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Effects of Biogas Plant Residues and NPK Fertilizers on Growth and Nutritional Quality of Amaranth (*Amaranthus tricolor* L.)

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Abstract

A pot experiment was conducted at crop field of the Dept. of Soil Science, University of Chittagong to study the effect of biogas plant residues (BPR) and NPK fertilizers on the growth of and nutrient uptake by Amaranth (*Amaranthus tricolor* L.). There were six treatments and treatments were consisted as the following: T_1=Control (No BPR+No inorganic fertilizers), T_2=recommended doses of NPK @ 156 kg N ha^{-1}, 36 kg P ha^{-1}, 80 kg K ha^{-1} from inorganic fertilizer, T_3=BPR @ 20 t ha^{-1}+calculated amount of inorganic NPK fertilizer, T_4=BPR @ 15 t ha^{-1}+calculated amount of inorganic NPK fertilizer, T_5=BPR @ 10 t ha^{-1}+calculated amount of inorganic NPK fertilizer, T_6=BPR @ 5 t ha^{-1}+calculated amount of inorganic NPK fertilizer. Each treatment was replicated thrice. The results showed that the minimum no. of leaves, plant height, root length and fresh and dry weight of shoot and root were found in control treatment T_1. The no. of leaves and plant height were the maximum in treatment T_4 in most cases. However, the highest shoot and root weight was observed in treatment T_6. Compared to inorganic fertilizer alone, the application of biogas residues along with NPK fertilizers applied at reduced rates significantly increased dry weight of shoot and root of amaranth by 38–54% and 91–166% respectively. Nutrient uptake was the lowest in control, higher in the treatment of chemical fertilizer alone and the highest in the treatments of biogas plant residues in combination with chemical fertilizers except Ca uptake in shoot. The results of the present study suggest that the application of biogas residues along with reduced rate of inorganic fertilizers is a viable strategy for the sustainable production of amaranth in valley soils of Chittagong.

Keywords: Biogas plant residues, fertilizers, amaranth, growth, nutrient uptake

1. Introduction

Biogas plant is basically designed to allow the anaerobic digestion of organic materials which produces "biogas," primarily composed of methane and carbon dioxide (Nasir et al., 2010). The residues, called digestate, are a complex mixture of water and a multitude of particulate, suspended, and dissolved organic and inorganic substances, including nutrients, not decomposed organic matter, and pollutants (Moller, 2015). Digestate is the by-product of methane and heat production in a biogas plant, coming from organic wastes. Depending on the biogas technology, the digestate could be a solid or a liquid material (Makadi et al., 2012). The digestate is a very useful organic fertilizer that can be used to offset the financial as well as the environmental costs associated with the use of mineral fertilizer (Lukehurst et al., 2010). Islam et al. (2010) suggested that bio-slurry is an environmentally friendly and non-polluting organic fertilizer that could be used as a source of organic matter and nutrients for sustainable crop production. The biogas slurry has 93% water and 7% of dry matter of which 4.5% is organic matter and 2.5% inorganic matter (Kumar et al., 2015). Crops are able to absorb these high available nutrients quickly and the organic matters contained in biogas residues and slurry can be used to improve soil structure, increase soil fertility (Jiang et al., 2009). Therefore, it is an effective way to use biogas residues as a good source of organic fertilizer as it contains considerable amounts of both macro and micro nutrients (Bachmann et al., 2011). Declining in soil fertility is a common scenario in Bangladesh though magnitudes vary in different Agro-Ecological Zones (AEZ). According to an appraisal report of Bangladesh soil resources, soils of about 6.10 mha contain very low (less than 1%) organic matter, 2.15 mha contain low (1–2%) organic matter and the remaining 0.90 mha contain more than 2% organic matter (Rahman et al., 2008). It is agreed that decreases in soil fertility is a major constraint for higher crop production in Bangladesh. So, there is no alternative to addition of organic fertilizers into the soil to increase soil fertility and sustain crop production. Application of biogas plant residues in soil could be one of the options to maintain declining soil fertility. Bangladesh has a good opportunity to use biogas residues as a nitrogen fertilizer, because 2000 biogas plants are already established in the country. From these existing biogas plants at least 60 t of biogas slurry is produced daily in Bangladesh. Proper application of these huge amounts of bio-slurry to crop land may help improve soil organic matter status. Bangladesh can make an eco-friendly environment by using this large quantity of biogas slurry in crop cultivation (Islam et al., 2010).

Amaranth (*Amaranthus tricolor*) is the most common leafy vegetable belongs to the family Amaranthaceae grown during summer and rainy reason in Bangladesh. It fits well in a crop rotation because of its very short duration and long yield of edible matter per unit area. Both in area and production, it ranks 5th in summer vegetable and 13th among all vegetable (BBS, 2010). As one of the nutritious and delicious vegetables, amaranth (*Amaranthus tricolor)* is a popular vegetable in Bangladesh because of its cheapest price, quick growing character and higher yield potential. Additionally it is considered as a potential subsidiary food crop (Teutonico and Knorr, 1995). Thus Amaranth plays a predominant role both in nutrition and food security. It contributes 5.42% in summer vegetables production. In Bangladesh, it is cultivated in an area of 25463 acre producing 65.98 thousand metric ton of fleshy edible part with per acre yield of 2.5 t (BBS, 2010).Yield responses of vegetable crops to biogas residues application have been reported in different crops including okra (Shahbaz et al., 2014) maize and cabbage (Karki, 2001). A very few research works have been done on the effect of biogas plant residues on plant growth and nutrition in Bangladesh especially on amaranth. With the above views in mind the present investigation has been undertaken. The objectives of this study were to: (1) compare the effects of biogas plant residues and NPK fertilizers on growth of amaranth in valley soils of Chittagong and (2) compare the effects of biogas plant residues and NPK fertilizers on nutritional quality of amaranth.

2. Materials and Methods

A pot experiment was conducted at crop field of the Dept. of Soil Science, University of Chittagong to study the effect of Biogas Plant Residues (BPR) and NPK fertilizers on the growth of and nutrient uptake by Amaranth (*Amaranthus tricolor* L.). Recommended doses of N (156 kg ha^{-1}), P (36 kg ha^{-1}) and K (80 kg ha^{-1}) for cultivation of amaranth were applied in each treatment except control. Recommended doses of NPK were supplied either from inorganic fertilizer or from particular amount of biogas plant residues and calculated amount of inorganic fertilizer on the basis of NPK requirement. The treatments were consisted of as the following: T_1=Control (No BPR+No inorganic fertilizers); T_2=Recommended doses of NPK @ 156 kg N ha^{-1}, 36 kg P ha^{-1}, 80 kg K ha^{-1} from inorganic fertilizer; T_3=Biogas Plant Residues @ 20 t ha^{-1}+Calculated amount of inorganic NPK fertilizer; T_4=Biogas Plant Residues @ 15 t ha^{-1}+Calculated amount of inorganic NPK fertilizer; T_5=Biogas Plant Residues @ 10 t ha^{-1}+Calculated amount of inorganic NPK fertilizer; T_6=Biogas Plant Residues @ 5 t ha^{-1}+Calculated amount of inorganic NPK fertilizer. The calculated amounts of inorganic fertilizer of different treatments for cultivation of amaranth are given in Table 1. However, the amount of K could not be adjusted due to oversupply of required K by biogas plant residues in treatment T_3, T_4, T_5. The inorganic fertilizer doses of N, P and K were applied from Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP), respectively. According to BARC (2012) recommendation, half N, and whole of P and K were applied during soil preparation for sowing seeds. Remaining N was applied in two equal installments after 15 and 30 days of sowing seeds. Biogas plant residues (BPR) collected from a biogas plant established at Jubra village in the vicinity of Chittagong University was mixed with the soil according to treatment plan and allowed to equilibrate for one month before sowing seeds. Eight kilograms soil was placed in each earthen pot having diameter and depth 28 and 25 cm, respectively. Each treatment was replicated thrice and the pots were arranged in a randomized complete block design (RCBD). Healthy seeds of *Amaranthus tricolor* were sown in each pot. After seedling emergence, nine seedlings of almost uniform size were kept in each pot after 15 days of sowing. Irrigation was applied as and when necessary. Weeds were removed by hands when necessary.

Table 1: Biogas plant residues (BPR) and inorganic fertilizer doses for different treatments

Treatment	BPR (kg ha^{-1})	Inorganic fertilizer (kg ha^{-1})		
		N	P	K
T_1	-	-	-	-
T_2	-	156	36	80
T_3	20	-	32.4	-
T_4	15	39	33.3	-
T_5	10	78	34.2	-
T_6	5	117	35.1	12.5

Soil used in the pot experiment was collected from the crop field of the Dept. of Soil Science, University of Chittagong. Soil samples were air dried, larger and massive aggregates were broken down by gentle crushing with wooden pluck. Dry roots, grasses and other particulate materials were discarded from the soil and processed for pot experiment. A portion of the soil passed through 2 mm sieve was taken for laboratory analysis for assessing the fertility status of the soil. The particle size distribution and textural class of the soil were determined by hydrometer method of Day (1965). 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 and Black (1934) was used for the determination of organic carbon followed by multiplying the values with 1.724 to calculate the organic matter content. Cation exchange capacity of soil was calculated based on pH, sand, clay and organic carbon content (Rashidi and Seilsepour, 2008). Total nitrogen was determined by micro-Kjeldahl method as described by Bremner and Mulvaney (1982). Soil samples were digested with nitric acid and perchloric acid as described by Olsen and Sommers (1982) for the determination of P and K in soil. Phosphorus was determined by ascorbic acid blue-color method by Murphy and Riley (1962). The potassium in the digest was measured by Atomic Absorption Spectrophotometer (Agilent Technologies 240AA). Water holding capacity was measured gravimetric method. The pH of the soil was 6.8; electrical conductivity (Ec) was 28.3 µS, texture was clay loam containing 33% sand, 19% silt and 48% clay; organic matter content was 1.32%; cation exchange capacity of the soil was 19.11 cmol kg^{-1}; Total nitrogen, phosphorus and potassium content of the soil were 0.09%, 0.01% and 1.23% respectively. The water holding capacity of the soil was 34.99%.

Biogas plant residues (BPR) were collected from a biogas plant at Jubra village in the vicinity of Chittagong University. Biogas plant residues were analyzed for chemical constituents. The same method as used for the respective element in the soil was followed. The pH of the biogas plant residues was 6.0; organic matter content was 6.00%. Total nitrogen, phosphorus and potassium content of the BPR were 0.78%, .02% and 1.35% respectively.

No. of leaves and plant height were recorded at 30, 45 and 60 days after sowing (DAS) to assess plant growth. Plants were harvested at 60 days after sowing. The shoots and roots were collected separately. The root length was measured and recorded. The plant materials were washed thoroughly first with tap water to remove adhering soil particles and then with distilled water. Fresh weight of shoots and roots were recorded. Oven dry (at 65 °C to constant weight) weight of shoots and roots were also recorded. Soil samples were also collected from each pot and air dried for further analysis.

Oven dried (65 °C to constant weight) and ground plant samples were digested with a mixture of H_2SO_4, H_2O_2 and lithium sulfate (Allen et al., 1986) for the determination of N, P, K, Ca, Mg and Na in the plant tissues. Micro-Kjeldahl method as described by Jackson (1973) was used for the determination of nitrogen. Phosphorus was determined by vanadomolybdo phosphoric yellow color method in nitric acid system according to Hanson (1950). The concentrations of K, Ca, Mg and Na in the digest were measured by atomic absorption spectrophotometer (Agilent Technologies 240AA).

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 at the significance level of 5%. Pearson's correlation coefficient was estimated to test the relations among metal contents in soil and soil properties and between metal concentrations in plant tissues and metal content in soils. The statistical software Excel and SPSS version 12 (SPSS, 2003) were used in the analysis.

3. Results and Discussion

3.1. Growth parameters of amaranth

No. of leaf was the minimum in the control at the periods of recording at 30, 45 and 60 days after sowing (Table 2). The corresponding values were 7.00, 7.04 and 8.09 respectively. Addition of inorganic fertilizer and biogas plant residues significantly increased the number of leaves compared to control. Application of recommended doses of NPK from inorganic fertilizer (Treatment T_2) increased the no. to 8.93 and 9.48 and 11.02 at the respective periods. The no. of leaves plant^{-1} found with T_2 did not differ significantly from that with T_3 at 30, 45 and 60 DAS. The highest no. of leaves plant^{-1} was found with T_4 at 30 DAS (10.11) and with T_6 at 45 DAS (11.41) and 60 DAS (13.56). However, the no. of leaves in treatments T_3, T_4, T_5 and T_6 were statistically similar to each other in all periods of recording at 30, 45 and 60 DAS.

Plants height of amaranth varied from 5.93 (control) to 15.2 cm (T_2) at 30 DAS, 9.18 (control) to 20.94 cm (T_4) at 45 DAS, and 11.19 (control) to 22.91 cm (T_4) at 60 DAS (Table 2). Thus, the minimum value was obtained in the control and the maximum values were obtained with recommended doses of NPK @ 156 kg N ha^{-1}, 36 Kg P ha^{-1} and 80 kg K ha^{-1}) from inorganic fertilizer at 30 DAS and with 15 t ha^{-1} biogas plant residues+calculated

Table 2: Effects of biogas plant residues and NPK fertilizer on no. of leaves, plant height and root length of amaranth

Treatment	No. of leaves plant^{-1}			Plant height (cm)			Root length (cm)
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS	60 DAS
T_1	7.00^c	7.04^c	8.09^c	5.93^d	9.18^c	11.19^b	8.94^d
T_2	8.93^b	9.48^b	11.02^b	15.20^a	20.19^a	21.84^a	11.73^{cd}
T_3	9.59^{ab}	10.37^{ab}	12.08^{ab}	12.32c	17.65^b	19.33^a	14.53^{bc}
T_4	10.11^a	11.29^a	13.09^a	14.23^{ab}	20.94^a	22.91^a	16.41^{ab}
T_5	9.74^a	11.15^a	13.21^a	12.96^{bc}	19.89^{ab}	19.87^a	18.41^a
T_6	9.59^{ab}	11.41^a	13.56^a	13.29^{bc}	20.32^a	22.09^a	16.22^{ab}
Significance of F value	0.001	0.001	0.001	0.001	0.001	0.01	0.001

Figures in the same column denoted by same letter (s) did not differ significantly according to DMRT at $p<0.05$

amount of inorganic fertilizer both at 45 and 60 DAS. Fertilizer increased height of plants but at different rates with kind and combination. Application of recommended doses of NPK (T_2) from inorganic fertilizer produced 15.20 cm at 30 DAS, 20.19 cm at 45 DAS and 21.84 cm at 60 DAS. Values of plant height found with treatment T_2 were significantly higher than those found with treatments T_3, T_5 and T_6 at 30 DAS and with T_3 at 45 DAS. Plant height at 60 DAS did not differ significantly among the treatments T_2, T_3, T_4, T_5 and T_6. Addition of inorganic fertilizer alone and their different combinations with biogas plant residues increased height of plants about 2–3 times compared to control treatment.

Length of root was measured only at 60 days after harvest. It ranged from 8.94 to 18.41 cm (Table 2). The minimum root length was found in T_1 (control) treatment and the maximum in T_5 (10 t ha^{-1} BPR+calculated amount inorganic fertilizer). Significantly similar root length to the maximum was obtained in the treatment T_4 and T_6. Application of recommended NPK fertilizer from only inorganic source (T_2) produced significantly lower root length than that with biogas plant residues up to 15 t ha^{-1} in combination with inorganic fertilizer (T_4, T_5 and T_6) but similar root length to that with T_1 (control) and T_3 treatments.

The variation in growth response of amaranth in terms of fresh weight of shoot and root is presented in Table 3.

Table 3: Effects of biogas plant residues and NPK fertilizer on fresh and dry weight of shoot and root of amaranth

Treatment	Fresh weight (g)		Oven dry weight (g)	
	Shoot	Root	Shoot	Root
T_1	5.01^c	1.79^c	2.57^c	1.29^e
T_2	20.51^{ab}	5.64^{bc}	8.16^b	2.54^{de}
T_3	18.53^b	5.76^{bc}	6.9^b	3.63^{cd}
T_4	28.13^{ab}	8.82^{ab}	11.28^a	4.86^{bc}
T_5	30.17^a	11.03^a	11.79^a	6.54^{ab}
T_6	30.86^a	12.53^a	12.59^a	6.78^a
Sig. of F value	0.001	0.01	0.001	0.001

Figures in the same column denoted by same letter (s) did not differ significantly according to DMRT at $p<0.05$

Fresh weight of shoot and root varied from 5.01–30.86 g pot^{-1} and 1.79–12.53 g pot^{-1}, respectively. The highest shoot and root weight was observed in treatment T_6 .The lowest shoot and root weight was observed in control treatment T_1 where no biogas plant residues and inorganic fertilizer was applied. Application of recommended level of NPK either from inorganic fertilizer alone or from combination of biogas plant residues and inorganic fertilizer significantly increased the fresh shoot weight of Amaranth compared to control. However, there were no significant differences among the treatments T_2, T_4, T_5 and T_6 in producing the fresh weight of shoot. The fresh root weight found with T_2 and T_3 was statistically similar with that of control. The treatments T_4, T_5 and T_6 produced significantly higher root weight than control but were statistically similar with each other.

Oven dry weight of shoot after harvest at 60 DAS varied from 2.57–12.59 g pot^{-1} (Table 3). The lowest weight of shoot was observed with T_1 (control) treatment and the highest shoot weight was found with T_6 treatment. However, the treatments T_4 and T_5 were statistically similar with treatment T_6 in producing the weight of shoot. There was no significant difference between treatment T_2 (8.16 g) and T_3 (6.90 g) in case of shoot weight but significantly higher than control and lower than T_4, T_5 and T_6. Root dry weight of amaranth ranged from 1.29 g pot^{-1} in T_1 treatment (Control)–6.78 g pot^{-1} in treatment T_6 where 5 t ha^{-1} biogas plant residues in combination with calculated amount of inorganic fertilizer was applied (Table 1). The treatment T_2 (2.54 g) did not show any significant difference from treatment T_1 (control). Application of recommended fertilizer doses from different rates of biogas plant residues and calculated amount of inorganic NPK fertilizers increased root dry weight compared with control treatment T_1. However, there were no significant differences in root dry weight between T_3 and T_4; between T_4 and T_5 and between T_5 and T_6.

3.2. Nutrient concentration in amaranth

Nitrogen concentration varied significantly from 1.64–2.78% in shoot and 1.07–1.65% in root (Table 4). The highest concentration of N in shoot and root was found in treatment T_2 (Recommended doses of NPK from inorganic fertilizer) and the lowest was in treatment T_1 (control). Application of recommended level of NPK either from inorganic fertilizer alone or from combination of biogas plant residues and inorganic fertilizer significantly increased N concentration in shoot compared to control. Similar amount of nitrogen was found in shoot by application of recommended NPK doses from inorganic fertilizer (T_2) and 5 t ha^{-1} BPR+calculate amount of inorganic fertilizer (T_6). There was no definite trend of variation in nitrogen concentration in shoot by application of

Table 4: Effects of biogas plant residues and NPK fertilizer on concentration of N, P and K in amaranth

Treat-ment	N (%)		P (%)		K (%)	
	Shoot	Root	Shoot	Root	Shoot	Root
T_1	1.64^c	1.07^d	0.20^d	0.21^b	1.24e	1.34^d
T_2	3.11^a	2.24^a	0.19^d	0.20^{bc}	4.18^a	4.25^a
T_3	2.40^b	1.11^d	0.31^a	0.27^a	3.87^{ab}	4.15^a
T_4	2.31^b	1.17^d	0.27^b	0.20^{bc}	3.66^b	3.11^b
T_5	2.32^b	1.45^c	0.23^{bc}	0.19^{bc}	2.10c	2.47^{bc}
T_6	2.78^{ab}	1.65^b	0.22^{cd}	0.16^c	1.64^d	2.26^c
Sig. of F value	0.01	0.001	0.001	0.01	0.001	0.001

Figures in the same column denoted by same letter (s) did not differ significantly according to DMRT at $p<0.05$

decreasing amount of biogas plant residues in combination with increasing inorganic fertilizer in treatments T_3, T_4, T_5 and T_6. However, nitrogen concentration in root with the same treatments gradually increased. In root, treatment T_3 (1.11%) and T_4 (1.17%) had no significant difference with control treatment T_1.

Phosphorus concentration ranged from 0.19–0.31% in shoot and 0.16–0.27% in root (Table 4). The highest concentration of P in shoot and root was observed in treatment T_3 and the lowest in T_2 and T_6, respectively. Shoot phosphorus concentrations in treatments T_3 (0.31%), T_4 (0.27%) and T_5 (0.23) are significantly higher compared with control treatment T_1. Application of recommended doses of NPK from inorganic fertilizer alone (0.19%; T_2) and from 5 t ha^{-1} BPR+calculated amount of inorganic fertilizer (0.22%; T_6) did not show any significant difference in P concentration in shoot compared to control (T_1). Increasing the proportion of inorganic fertilizer with decreasing biogas plant residues in treatments T_3, T_4, T_5 and T_6 showed gradual decrease of P concentration in shoot. Similar results were found in case of root. Root P concentration in treatments T_2, T_4 and T_5 were statistically similar with that of control (T_1) treatment but significantly lower than that with T_3.

Potassium concentration in shoot ranged from 1.24 (control)–4.18% (T_2). The second highest K concentration was found in treatment T_3 (3.87%) when 20 t ha^{-1} BPR+calculated amount of inorganic fertilizer were applied (Table 4). However, K concentration in shoot in treatments T_2 and T_3 were statistically similar with each other. A gradual decrease in concentration of K in comparison with the treatment T_3 in amaranth shoot was observed with increasing proportion of inorganic fertilizer combined with decreasing amount of biogas plant residues. Potassium concentration in root varied from 1.34% in treatment T_1 (control)–4.25% in treatment T_2 where recommended NPK from inorganic fertilizer was added. Application of biogas plant residues in combination with inorganic fertilizer significantly increased K concentration in root compared with control treatment. Potassium concentration in root found with the application of 20 t ha^{-1} BPR+calculated amount of inorganic fertilizer was similar to that found with recommended NPK addition from inorganic fertilizer alone. Amount of K decreased gradually in treatment T_4 (3.11%), T_5 (2.47%) and T_6 (2.26%) where increasing proportion of synthetic fertilizer combined with decreasing proportion of biogas plant residues were arranged

Calcium concentration in shoot of amaranth varied from 0.33 (T_1)–0.69% (T_2). Biogas plant residues @ 20 t ha^{-1} +calculated amount of inorganic fertilizer (0.46%; T_3), 15 t ha^{-1} BPR+calculated amount of inorganic fertilizer (0.39%, T4), 10 t ha^{-1} BPR+calculated amount of inorganic fertilizer (0.36; T_5) and 5 t ha^{-1} BPR+calculated amount of inorganic fertilizer (0.37%; T_6) showed similar concentration of Ca and no significant difference was found compared with control treatment T_1 (Table 5). The highest concentration of Ca in root was found to be 0.19% in the treatment T_2 whereas, the lowest concentration was found in the treatment T_3 (0.09%). The second highest concentration was found in treatment T_4 (0.14%), which did not differ significantly from the control. Same amount of Ca concentration had been found in T_5 (0.12%) and T_6 (0.12%) treatments.

Table 5: Effects of biogas plant residues and NPK fertilizer on concentration of Ca, Mg and Na in amaranth

Treatment	Ca (%)		Mg (%)		Na (%)	
	Shoot	Root	Shoot	Root	Shoot	Root
T_1	0.33^b	0.11^b	0.44^c	0.13^d	0.06^a	0.04^d
T_2	0.69^a	0.19^a	0.58^{ab}	0.29^a	0.07^a	0.11^{ab}
T_3	0.46^b	0.09^b	0.51^{bc}	0.17^{bc}	0.07^a	0.09^{bc}
T_4	0.39^b	0.14^{ab}	0.57^{ab}	0.15^c	0.07^a	0.07^c
T_5	0.36^b	0.12^b	0.62^a	0.16^{bc}	0.08^a	0.12^a
T_6	0.37^b	$0. 12^b$	0.61^a	0.18^b	0.07^a	0.10^{ab}
Sig of F value	0.001	0.001	0.001	0.01	NS	0.001

Figures in the same column denoted by same letter (s) did not differ significantly according to DMRT at $p<0.05$

In shoot of amaranth, Mg concentration ranged from 0.44 (control)–0.62% (T_5) (Table 5). The values of Mg concentration in treatment T_2 (0.58%), T_4 (0.57%), T_5 (0.62%) and T_6 (0.61%) were statistically similar with each other but significantly different from control treatment T_1. Magnesium value in treatment T_3 (0.51%) was statistically similar with the control treatment T_1. The highest magnesium concentration in root was found in Treatment T_2 (0.29%) where recommended doses of NPK from inorganic fertilizer was applied, and the lowest value was found in treatment T_1 (0.13%) control. Magnesium concentration data of amaranth root show that treatments T_3 (0.17%), T_4 (0.15%), T_5 (0.16%) and T_6 (0.18%) were significantly higher than the control but lower than the T_2 treatment.

Sodium concentration in shoot and root of amaranth varied from 0.06–0.08% and 0.04–0.12% respectively. There had been no significant effect of biogas plant residues and fertilizers on Na concentration in amaranth shoot. The highest concentration of Na in root was observed in treatment T_5 and the lowest Na concentration was found in T_1 (control) treatment. Comparing the values of Na in amaranth root with control treatment, positive significant differences were found by application of biogas plant residues and inorganic fertilizers in treatments T_2 (0.11%), T_3 (0.09%), T_4 (0.07%), T_5 (0.12%) and T_6 (0.10%). However, the treatments T_2, T_5 and T_6 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 as indicated by the no. of leaves shoots height and root length, fresh and dries weights of shoot and root. But there were significant differences among the fertilizer treatments. For example, the highest plant height of amaranth was obtained in the treatment T_4 followed by T_6, T_2, T_5 and T_3 in both 45 and 60 days after sowing. The treatment T_1 (control) showed the minimum mean value for the plant height. In a field experiment conducted for investigating the growth response and yield production of okra fertilized with various combination of bio-slurry obtained from biogas plants and nitrogen fertilizer, Shahbaz et al. (2014) recorded higher growth performance of okra plants with bio-slurry application alongside different rates of N fertilizer as compared to control and recommended inorganic N without bio-slurry. Stem height of okra, measured at 30 and 90 DAS, was the highest when plants were supplied with bio-slurry along with 100% of the recommended dose of an inorganic N fertilizer followed by the plots receiving bio-slurry supplemented with 75% and 50% of the recommended dose of N from inorganic N fertilizer. Application of bio slurry without inorganic N fertilizer also showed a significant positive effect on stem height when compared with the control (Shahbaz et al., 2014). Maximum root length was observed by Shahbaz et al. (2014) in the okra plants with 100% of the recommended inorganic N dose alongside bio-slurry application. Hossain et al. (2014) reported that the highest plant height of Indian spinach was found with biogas plant residues @ 50 t ha^{-1} and 40 t ha^{-1} at 30 and 60 DAS, respectively while the lowest plant height was found with control treatment at both the periods. Plant height was increased by 47.77% and 64.50% with 50 t ha^{-1} biogas plant residues compared to control at 30 and 60 DAS respectively.

In the present study, the highest fresh weight of shoot (30.86 g pot^{-1}) was obtained in the treatment with 5 t ha^{-1} BPR+calculated amount of inorganic fertilizer. This treatment increased fresh weight of amaranth shoot by 516% over the control (no fertilizer). Addition of recommended doses of NPK (156 kg N ha^{-1}, 36 kg P ha^{-1}, 80 kg K ha^{-1}) from inorganic fertilizer alone also increased fresh weight of shoot but by 309%. The treatment 20 ton ha^{-1} BPR+calculated amount of inorganic fertilizer increased fresh shoot weight by 269%. Shahbaz et al. (2014) found that the application of bio-slurry alongside NPK fertilizers applied at reduced rates significantly increased the okra fruit yield as compared to inorganic N alone. They found maximum okra fruit yield with the application of bio-slurry @ 600 kg ha^{-1} and half of recommended nitrogenous fertilizer. Kumar et al. (2015) reported that the combination of biogas slurry and synthetic fertilizers enhanced the C: N transformation on the crop and increased the yield by 6.5%, 8.9%, 15.2%, and 15.9% of cotton, wheat, maize and rice respectively. In a field trial to study the effects of cow dung and poultry litter biogas residues on cabbage, brinjal and tomato Shakti (2006) found that biogas residues had favourable influences in increasing the yields of the crops. Application of 50% recommended dose inorganic fertilizer+2 t ha^{-1} 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.

The significant increase in growth of amaranth due to biogas plant residues and NPK fertilizer confirm the deficiency of organic matter, N and P in the soil and biogas plant residues as effective source of plant nutrients. Nitrogen, phosphorus and potassium are essential for good growth of plants. In the present study, higher leaf numbers and plant heights obtained could also be attributed to better levels of major nutrients in the biogas plant residues. Islam (2006) reported that cow dung bio-slurry contains 1.29% N, 2.80% P and 0.75% K. Rivard et al. (1995) showed that dried and composted biogas residue produced from municipal solid waste induced an increase in crop weight (i.e., corn) and plant yield in direct proportion to the residue application rate. These findings would be attributed to improved nutrient availability and better soil structure that could have favored shoots and root growth. Organic manures are known to have the ability to supply both macro and micro nutrients required for crop growth, development and final economic yield (Parry et al., 2005).

It is of great significant and interesting issue that how effectively biogas residue can substitute common artificially produced mineral fertilizers in terms of crop yield. The similar fertilizer values of raw and anaerobically treated liquid swine manure to that of mineral fertilizer upon immediate incorporation into soil was reported by Chantigny et al. (2008) supporting the significant potential of biogas residue as a valuable substitute and/or complement to mineral fertilizers. Furukawa and Hasegawa (2006) reported that biogas residue produced from source-separated household waste was comparable to NPK fertilizers in terms of early N uptake, fresh yield, and N uptake at harvest of spinach and komatsuna. Since biogas residue is rich in NH^{4+}-N and K but low in P (Bachmann, 2011), and soil-exchangeable K is high (Furukawa and Hasegawa, 2006), its fertilizer value may be mainly attributed to the N effect (Furukawa and Hasegawa, 2006). It is important to remember that N is the most common limiting factor for crop growth in organic farming systems (Pang and Letey, 2000) owing to failure in synchronizing crop N demand and supply to the soil by mineralization of organic fertilizers (Moller and Stinner, 2009).

Status of nutrition of amaranth was evaluated from the concentrations of some major nutrient elements in amaranth shoot and root. The elements were nitrogen, phosphorus, potassium, calcium and magnesium and sodium. The concentrations of the corresponding elements in amaranth shoot varied from 1.64–3.11%, 0.19–0.31%, 1.24–4.18%, 0.33–0.69%, 0.44–0.62% and 0.06–0.08%. The concentration of N, P, K, Ca, Mg and Na in amaranth roots were in the ranges 1.07–2.24%, 0.16–0.27%, 1.34–4.25%, 0.09–0.19%, 0.13–0.29% and 0.04–0.12%, respectively. The mineral nutrient composition of amaranth leaves was reported by Akubugwo et al. (2007). They found 0.035% P, 0.054% K, 0.044% Ca, 0.231% Mg, 0.007% Na. The ratio of sodium to potassium (Na/K) in amaranth leaves was 0.14. The Na/K ratio in the body is of great concern for prevention high blood pressure. Na/K ratio less than one is recommended (FND, 2002). Hence, consumption of amaranth would probably reduce high blood pressure disease because its Na/K is less than one. The maximum nitrogen concentration in amaranth was observed in treatment where recommended inorganic fertilizer was applied alone. This may be due to the rapid supply of nitrogen in readily available forms from inorganic fertilizers. Muhmood et al. (2014) found the maximum nutrient contents in leaves of spinach and chilli in treatment with recommended dose of chemical fertilizer followed by treatment where 50% N from chemical fertilizer and 50% N from liquid slurry were applied. Al-Turki et al. (2004) reported that bio-slurry is a good soil conditioner and has the potential to increase N, P and K contents in different crops. Shahzad et al. (2015) recorded the higher concentration of N, P and K in the maize shoot in treatment with 50% recommended N applied as chemical fertilizer+25% recommended N applied as bio-slurry+25% recommended N applied as poultry manure. This might be due to increased organic matter, N, P and K in soil and uptake of more soil nutrients by following fertilization with bio-slurry and poultry manure. Similar results were found by Nasir et al. (2010).

4. Conclusion

Application of biogas plant residues and inorganic NPK fertilizers significantly increased growth of and nutrient concentration in amaranth. The combination of biogas plant residues and inorganic fertilizers showed better performance in growth and nutrient concentration in amaranth compared to inorganic fertilizer alone. Overall, application of biogas plant residues @ 5 t ha^{-1} along with calculated amount of NPK fertilizer (T_6) shows the best results. So, it is recommended integrated application of biogas plant residues and inorganic fertilizer instead of applying inorganic fertilizer alone, which will be economically profitable and environment friendly for the amaranth production in the valley soils of Chittagong. Further research has been suggested in field condition.

5. References

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