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EFFECT OF BIOGAS PLANT RESIDUES ON NUTRIENT UPTAKE BY AMARANTH (*Amaranthus tricolor* L.)

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ABSTRACT

A pot experiment was conducted in the research field of the Department of Soil Science, University of Chittagong to study the effect of biogas plant residues (BPR) and NPK fertilizers on nutrient uptake by amaranth (*Amaranthus tricolor* L.). Six treatments having three replications were as follows: T1=Control (No BPR+No inorganic fertilizers), T2= $N_{156}P_{36}\ K_{80}$ kg ha^{-1} from inorganic fertilizer (recommended dose), T3=BPR 20 t ha^{-1}+rest from inorganic NPK fertilizer, T4=BPR 15 t ha^{-1}+ rest from inorganic NPK fertilizer, T5=BPR 10 t ha^{-1}+ rest from inorganic NPK fertilizer, T6=BPR 5 t ha^{-1}+ rest from inorganic NPK fertilizer. The results showed that application of biogas plant residues and inorganic NPK fertilizers significantly increased nutrient uptake by amaranth compared to control. The values of uptake of N, P, K, Ca, Mg, and Na were 4.61- 38.85, 0.55 - 3.36, 3.56 - 45.76, 0.93 -6.09, 1.25 -8.56 and 0.17 - 0.99 mg $plant^{-1}$ in shoot and 1.54 - 12.51, 0.31 - 1.36, 1.92- 17.34, 0.16 - 0.95 and 0.22- 1.33 and 0.05- 0.85 mg $plant^{-1}$ in root, 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. Overall, application of biogas plant residues at the rate of 5 ton ha^{-1} along with calculated amount of NPK fertilizer (T6) showed the best results.

Key words: Biogas plant residues, NPK fertilizers, nutrient uptake, amaranth.

INTRODUCTION

Amaranth (*Amaranthus tricolor* L.) belongs to the family Amaranthaceae. It is the most common leafy vegetable in Bangladesh. Amaranth is one of the nutritious and delicious vegetables. Teutonico and Knorr (1995) considered it to be a potential subsidiary food crop. Amaranth has an impressive nutrient profile and been associated with a number of impressive health benefits. It is a good source of fiber, protein, manganese, magnesium, phosphorus and iron, along with several other important micronutrients (Rachael, 2018). Amaranth is high in several antioxidants, such as gallic acid, *p*-hydroxybenzoic acid and vanillic acid, which may help protect against disease. Because of its cheapest price, quick growing character and higher yield potential amaranth is a popular vegetable in Bangladesh. Both in area and production, it ranks 5th in summer vegetable and 13th among

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all vegetable (BBS, 2010) and constitutes 5.42% of summer vegetables production. 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 in Bangladesh (BBS, 2010).

The decrease in soil fertility in Bangladesh is a major constraint for higher crop production. The addition of organic fertilizers into the soil is the alternative to increase soil fertility and sustain crop production under this situation. The presence of growth promoting agents in organic fertilizers makes them important for enhancement of soil fertility and productivity despite the small quantities of plant nutrients contained in them as compared to inorganic fertilizers (Sanwal et al., 2007). Biogas plant residues could be used as a source of organic matter and nutrients for sustainable crop production that is an environmentally friendly and non-polluting organic fertilizer (Islam et al., 2010). It contains considerable amounts of nutrients and organic matter (Bachmann et al, 2011; Lošák et al., 2012). In Bangladesh, at least 60 t of biogas residues is produced daily from about 2000 biogas plants already established in the country (Islam, 2010). The soil organic matter status of Bangladesh may be improved by proper utilization of these huge amounts of biogas residues in crop land.

The effects of biogas residues on growth and yield responses of different vegetable crops like maize and cabbage (Karki, 2001), okra (Shahbaz et al., 2014), Indian spinach (Hossain et al., 2014) were reported. However, a very few information is available on the effects of biogas residues on the nutrient uptake by amaranth in Bangladesh. Thus, the objectives of the present study were to evaluate the effect of biogas plant residues on nutrient uptake by amaranth and compare its effect with that of NPK fertilizers.

MATERIALS AND METHODS

A pot experiment was conducted in the research field of the Department of Soil Science, University of Chittagong to study the effect of Biogas Plant Residues (BPR) and NPK fertilizers on the growth and nutrient uptake by amaranth (*Amaranthus tricolor* L.). Recommended doses (BARC, 2012) 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 entirely from inorganic fertilizer or from particular amount of biogas plant residues and the rest from inorganic fertilizer calculated on the basis of NPK requirement. The treatments were as follows: T1=Control (No BPR+No inorganic fertilizers); T2= $N_{156}P_{36}$ K_{80} kg ha^{-1} from inorganic fertilizer (recommended dose), T3=BPR 20 t ha^{-1}+rest from inorganic NPK fertilizer, T4=BPR 15 t ha^{-1}+ rest from inorganic NPK fertilizer, T5=BPR 10 t ha^{-1}+ rest from inorganic NPK fertilizer, T6=BPR 5 t ha^{-1}+ rest from inorganic NPK fertilizer. The calculated amounts of inorganic fertilizer of different treatments for cultivation of amaranth are presented in Table 1. However, the amount of K could not be adjusted due to excess supply of required K by biogas plant residues in treatment T3, T4, T5. 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. Cow dung 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 combinations and allowed to equilibrate for one month before sowing seeds. Eight kilograms soil was placed in each earthen pot having diameter and depth of 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 emergence, nine seedlings of almost uniform size were kept in each pot after 15 days of sowing. Irrigation was applied as and when necessary.

TABLE 1. BIOGAS PLANT RESIDUES AND INORGANIC FERTILIZER DOSES OF DIFFERENT TREATMENTS FOR CULTIVATION OF AMARANTH

Treatment	BPR (t ha^{-1})	Inorganic fertilizer (kg ha^{-1})		
		N	P	K
T1	-	-	-	-
T2	-	156	36	80
T3	20	-	32.4	-
T4	15	39	33.3	-
T5	10	78	34.2	-
T6	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. Dry roots, grasses and other materials were discarded from the soil. 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). Water holding capacity was measured by gravimetric method. Soil pH was measured in a 1:2.5 soil water suspension with glass electrode pH meter. Electrical conductivity (Ec) of the soil was measured by Ec 214 Conductivity Meter. 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). Potassium in the digest was measured by Atomic Absorption Spectrophotometer (Agilent Technologies 240AA). Texture of the soil was clay loam containing 33% sand, 19% silt and 48% clay. Wwater holding capacity, soil pH, electrical conductivity, organic matter content, and cation exchange capacity were 34.99 %, 6.8, 28.3 µS, 1.32%, and 19.11 cmol kg^{-1}, respectively. Total nitrogen, phosphorus and potassium content of the soil were 0.09, 0.01 and 1.23%, respectively. Similar methods were also used for determination and quantification of biogas plant residues. The pH of the biogas plant residues was 6.0 and organic matter content was 6.00%. Total nitrogen, phosphorus and potassium content of the BPR were 0.78, .02 and 1.35%, respectively.

Plants were harvested as shoots and roots at 60 days after sowing. They were washed thoroughly, first with tap water to remove adhering soil particles and then with distilled water. Oven dry (at 65 °C to constant weight) weight of shoots and roots were recorded and grounded. 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 uptake was calculated by multiplying the concentration with weight of shoot and root.

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%. The statistical software Excel and SPSS version 12 were used in the analysis.

RESULTS AND DISCUSSION

Nitrogen Uptake

Nitrogen uptake by shoot and root of amaranth varied significantly from 4.61 to 38.85 and 1.54 to 12.51 mg plant^{-1}, respectively (Table 2). The highest value was found in T6 and the lowest was in T1 (control). Application of recommended doses of NPK from inorganic fertilizer and from different combination of biogas plant residues and inorganic fertilizer significantly increased N uptake in shoot and root of amaranth compared to control except by root in treatment T3. Increasing proportion of inorganic fertilizer with decreasing proportion of biogas plant residues in treatments T4, T5 and T6 gradually increased N uptake by shoot and root.

TABLE 2. EFFECTS OF BIOGAS PLANT RESIDUES AND NPK FERTILIZER ON THE UPTAKE OF N, P AND K BY AMARANTH (*Amaranthus tricolor* L.)

Treatment	N (mg plant^{-1})		P (mg plant^{-1})		K (mg plant^{-1})	
	Shoot	Root	Shoot	Root	Shoot	Root
T1	4.61 d	1.54 c	0.55 c	0.31 b	3.56 d	1.92 b
T2	27.61 b	6.24 b	1.68 b	0.59 b	37.80 ab	11.47 a
T3	18.62 c	4.45 bc	2.30 b	1.05 a	29.78 bc	16.87 a
T4	29.04 b	6.28 b	3.36 a	1.07 a	45.76 a	16.78 a
T5	30.46 ab	10.34 a	3.05 a	1.36 a	27.36 bc	17.34 a
T6	38.85 a	12.51 a	3.01 a	1.23 a	22.99 c	17.07 a

Figures in the same column denoted by same letter (s) did not differ significantly ($p \leq 0.05$)

Phosphorus Uptake

Phosphorus uptake ranged from 0.55 to 3.36 mg $plant^{-1}$ in shoot and 0.31 to 1.36 mg $plant^{-1}$ in root of amaranth (Table 2). Application of recommended doses of NPK from inorganic fertilizer (T2) significantly increased P uptake by shoot but not by root. Different combinations of biogas plant residues and inorganic fertilizers (T4, T5 and T6) showed similar P uptake by both shoot and root but significantly higher than that of control (T1) and NPK from inorganic fertilizer alone (T2).

Potassium Uptake

The uptake of potassium varied between 3.56 and 45.76 mg $plant^{-1}$ and between 1.92 and 17.34 mg $plant^{-1}$ by shoot and root of amaranth, respectively (Table 2). Application of inorganic fertilizer and biogas residues alone and in different combination significantly increased K uptake by shoot and root of amaranth compared to control. Treatment T4 showed the best result in K uptake by shoot. Root uptake of K was similar in treatment T2, T3, T4, T5 andT6 where inorganic fertilizer and biogas residues were applied alone or combined.

Calcium Uptake

Calcium uptake in shoot varied from 0.93 to 6.09 mg $plant^{-1}$ and in root from 0.16 to 0.95 mg $plant^{-1}$ (Table 3). Application of inorganic fertilizer and biogas plant residues alone or their different combination significantly increased Ca uptake in shoot of amaranth compared to control. However, shoot Ca uptake was similar in treatment T3, T4, T5 and T6. Root Ca uptake was not significantly affected by inorganic fertilizer and biogas residues alone, but by their different combination in treatment T6 showed the best result in root Ca uptake.

TABLE 3. EFFECT OF BIOGAS PLANT RESIDUES AND NPK FERTILIZER ON THE UPTAKE OF Ca, Mg AND Na BY AMARANTH (*Amaranthus tricolor* L.)

Treatment	Ca (mg $plant^{-1}$)		Mg (mg $plant^{-1}$)		Na (mg $plant^{-1}$)	
	Shoot	Root	Shoot	Root	Shoot	Root
T1	0.93 c	0.16 d	1.25 c	0.22 d	0.17 c	0.05 c
T2	6.09 a	0.50 bcd	5.10 b	0.82 bc	0.58 b	0.30 bc
T3	3.75 b	0.37 cd	3.85 b	0.69 c	0.55 b	0.36 b
T4	4.93 ab	0.75 abc	7.18 a	0.83 bc	0.92 a	0.39 b
T5	4.70 ab	0.87 ab	8.14 a	1.16 ab	0.99 a	0.85 a
T6	5.17 ab	0.95 a	8.56 a	1.33 a	0.96 a	0.78 a

Figures in the same column denoted by same letter (s) did not differ significantly ($p \leq 0.05$)

Magnesium Uptake

Magnesium uptake ranged from 1.25 to 8.56 mg $plant^{-1}$ in shoot and 0.22 to 1.33 mg $plant^{-1}$ in root of amaranth (Table 3). Magnesium uptake in shoot and root of amaranth was significantly increased by inorganic fertilizer and biogas residues alone and by their different combination. However, different combination of inorganic fertilizer and biogas residues in treatment T4, T5 and T6 showed significantly better results than inorganic fertilizer and biogas residues alone in Mg uptake by shoot of amaranth. A gradual increase in Mg uptake in both shoot and root was observed with increasing proportion of inorganic fertilizer with decreasing proportion of biogas plant residues in treatments T4, T5 and T6.

Sodium Uptake

Sodium uptake by shoot and root varied significantly from 0.17 to 0.99 mg $plant^{-1}$ and 0.05 to 0.85 mg $plant^{-1}$, respectively (Table 3). Application of inorganic fertilizer alone significantly increased Na uptake in shoot but not in root compared to control. Biogas residues alone (T3) and its different combination with inorganic fertilizer (T4, T5 and T6) increased Na uptake in both shoot and root. Combined application of inorganic fertilizer and biogas residues showed better results than their application alone.

This study revealed that 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. Shahbaz et al., (2014) reported that application of mineral fertilizer along with bio slurry demonstrated a positive contribution on the availability of N, P, and K content in soil. Changes in soil nutrient reserves and alterations in root systems under different sources of N supply, including organic sources, might have bearing on nutrient availability and uptake by crops. An increase of nitrogen use efficiency as a result of changes in soil organic matter, nutrient concentrations, bulk density, water holding capacity, and soil temperature, among others, by combined use of bio-slurry and chemical fertilizer was also reported by Akanbi et al., (2010). Application of inorganic N alongside bio slurry significantly improved N uptake by plant roots and fruits and stems in conjunction with leaves (Shahbaz et al., 2014). Do and Scherer (2012) found that total nitrogen uptake by ryegrass was lowest in the control and highest in the compost treatments; while the biogas plant residues treatments were ranging in between. As compared to the control P uptake of amaranth grown in biogas residues was higher in the present study. Higher P uptake of amaranth grown in biogas residues might be due to higher content of plant available P of this material. According to Gungor and Karthikeyan (2008) organic phosphorus compounds become partly mineralized during the anaerobic digestion in the biogas plant. Do and Scherer (2012) also reported increased phosphorus utilization with application of biogas residues.

Potassium uptake of amaranth shoots and roots grown in biogas residues treatments was higher than that of control but was similar in most cases to inorganic fertilizer treatment. The results of the present study confirm those of Wen et al., (1997) who stated that K applied with wastes is equally available as K from mineral fertilizer. As compared to the control, Ca and Mg uptake were higher in biogas plant residues grown amaranth. This might be the result of the higher content of plant available Ca and Mg in biogas plant residues. Do and Scherer (2012) reported that Mg uptake was higher in biogas residues grown ryegrass as compared the control while Mg uptake independently of ryegrass of the compost treatments were in the same order of magnitude.

These observations together revealed that the combined application of biogas residues and inorganic fertilizer had better performance in nutrient uptake by amaranth compared to inorganic fertilizer alone. Overall, application of biogas residues at the rate of 5 t ha^{-1} along with calculated amount of inorganic fertilizer, as observed in treatment T6 may aid crop improvement from nutrition status viewpoint.

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