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RESPONSE OF GROWTH, BIOMASS PRODUCTION AND NUTRIENT UPTAKE OF RED AMARANTH (*Amaranthus tricolor* L.) TO VARIOUS ORGANIC MANURES AND CHEMICAL FERTILIZERS

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Abstract

A pot experiment was conducted at the Department of Soil, Water and Environment, University of Dhaka, from 10 January to 24 February 2021, to evaluate the growth parameters, biomass production, and nutrient uptake of red amaranth (*Amaranthus tricolor* L.) as influenced by different types of organic manures manufactured by companies, *viz*. ACI, Agro, Kazi, Mazim, McDonald, Naafco, Paragon and Sharib, and by 50% of recommended dose of NPK fertilizers. The experiment consisted of ten treatments with three replications each and was laid out in a Completely Randomized Design (CRD). On the day of harvest, Naafco displayed the greatest number of leaves (10.67±2.31), the longest leaf length (8.60 ±2.07 cm), and the largest leaf area (275.10±118.8 cm^2 $plant^{-1}$), whereas the highest plant height (24.53±3.27cm) and stem girth (24.53±3.27cm) were observed in McDonald. Conversely, Kazi exhibited the poorest performance in all aforementioned parameters. Both the highest fresh and dry weights (10.75±6.09 g $plant^{-1}$ and 1.31±0.87 g $plant^{-1}$ respectively) were recorded in Naafco treated plants, and the lowest weights in Kazi (1.98 g $plant^{-1}$ and 0.23 g $plant^{-1}$ respectively). The highest total nutrient content (NPKS and Fe) (46.02 mg $plant^{-1}$) in plants was found in Naafco, while the lowest was in Kazi (3.96 mg $plant^{-1}$). Judging from the results, Kazi treated plants consistently showed the lowest growth, biomass, and nutrient accumulation.

***Key words*:** Red amaranth; Organic manures; Inorganic fertilizers; Nutrient uptake; Growth; Yield.

INTRODUCTION

Red amaranth (*Amaranthus tricolor* L.: *Amaranthaceae*) is a leafy vegetable. It is fast growing, high yielding and popular in Bangladesh. It is rich in protein, ascorbic acid, riboflavin niacin, calcium, phosphorus, etc. (Miah *et al*. 2013b). Nowadays, this crop is receiving attention from all over the world, and people suffering from anaemia are recommended to consume red amaranth by physicians (Olumakaiye 2011). This species of amaranthus is commonly grown in all over the country throughout the year (Saha *et al*. 2003). It is due to its wide adaptability to different climate and soil types (Alam *et al*. 2007). According to BBS (2020), Bangladesh has seen a general rise in the area under cultivation of red amaranth from the year 2017-2018, with the production amounting to 61,096 metric tonnes in 2019-2020. It is thereby playing a principal role in ensuring both nutrition and food security of the people (Miah *et al*. 2013b).

The addition of organic matter improves the physical (e.g. soil structure), chemical (e.g. supply of essential and trace elements) and biological properties (e.g. provision of ideal microclimate for soil microorganisms) of soil. As a result, it also enhances the productivity and quality of a good crop (Ferdous *et al.* 2020). However, with the advent of the ‘Green Revolution’ in the late 1960s and when increasing cropping intensity became imperative to ensure food security in Bangladesh began relying heavily on inorganic fertilizers resulting in the decline of organic matter use in soils. As a result, more than half of the country’s soils contain less than 1.5% organic matter, which is critically hampering the crop production (Ferdous *et al*. 2020). According to him organic manure application is practiced only in 0.1 % of the total cultivable land, while, simultaneously, indiscriminate use and over application of chemical fertilizers have been creating soil problems as well as water, environmental and health risks jeopardizing the sustainability of crop production. Studies have shown that the application of NPK amendment decreased the organic carbon content in post-harvest soils, whereas organic manure application significantly improved the nutrient status of soils (Mondal *et al*. 2019) and decreased disease occurrence (Lim and Vimala 2012).

The rapid declining soil fertility and the burgeoning interests of people in organically produced vegetables in Bangladesh have generated demands on the production and application of organic manures to soils. The high price and the unavailability of inorganic fertilizers are motivating farmers to shift to less costly and easily accessible organic sources to obtain the optimum economic return (Alam *et al*. 2007). Every day, around 16,500 tonnes of wastes are produced in cities, if processed properly can create an excellent opportunity to meet the rising need of organic fertilizers (Howlader 2017). Several studies conducted on the effects of the application of organic manures such as poultry manure, cow dung, mustard oil cake, vermicompost and other composts, have recorded increases in growth and yield of vegetables, such as red amaranth (Mondal *et al*. 2019, Alam *et al*. 2007) and okra (Haque *et a*l. 2020), Burmese grapes (*Baccaurea ramiflora*) (Munna *et al*. 2021), mint (*Mentha* sp.) (Shushupti *et al.* 2021), and have also found improved quality of leafy vegetables. However, there haven't been adequate studies available which are related to the individual influences of organic manures that are locally available at market under various companies' names in Dhaka, Bangladesh, on the growth performance of the red amaranth. The experiment was, hence, undertaken to observe and compare the variations of plant growth and nutrient accumulation of red amaranth to various commercially available organic manures as well to 50% recommended dose for NPK fertilizers for any significant differences, and also to determine the overall good and poor performance among the companies of the organic manures.

METERIAL AND METHODS

Soil sample processing and analysis

The bulk soil sample (0-15 cm depth) was collected from Araihazar upazila, Narayanganj district, Dhaka, Bangladesh, for the pot experiment. The soil was then air dried, cleared of any visible roots or debris, crushed gently to break down any large clods and sieved through 2mm sieve. A portion of the soil was broken gently with a wooden hammer and screened through a 0.5mm sieve to be stored in a labeled plastic bottle for various laboratory analyses.

In the laboratory, the particle size analysis of the soil was determined following the hydrometer method (Bouyoucos 1962), and using the proportion percentages data, its textural class was then found from the Marshall's soil texture triangle. The soil comprised 1.43% sand, 67.27% silt and 31.30% clay, and its textural class was silt loam. The matrix color of the soil was pale yellow, which was evaluated visually under bright sunlight using the Munsell color chart.

The pH and EC values of the soil were 7.25 (1: 2.5 w/v H_2O) and 71.1 µS/cm (1:5 w/v H_2O), respectively (Jackson 1958). Organic carbon content was determined following the Walkley and Black 1934's wet oxidation method, which was multiplied by van Bemmelen factor of 1.72 for the organic matter content. The organic carbon and organic matter of the soil were 0.42% and 0.72%, respectively, which is considered very low in organic matter content classes.

For the analyses of total P, K, S and Fe present in soil, the soil sample was digested in nitric acid and perchloric acid following procedures practiced in the department of Soil, Water and Environment, University of Dhaka. Total P was measured at 430nm with the aid of a T-60 OV-visible spectrophotometer following vanado-molybdo-phosphoric yellow color method in nitric acid system (Jackson 1958). Total S was also determined with the help of the spectrophotometer after developing a turbid solution using $BaCl_2$ with Tween 80 as suspending agents. Total K was analyzed with the aid of a JENWAY flame photometer (PFP 7), and total Fe with an atomic aabsorption sspectrophotometer (AAS). Another portion of the sample was digested separately in concentrated H_2SO_4 and digestion mixture to find total N, which was determined by using Kjeldahl method (Marr and Cresser 1983). The total N, P, K, S and Fe contents of the soil sample were 0.04, 0.02, 0.22, 0.03 and 2.14%, respectively.

Experimental setup

A pot experiment consisting of 10 treatments was carried out from 10 January to 24 February, 2021, at the Department of Soil, Water and Environment, University of Dhaka. Seven kilograms of the properly air-dried and grounded soil were taken in each plastic pot of height 23 cm and diameter 25.6 cm. The commercially available organic manures from 8 different companies, viz. ACI, Agro, Kazi, McDonald, Mazim, Naafco, Paragon, and Sharib, were collected from local markets in Dhaka, Bangladesh. The pots were perforated at the bottom and filled with the soil. Organic manures at a rate of 10 ton ha^{-1} were mixed well with the soil and left for about a week to facilitate their proper decomposition. For the other two treatments, 50 % recommended dose (RD) of inorganic NPK fertilizers and a control without any fertilizer type were taken. For 50% NPK RD, 20 kg N ha^{-1}, 4 kg P ha^{-1} and 7 kg K ha^{-1} were applied from urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP). Half of the N dose was applied at the time of pot preparation, and the other half at two weeks after sowing of seeds. Each treatment was replicated thrice, and the pots were laid out in a Completely Randomized Design (CRD).

The seeds of red amaranth were collected from a seed shop at Siddique Bazaar, Dhaka. Fifteen seeds were broadcasted in each pot. After two weeks of germination, five healthy seedlings were allowed to grow in each pot. Light irrigation was practiced every other day, and weeding was done every other 5 days. The number of leaves, plant height, stem girth, length and breadth of leaves of the plants from each pot had been measured from 23 days after sowing (DAS) at 7 days' interval until 44 days after sowing (DAS).

The numbers of leaves were counted with a Talley counter, and the plant height was measured from the soil surface to the tip of the stem using a scale. Leaf area was determined by measuring length (L) and width (W) of the leaves of each plant, and then by multiplying L, W and a factor of 0.75 (Qulsum *et al*. 2020). Stem girth was measured from 3cm above soil surface using calibrated Vernier callipers.

Harvesting and analysis

After 44 days of sowing, the plants were harvested by carefully uprooting, then were washed with tap water and lastly with distilled water. They were later dried by using a soft tissue paper. Immediately after harvest, the root lengths and fresh weights of individual plants were taken. The plants were air dried for two days before finally oven-drying at 65°C for 48 hours. The dried plant samples were weighed as individual root, stem and leaves' weights. The root-shoot ratio was determined by dividing the dry weights of the roots with those of the shoots. The dried leaves of each sample were finely grounded and stored in labeled plastic bottles for chemical analysis. The concentrations of N, P, K, S and Fe in leaves were determined.

Fig. 1. *Amaranthus tricolor* plants: **a.** Cultivation of *Amaranthus tricolor* in a field; **b**. A general view of the pot experiment.

For total nitrogen, oven-dried leaves and organic manures were digested in a Kjeldahl digestion flask (Marr and Cresser 1983), and for their total potassium, sulphur, phosphorous and iron, they were digested with nitric-perchloric acid. The phosphorous of the digest was determined by following vanadomolybdophosphoric yellow color method with a T-60 OV-visible spectrophotometer. The potassium of the digest was determined by the flame photometer. The sulfur of the digest was determined by following turbidimetric method and Iron by atomic absorption spectrophotometer (AAS).

The N, P, K, S and Fe contents in the products of ACI, Agro, Kazi, Mazim, McDonald, Naafco, Paragon and Sharib, as percentages were: 1.30, 0.37, 1.27, 0.02 and 0.01, respectively; 1.56, 1.94, 2.07, 0.33 and 0.32, respectively; 2.52, 1.80, 3.18, 0.61 and 0.29, respectively; 1.22, 1.31, 1.73, 0.23 and 0.04, respectively; 2.23, 1.43, 1.94, 0.23 and 0.34, respectively; 1.48, 2.11, 2.03, 0.35 and 0.21, respectively; 1.82, 1.55, 2.05, 0.41 and 0.12, respectively; and 2.41,0.50, 1.59, 0.14 and 0.10, respectively.

The data obtained were subjected to statistical analyses including means, standard deviation, and Analysis of Variance (ANOVA) using Excel 16 and Minitab 17.

RESULTS AND DISCUSSION

Growth Performance Assessment

The growth of red amaranth plants was assessed in terms of the number of leaves and plant height (Table 1), longest leaf and leaf area (Table 2), stem girth (Table 3), and biomass production (Table 4), which are discussed in the following sections, along with the nutrient uptake by plants (Table 5).

Number of leaves and plant height

The influences of organic manures and inorganic fertilizers on the number of leaf per red amaranth plant were found to insignificant differences ($p>0.05$) (Table 1). All the treatments, except Agro and

Mazim, displayed increases in their leaf numbers during the growing period and reached at peak at the harvesting time. At 23 DAS, the number of leaf ranged from 2.33±0.58 (Kazi) to 5.33±2.31 (Mazim) and 5.33±0.58 plant^{-1}(Control). At 30 and 37 DAS, the highest number of leaf was again found in Mazim (7.33±1.16 and 10.00±2.65 plant^{-1}, respectively); however, on the day of harvesting, NPK-50 and Naafco had the most leaf/plant. At 37 DAS, ACI had the lowest count on leaf/ plant (6.00±1.00); however, at 30 DAS and 44 DAS, it was found in Kazi (3.33±0.58 and 7.33±1.53 plant^{-1}, respectively). In a similar study conducted on the effects of organic manures on okra, Kazi also produced the minimum leaf number (Haque *et al.* 2020). It can be revealed from the insignificant results in the amount of leaf production in all the treatments that neither the organic nor the inorganic fertilizers played a remarkable role on the production of leaf number which was similar to the reports by Talukder (1999), even though it is expected of organic manures or inorganic fertilizers to produce better leaf production than the treatment which received no fertilizer.

Table 1. Effects of organic manures and NPK fertilizers on the number of leaf (leaf plant^{-1}) and height (cm) of red amaranth plants at seven days interval.

Treatments	Days after sowing (DAS)							
	Number of leaves/plant				Height (cm)			
10 tonha^{-1}	23 DAS	30 DAS	37 DAS	44 DAS	23 DAS	30 DAS	37 DAS	44 DAS
Control	5.33±0.58	6.67±0.58	8.67±1.53	10.33±0.58	7.00±1.23	11.93±1.10	15.37±1.70	20.00±4.26
NPK-50	3.67±0.58	6.00±1.00	8.33±1.16	10.67±0.58	6.00±2.29	12.53±2.64	17.13±2.27	21.53±5.78
ACI	4.00±0.00	4.67±0.58	6.00±1.00	9.67±1.16	2.63±0.32	5.83±0.76	11.20±3.12	18.33±4.05
Agro	4.00±2.65	7.00±3.61	8.33±4.51	8.33±.51	9.57±7.95	15.97±15.71	15.47±13.16	21.07±14.31
Kazi	2.33±0.58	3.33±0.58	6.33±1.53	7.33±1.53	3.60±1.31	6.33±2.37	7.37±3.77	11.50±4.27
Mazim	5.33±2.31	7.33±1.16	10.00±2.65	9.33±3.79	7.30±5.50	11.43±7.87	19.00±9.50	24.30±8.27
McDonald	4.67±2.08	7.00±1.73	8.33±1.16	10.00±1.00	9.07±1.89	14.00±3.40	18.93±3.16	24.53±3.27
Naafco	4.67±2.52	6.33±2.08	9.00±3.00	10.67±2.31	8.17±2.84	13.10±2.07	17.17±4.48	23.43±3.74
Paragon	4.00±2.00	6.00±2.00	8.67±4.04	9.67±3.21	7.87±5.99	12.47±9.39	14.60±10.52	18.83±11.90
Sharib	3.33±1.16	6.00±1.00	7.00±1.00	10.00±1.00	4.67±2.02	8.37±3.43	10.97±3.87	17.73±4.58

*± means standard deviation

Plants grew well during the whole growing period as evident by the remarkable increases in their heights (Table 1). However, the application of different treatments also produced no significant effects on this parameter ($p>0.05$). At 23 and 30 DAS, the mean highest plant height was observed in Agro (9.57±7.95 and 15.97±15.71cm, respectively), whereas at 37 and 44 DAS, Mazim (19.00±9.50cm) and McDonald (24.53±3.27cm), respectively produced the tallest plant. Although ACI had the least height at 23 and 30 DAS (2.63±0.32 and 5.83±0.76 cm, respectively), it was Kazi which ended up with the lowest plant height both at 37 DAS (7.37±3.77cm) and 44 DAS (11.50±4.27cm). The results were quite similar to the reports concluded by Hamid *et al.* (1989) and Roy (2008).

Longest leaf and leaf area

The length of the longest leaf can be used as an indicator of plant size and also of the yield of red amaranth (Alam *et al.* 2007). The longest leaf lengths of the plants displayed by each treatment were measured and averaged, which have been presented in the Table 2. It was observed that the average length of the longest leaf increased gradually with the growing period for all treatments. At 23 and 30 DAS, McDonald manure showed the highest leaf length values of 3.93 ± 1.03cm and 5.83±1.06 cm respectively. However, at 37 and 44 DAS, NPK-50 (7.47±0.12cm) and Naafco (8.60±2.07 cm) respectively displayed the maximum leaf length. The longest leaf by Naafco can be used to correlate with its high plant height and maximum number of leaf at the time of harvesting. In case of the treatment showing the least leaf length, Kazi consistently held the position throughout the growing season.

Table 2. Effects of organic manures and NPK fertilizers on the longest leaf (cm) and leaf area (cm^2 $plant^{-1}$) of red amaranth plants at seven days interval.

Treatments	Days after sowing (DAS)							
	Leaf length (cm)				Leaf area (cm^2 $plant^{-1}$)			
10 $tonha^{-1}$	23DAS	30DAS	37DAS	44DAS	23DAS	30DAS	37DAS	44DAS
Control	2.63 ± 0.46	4.47 ± 0.78	5.83 ± 0.68	6.93 ± 0.72	19.35 ± 6.20	71.40 ± 20.7	121.40 ± 21.3	198.68 ± 15.54
NPK-50	2.93 ± 0.99	5.47 ± 0.97	7.47 ± 0.12	8.40 ± 1.73	19.05 ± 11.66	102.10 ± 43.0	180.92 ±15.64	268.80 ± 109.2
ACI	2.13 ± 0.32	3.77 ± 1.52	5.57 ± 1.35	6.53 ± 0.61	11.38 ± 2.50	42.70 ± 36.0	112.80 ± 61.6	175.30 ± 76.6
Agro	3.27 ± 1.91	4.63 ± 2.70	5.33 ± 3.31	6.87 ± 3.16	26.60 ± 35.6	81.90 ± 74.6	117.20 ± 101.7	198.50 ± 166.7
Kazi	1.27 ± 0.81	2.57 ± 1.59	3.57 ± 1.44	4.63 ±1.10	3.49 ± 5.12	11.95 ± 13.67	47.70 ± 50.6	87.20 ± 59.7
McDonald	3.93 ± 1.03	5.83 ± 1.06	6.73 ± 1.22	7.33 ± 1.36	35.90 ± 18.6	96.40 ± 33.7	161.60 ± 50.9	243.40 ± 81.2
Mazim	2.77 ± 1.16	4.00 ± 1.22	6.13 ± 2.30	7.17 ± 1.68	25.80 ± 24.8	70.00 ± 49.4	145.60 ± 83.3	215.00 ± 91.8
Naafco	3.30 ± 1.39	5.23 ± 1.75	7.17 ± 2.21	8.60 ± 2.07	23.90 ± 21.4	103.20 ± 85.3	178.80 ± 91.3	275.10 ± 118.8
Paragon	2.63 ±1.42	4.37 ± 1.89	5.10 ± 2.52	6.20 ± 2.84	24.00 ± 20.0	78.60 ± 62.4	134.70 ± 108.5	210.30 ± 159.6
Sharib	2.13 ± 0.40	3.20 ± 1.02	5.00 ± 1.08	6.50 ± 1.50	10.37 ± 6.02	44.40 ± 29.5	105.50 ± 49.1	182.00 ± 89.7

'±' standard deviation

Leaf area indicates the extent of assimilation in plants and also the production of dry matter of the plants (Sharif *et al.* 2020). In Table 2, the mean leaf area (LA) of red amaranth plants treated with chemical fertilizers and organic manures showed no significant differences ($p>0.05$). During their entire growing period, all treatments generally displayed a remarkable increase in LA, with Naafco treated plants having the largest leaf area (275.10 ±118 cm^2 $plant^{-1}$) on the day of harvesting (44 DAS). At 23 DAS, the leaf area of the fertilized plants ranged from 3.49 cm^2 $plant^{-1}$ (Kazi) to 26.60 cm^2 $plant^{-1}$ (Agro). At 30 and 37 DAS, Naafco had the largest leaf area (103.20 ± 85.3 cm^2 and 178.80 ± 91.3 cm^2 $plant^{-1}$, respectively), which was followed closely by McDonald. At 30, 37 and 44 DAS, the lowest leaf areas were recorded again in Kazi treated plants. The increment in leaf areas and the subsequent biomass of the plants are caused by the Nitrogen released by the organic fertilizers and the applied urea, which promote vegetative growth of the plants (Mondal *et al*. 2019). However, the remarkable increase in LA during the period in NPK-50 over organic manures indicates the rapid release and uptake of nitrogen from the urea and the slow mineralization of organic manures.

Stem girth

The results presented in the Table 3 indicate that all treatments generally increased the stem girth of the plants across the 44-day growth period. Similar results were observed by Alam *et al.* (2007) and Miah *et al.* (2013a) for stem girth. However, no significant difference ($p>0.05$) was observed among the stem girth means after 23, 30, 37 and 44 days of sowing. At 23 DAS, control has the smallest stem girth of 0.30±0.17 cm, while ACI had the largest girth value of 0.80±0.56 cm. At 30 DAS, Kazi showed the lowest stem girth value (0.53±0.25cm), whereas, Naafco and ACI shared the same highest value for stem girth (1.23±0.61cm). However, at 37 DAS, the plants treated with Mcdonald had the maximum stem girth (1.77±0.25cm). On the day of harvesting, the mean stem girth ranged from 1.00±0.30cm (Kazi) to 2.13±0.49cm (McDonald).

Table 3. Effects of organic manures and NPK fertilizers on the stem girth (cm) of red amaranth plants at seven days interval.

Treatments 10 tonha^{-1}	Days after sowing (DAS)			
	23 DAS	30 DAS	37 DAS	44 DAS
Control	0.30 ±0.17	0.70±0.20	1.27± 0.21	1.60±0.35
NPK-50	0.47 ±0.31	0.87±0.40	1.33±0.45	1.80±0.56
ACI	0.80 ±0.56	1.23±0.61	1.47±0.67	1.80±0.79
Agro	0.47 ±0.40	0.93±0.55	1.60±0.85	1.87±0.91
Kazi	0.37 ±0.15	0.53±0.25	0.80±0.30	1.00±0.30
Mazim	0.77 ±0.32	1.03±0.29	1.43±0.38	1.80±0.46
McDonald	0.77 ±0.12	1.17±0.21	1.77±0.25	2.13±0.49
Naafco	0.70 ±0.30	1.23±0.60	1.60±0.56	2.03±0.60
Paragon	0.57 ±0.32	0.87±0.40	1.33±0.67	1.67±0.84
Sharib	0.47 ±0.25	0.83±0.21	1.13±0.25	1.63±0.29

'±' standard deviation

Biomass production

The influences of organic manures and inorganic fertilizers on red amaranth plants can be observed to produce no statistical differences ($p>0.05$) in fresh weights, dry weights, and root lengths of the plants (Table 4). In case of fresh yield, Naafco had the highest weight of 10.75±6.09 g plant^{-1}, while Kazi had the least weight of 1.98±1.49 g plant^{-1}. Similarly, the highest and lowest total dry weights were respectively found in Naafco (1.31±0.87 g plant^{-1}) and Kazi (0.23±0.17 g plant^{-1}). From the results, it can be observed that soil treated with NPK and organic fertilizers generally increased the biomass of the plants than the soil which was not fertilized. In Mondal *et al.* (2019)'s work, no significant variations were found in the dry matter of red amaranth due to application of various manures; whereas, Rahman *et al.* (2014)'s study reported a significant variation in fresh and dry matter yields due to various composts.

Table 4. Effects of organic manures and NPK fertilizers on the biomass production of red amaranth plants at harvest.

Treatments 10 ton ha^{-1}	Fresh weight(g plant^{-1})	Dry weight(g plant^{-1})	Root Length (cm)	Root/shoot ratio
Control	6.25±1.67	0.72±0.10	5.10±1.47	0.13±0.02
NPK-50	9.18±7.01	1.00±0.72	6.97±4.45	0.14±0.03
ACI	5.55±2.13	0.52±0.20	3.70±0.76	0.13±0.06
Agro	8.98±9.32	0.91±1.02	6.20±3.77	0.14±0.03
Kazi	1.98±1.49	0.23±0.17	4.63±2.12	0.14±0.06
McDonald	9.02±4.37	1.12±0.51	5.67±2.08	0.16±0.04
Mazim	9.28±6.11	1.01±0.76	6.90±3.44	0.13±0.05
Naafco	10.75±6.09	1.31±0.87	5.67±1.01	0.18±0.05
Paragon	7.34±5.86	0.78±0.61	4.67±3.76	0.17±0.03
Sharib	5.98±2.57	0.65±0.28	4.40±3.14	0.11±0.02

'±' standard deviation

It is assumed that there is proportionality between root length and resource acquisition (Ostonen *et al*. 2007), which suggests that the greater the root length, the greater is the exploration of the plant roots in the soil, serving as an indication of their better growth. Root length was the highest in NPK-50 (6.97±4.45cm) followed closely by Mazim (6.90±3.44cm), and the plants treated with ACI exhibited the lowest root length (3.70±0.76cm). Miah and his coworkers (2013b) also reported insignificant differences in the root lengths of red amaranth; however, the experiment was conducted in different combinations of urea fertilizer. On the other hand, Mondal *et al*. (2019)'s results found significant variations in root lengths in the interactive effects of organic and inorganic fertilizers.

The mean of the root shoot ratios also do not differ significantly ($p>0.05$) under the influence of different organic and chemical fertilizers, values ranging from Sharib (0.11±0.02) to Naafco (0.18±0.05). However, the parameter generally increased with the fertilizer application. It can be observed from the results that the application of both the organic and inorganic fertilizers had generally contributed to the biomass production of the plants, as these contribute to the increase in NPK contents in soil (Rahman *et al*. 2014). However, the maintenance of the long-term soil fertility and avoidance of possible soil degradation can only be ensured by using different organic fertilizers.

Nutrient Uptake

The nutrient uptakes by the plants were assessed to evaluate the accumulation of N, P, K, S and Fe in leaves and relate them to the growth parameters' responses. There is no significant difference among the treatments in respect with nutrient uptake /red amaranth plant. The average nitrogen uptake in the plants ranged from 1.85mg (Kazi) to 31.91mg (Naafco), the average phosphorus uptake from 0.18 mg (Kazi) to 1.95mg (NPK-50), the mean potassium uptake from 1.42 mg (Kazi) to 14.02 mg (NPK-50), and the mean sulphur uptake from 0.50mg (Kazi) to 2.04mg (Naafco) per plant. The maximum average content of iron in the plants' leaf was found in Paragon treated plants (0.27 mg plant^{-1}). Red amaranths are popularly eaten for their leaves' richness in iron among the other important constituents, which helps in the formation of haemoglobin (Olumakaiye 2011). Our present study shows that red amaranth produced by organic manures generally had high amount of iron in their leaves, which can motivate farmers to organically grow them, which is also healthy for the soil.

Table 5. Effects of organic manures and NPK fertilizers on the nutrient uptake (mg plant^{-1}) by leaves of red amaranth.

Treatments 10 ton ha^{-1}	**Nutrient uptake by plants (mg plant^{-1})**				
	Nitrogen	**Phosphorus**	**Potassium**	**Sulphur**	**Iron**
Control	12.49	0.89	9.06	0.95	0.02
NPK-50	18.01	1.95	14.02	1.77	0.09
ACI	13.14	0.62	5.90	1.06	0.03
Agro	17.65	1.90	8.49	1.94	0.07
Kazi	1.85	0.18	1.42	0.50	0.01
Mazim	17.10	1.13	8.54	1.71	0.12
McDonald	20.77	1.39	11.51	1.75	0.11
Naafco	31.91	1.56	10.45	2.04	0.06
Paragon	15.50	1.57	7.73	0.92	0.27
Sharib	15.38	1.66	7.78	1.56	0.12
LSD at 5% level	NS	NS	NS	NS	NS

NS = Non-significant

From the results, it can be said that application of any of the organic manures used in this experiment to soil cannot be a viable option for the better growth and productivity of red amaranth, since neither of the treatments produced any significant difference in the parameters assessed for the growth when compared with the control. In fact, the results of some of the organic manures were relatively lower than those of the control. This could be attributed to failure to maintain a standard fertilizer grade by some organic fertilizer manufacturers in Bangladesh as pointed out by Akon *et al*. (2018), leading to uniform availability of nutrients not being assured. Besides, there are factors in the environment, such as microbes, temperature and light intensity, which also influence the growth of the plants (Akon *et al*. 2018). Nonetheless, if the organic manure companies are to be compared, Kazi treated plants showed poor growth performance, which has been supported by low nutrient accumulation (3.96 mg plant^{-1}) in their leaves, despite the fertilizer having relatively higher contents of N, P, K, S and Fe among other fertilizer companies. However, a study conducted on Burmese grapes with organic manures reported that Kazi and Payel are preferred for healthy and strong growth of the seedlings (Munna *et al*. 2021). In our study, the overall good growth performance was recorded in Naafco treated plants, with the highest nitrogen and sulphur accumulation in their leaves. However, more research are recommended to be undertaken in similar fashion and under varying agro-climatic conditions in Bangladesh to determine and compare the influences of the organic manures on the growth and nutrient uptake of a fast-growing vegetable like *Amaranthus tricolor*.

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