer application to ameliorate the environment and crop production. Pak. J. Agri. Sci. 2012;49(4):527-31.
 47. Vanlauwe B, Kihara J, Chivenge P, Pypers P, Coe R, Six J. Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. Plant Soil. 2011;339:35–50.
 48. Kopsell DA, Kopsell DE. Accumulation and bioavailability of dietary carotenoids in vegetable crops. Trends Plant Sci. 2006;11:499–507.
 49. Chenard CH, Kopsell DA, Kopsell DE. Nitrogen concentration affects nutrient and carotenoid accumulation in parsley. J Plant Nutr. 2005;28:285–297.
 50. Lumpkin HM. A comparison of lycopene and other phytochemicals in tomatoes grown under conventional and organic management systems. Tech. Bullet. 2005;34:4-48.
 51. Adeniyi H, Ademoyegun O. Effects of different rates and sources of fertilizer on yield and antioxidant components of tomato (*Lycopersicon esculentum*). Agri. J. 2012;7(2):135-138.

© 2016 Kibria et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<http://sciencedomain.org/review-history/16663>