RED AMARANTH GROWTH IN RESPONSE TO NITROGEN FERTILIZATION

KHALED- IBNE- FAZAL

Registration No. 04-1412

A Thesis

Submitted to the Faculty of Agriculture

Sher-e-Bangla Agricultural University

In partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE (MS)

IN

AGRICULTURAL CHEMISTRY

SEMESTER: July-December '10

APPROVED BY

Dr. Md. Yunus Miah

Associate Professor
Department of Soil Science
BSMRAU, Gazipur-1706
(Supervisor)

Professor Md. Azizur Rahman Mazumder

Professor
Department of Agricultural Chemistry
SAU, Dhaka-1207.
(Co-Supervisor)

Professor Dr. Rokeya Begum

Chairman
Examination Committee

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka - 1207

PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled "RED AMARANTH GROWTH IN RESPONSE TO NITROGEN FERTILIZATION " submitted to the DEPARTMENT OF AGRICULTURAL CHEMISTRY, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of *bonafide* research work carried out by KHALED-IBNE- FAZAL, Registration. No. 04-1412, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation has duly been acknowledged.

Dated: 07.08.2012

Dhaka, Bangladesh

(Dr. Md. Yunus Miah)
Associate Professor
Department of Soil Science

BSMRAU, Gazipur-1706

Supervisor

ACKNOWLEDGEMENTS

First of all, I am very much grateful to almighty Allah who always helps us for facing any difficult situation and has enabled me to complete this thesis. I take profound pleasure to express my heartiest gratitude to my supervisor Professor Dr. Md. Yunus Miah, Associate professor and Head, department of Soil Science, BSMRAU, Gazipur-1706 for his cordial love, brilliant suggestions, encouragement and continuous inspirations.

Additionally, I am deemed to the proud privilege to express my sincere gratitude and unfettered gratification to my Co-supervisor, Md. Azizur Rahman Mazumder, Professor, Department of Agricultural Chemistry, Sher-E-Bangla Agricultural University, Dhaka-1207 for his whole hearted guidance and encouragement. I do appreciate my teacher Dr. Md. Abdur Razzaque, Professor, Department of Agricultural Chemistry, Sher-E-Bangla Agricultural University for his advice and encouragement. Special thanks are also due to Professor Dr. Rokeya Begum, Head, Department of Agricultural Chemistry, Sher-E-Bangla , Agricultural University, Dhaka-1207 for her valuable advice and suggestions. The author wisher to express special thanks to Mr. M. A. Latif and Mr. M. N. Hoq belonging to the department of Soil Science, BSMRAU for their co-operations received for analysis and conduction of experiment in the field. I ma also thankful to the teachers and post graduate students and laborers of the department of Soil Science, BSMRAU, Gazipur-1706 for their help and encouragement during the period of experimentation. I extend my thankful gratitude to Mr. Zia Uddin Kamal, Assistant Professor, department of Soil Science, BSMRAU, Gazipur-1706 for his generous help and co-operations conferred on during data analysis. Finally, the author wishes to express his sincere gratitude to his beloved parents, sisters and brothers and all of his friends for their extended encouragement and support.

February, 2012

The Author

ABSTRACT

The study was conducted at the farm of BSMRAU, Gazipur during the period of November to December, 2010 to enhance the production of red amaranth (*Amaranthus tricolor* cv: BARI lal shak 1) through the improvement of growth and yield of red amaranth by optimizing the appropriate levels of nitrogen fertilizer. The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising six treatments with four replicates each. The treatment combinations were T_0 (0 kg N ha^{-1}), T_1 (50 kg N ha^{-1}), T_2 (75 kg N ha^{-1}), T_3 (100 kg N ha^{-1}), T_4 (125 kg N ha^{-1}) and T_5 (150 kg N ha^{-1}), respectively. N was applied as urea fertilizer and different rates were used according to the treatments. P, K and S were applied as TSP, MOP and gypsum @ 23, 17 and 4 kg ha^{-1}, respectively on being calculated by the methods of BARC (2008). Obtained data on plant height, leaf number, root-shoot growth and yield encompassing nutrient accumulation both in root and shoot revealed that nitrogen fertilization had a significant ($p<0.01$) effect on the short term growth and yield of red amaranth. Further relationship between N, P, K, S, Ca, Mg, Fe and Zn uptake and applied N doses followed by preferential BCR (benefit cost ratio) indicated that nitrogen fertilizer applied at the rate of 150 kg N ha^{-1} had the better potential for the production of red amaranth.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER-I

INTRODUCTION

Originated from the Greek word "amarantos", *Amaranthus* collectively known as amaranths is a cosmopolitan genus of herbs. Nearly 60 species are recognized ranging from purple, red and gold. With its considerable nutritional value, amaranth (*Amaranthus tricolor*) belonging to the family Amaranthaceae is a delicious vegetable world wide. Mainly it is grown as green vegetables in parts of tropical and subtropical Asia, Africa and Central America. Chiefly grown during summer and rainy season, amaranth is an important and popular vegetable in Bangladesh because of its cheapest price, quick growing character and higher yield potential (Hossain, 1996). Therefore, in Bangladesh context, it is one of the cheapest nutritious vegetables and is referred as poor man's vegetable to a great extent. Moreover, it leaves and tips are very tender and used in salads. Even more, it can be harvested after 30 days of sowing. So it is considered as a potential upcoming subsidiary food crop (Teutonico and Knorr, 1985). Thus amaranth plays a predominant role in nutrition as a cheapest source of mineral and vitamin.

The leaves and stems of amaranth are rich in protein, fat, calcium, phosphorus riboflavin niacin, sodium, iron and ascorbic acid. Additionally, it contains food caloric value higher than any other vegetables except potato and tomato (Chaudhury, 1967 and FAO, 1972). A part from this, it is processed into table products like soup. Even it seeds are used in making sweet rolls, crepes cookies crackers, etc. (Muthukrisna and Irulappan, 1986 and Shanmugavelu, 1989). However, at present amaranth is cultivated in an area of 8,647.77 ha with total production of 58,095 tones of amaranth and it is increasing day by day due to high yield, easy cultivation process with nutritional value (BBS, 2010). The average yield is 4.79 t/ha which is lower than other amaranth producing countries (Talukder, 1999). This author also stated that daily recommended requirement of vegetables is 200 g per head but our consumption is 60 g per head with potato and sweet potato, it was 70 g/day/ person. So the nation runs with an acute shortage of vegetables and its production should be increased to feed the increasing population of the country. Total vegetable production in our country is about 1,879.83 thousand tons per year of which 61.9 % is produced in rabi season and 38.09 % in kharif season (BBS, 2010). It is clear that vegetable production in kharif is very low. However, the maximum production of different vegetables are found during the month of November to April. So, during the month of May to September there is a serious scarcity of vegetables. As a result the price of vegetables remains high during that period. Due to high price rate and shortage of vegetable, malnutrition is acute during late summer in Bangladesh. Amaranths can be cultivated as the year round crop to solve problem. These facts suggest that there is a great possibility of increasing amaranth yield per unit area with the appropriate use of nitrogen and organic manure. The total area and production of stem amaranth was 7.25 thousand hectors and 18.2 thousand tons that was increasing day by day (BBS, 2010).

In Bangladesh, the fertilizer specially the nitrogenous is the most critical input for increasing crop production and had been recognized as the central element for agricultural development (Monira, 2007). More over, nitrogen is essential for building up of protoplasm and protein which induce cell division and initial meristametic activity when applied in optimum quantity. Available data indicate that the fertility of most of our soils has been deteriorated over years (Karim *et al.*, 1994 and Ali *et al.*, 1997) which is responsible for stagnation and in some cases, even decline crop yield. The use of chemical fertilizers as a supplement source of nitrogen has been steadily increasing in Bangladesh but they are not usually applied in balanced proportion by most of our farmers (Anon, 1997).

The fact that established is as a leafy vegetable, red amaranth requires more of nitrogen for better growth and higher yield. Additionally, its yield is closely related to available nitrogen. Further nitrogen application increases the protein, carotene, sugars and ascorbic acid contents in amaranths. So in context of red amaranth production in Bangladesh, the facts as mentioned above suggests that there is a great possibility to increase red amaranth yield per unit area with the appropriate use of nitrogen fertilizer. Additionally, these days else where in Bangladesh, there is a year round increasing demand of red amaranth.

Balanced fertilizer application ensures optimum yield of vegetable crop. Thus economic and eco-friendly use of nitrogen encompassing profitable vegetable yield and unacceptable loss to the soil environment is a long awaited demand both in agriculture and horticulture. Information on the use of appropriate levels of nitrogen fertilizer with particular reference to red amaranth cultivation under specific agro-climatic conditions is lacking in general. So the objectives of the current investigation were as follows-

1) To determine the growth and yield of red amaranth as influenced by the application of various levels of nitrogen for short term growth period.
2) To assess the nutrient accumulation in leaves, stems and roots of red amaranth.
3) To quantify the suitable rate of nitrogen fertilizer for stem amaranth cultivation.

CHAPTER-II

REVIEW OF LITERATURE

Widely grown in Bangladesh, red amaranth is a unique amaranth variety with red leaves and deep red stems. A brief and pertinent review of literature has been presented in this chapter. Attention has been made to focus the effect of fertilizers on the yield contributing characters and yield of amaranths followed by nutrient accumulation in plant- parts.

As regards of amaranth cultivation, agricultural fields through the region exhibit low productivity associated with pollution. Application of organic matter as cow dung and poultry manure is a restorative option. The value of manure as an amendment for restoring the productivity of slightly unfertile land is sufficient to allow manure to be hauled further than would be the case on unfertile land. The application of cow-dung and poultry manure significantly decreased the toxic metal Cr, Co, Cd and Pb in red amaranth. Application of above manures reduced the uptake of heavy metals appreciably followed by the better growth of the crop (Freeze *et al.*, 1993).

Materechera and Mukwevho (2007) reported that leaf Amaranth is a common indigenous food plant with a high potential to improve the nutritional security, especially of rural households in South Africa. A field study was conducted at the North West University farm during the 2002/03 crop season to determine growth and yield of *Amaranthus cruentus* in response to nitrogen supplied from chicken manure and defoliation frequency (weekly and fortnightly). Increasing the rate of manure N application significantly improved ($P < 0.05$) growth and dry matter yields of edible leaves over the control. Differences among the manure rates were small at the beginning of the harvesting period but became more apparent towards the end, suggesting higher N release due to mineralization of the manure. The cumulative leaf dry matter yields of amaranth that were defoliated weekly were significantly lower ($P<0.05$) than those defoliated fortnightly. The study confirms that chicken manure is an important resource that can be used by resource poor farmers to supply nutrients and improve productivity of this less conventional crop. It is recommended that a bi-weekly harvesting interval should be adopted in order to ensure high yields. Furthermore, intensive advocacy needs to be undertaken in order to promote the integration of this nutritionally rich indigenous plant species into existing cropping systems in this semi-arid region.

Agele *et al.* (2004) reported that the patterns of nutrients (N, P, K, Ca, Mg) and organic matter release, leaching losses from applied organic materials (poultry manure and wood ash) and a compound NPK mineral fertilizer and the growth response of *Amaranthus* (*Amaranthus cruentus*) were investigated in drainage lysimeter tanks. The soil at the site of the experiment was sandy clay loam (Alfisol, clayey skeletal oxic paleustalf). Subsurface drain water (leachates) recovered from the lysimeters was analyzed for concentrations of nutrients and from the time course of nutrient analyses, contrasting patterns of nutrient concentrations were obtained for the different treatments. The application rate of N 150 kg ha^{-1} from NPK fertilizer and 10 t ha^{-1} of wood ash resulted in the highest nutrient concentrations in subsurface drain water in comparison with application of poultry manure at 10 t ha^{-1}. However, significantly lower nutrient concentrations in subsurface drainage water was obtained in the treatment where neither mineral fertilizer nor manures were applied. Nitrogen recoveries in the leachates were reduced over time regardless of the sources of nutrients. However, a significantly higher rate of N depletion was obtained under wood ash application. The recovery of N in plant tissues and in leachates as a percentage of N added from the tested materials in increasing order of magnitude was wood ash (9%), poultry manure (14%) and NPK fertilizer (23%). Remarkably higher values of fresh and dry weights of root and shoot biomass were produced by vegetable *Amaranthus* grown in lysimeters in which NPK, poultry manure, or wood ash was applied than in unfertilized treatment. Application of poultry manure to lysimeters resulted in higher shoot biomass yield over treatments involving application of wood ash and NPK fertilizer. The nutrient release characteristics of poultry manure matched the nutrient requirements of amaranths more closely than the inorganic fertilizer and wood ash. Wood ash and mineral fertilizer were more susceptible to leaching losses of nutrients during the establishment of *Amaranthus*. The use of poultry manure did not result in significant effects on the quality of *Amaranthus*. Poultry manure and unfertilized control had considerably lower 2-year average N concentration in subsurface drainage water in comparison with lysimeters treated with NPK or wood ash. Lower N recoveries in plant tissues and in leachates were obtained from lysimeters in which poultry manure was applied compared to NPK fertilized lysimeters. A higher proportion of the N present in poultry manure appeared to be resistant to microbial degradation and was thus unavailable for plant uptake.

The soil which was collected from the pharmaceutical and textiles industries of Maouna, Gazipur – polluted by pharmaceutical industrial effluent water led to nutrient imbalance on the growth of red amaranth. The excessive enrichment of the elements N, Zn, Pb, Cr, Cu, As, Mn, Ni and Co created entrophicaion and decrease the quality of soil water. The pharmaceutical site has created some elements adversely affected red amaranth during its establishment. The effluent produced from the Sunipun Pharmaceutical specially producing raw materials for antibiotics are rich in organic nutrients such as N, K, and very rich in total organic carbon (Begume, 2005). Grunhage and Jager (1985) have stated that maximum amount of heavy metals (Cu, Co, Cd, Zn and Ni) was absorbed in the leaves, stems and root of red amaranth due to the imbibitions of metals with each other which depressed the growth and yield.

The application of cow dung was found satisfactory to reduce the toxic effects of heavy metals. The application of cow dung and poultry manure significantly decreased the toxic metal Cr, Co, Cd and Pb in red amaranth (Nuruzzaman *et al.*, 1993).

Latiff and Maraiker (2003) carried out an experiment in the season of 1999/2000, on a reddish latosolic soil, at Gannonuwa in the mid-country wet zone of Srilanka, to study the performance of different vegetable farming system. Cow-dung (CD) and poultry manure (PM) applied at the rates of 20, 30, 40 and 10, 20, 30 t ha^{-1}, were the only source of nutrients for the crops. In the mono-crop experiment, aubergine, cabbage and tomato gave comparable or sometimes higher yields when treated with manure than with NPK. In the mixed cropped rates of CD, but changes in soil quality, particularly pH and Olsen P content, were evident after 6 seasons of continuous manure application. The medium rate used in this study seems sufficient to produce satisfactory organic vegetable yields.

A field experiment was conducted by Jingxue *et al.* (2004) in China to study the effect of the combined application of organic manure and chemical fertilizer on the yield and quality of Chinese cabbage. The combined application of organic manure and fertilizer improved the yield and quality of Chinese cabbage. Greater yield and quality were obtained when organic manure was applied at 3,750 kg/667 m^2 and when the chemical fertilizers were applied at 30 kg/667 m^2. This treatment gave the highest soluble substance, soluble sugar and nitrite contents (6.25 %, 45.38gkg^{-1} and 0.5575 mg kg^{-1} respectively). The nitrate content did not significantly vary among the treatments.

Suchorska (1992) carried out field trials between 1980 and 1985 with the head cabbage cultivar Kamienna Glowa, onion cv. Wolska and beetroot cv. Czerwona kula, grown in a clay soil fertilized with Nowmin (containing brown coal dust enriched with K and P) at 4, 6, 12 or 18 t ha^{-1} + N at 200 or 300 kg ha^{-1} or with Nowmin components equivalent to rate of 12 t Nowmin ha^{-1} + N or with FYM at 50 t ha^{-1}, giving 12 different treatments plus a non-fertlilized control. High yields of all 3 crops were obtained on plots treated with Nowmin, demonstrating that it can be successfully used quality. Generally the 12 t ha^{-1} rate gave the highest total and commercial yields which were 110.2 t ha^{-1} for cabbage, 22.9 t ha^{-1} for onions and 39.27 t ha^{-1} for beet roots.

Yamazaki and Roppongi (1998) studied the effect of soybean meal (SM), composted pig manure (PM) and composted studied cattle dung mixed with sawdust (CMS), applied singly or with chemical fertilizer, on the yield and quality of leafy vegetables in a 5 year experiment. Soil chemical properties improved with continuous applications of organic manures. CMS increased total C and increased soil cation exchange capacity.

Shahidulla *et al.*, (1997) conducted an experiment in Bangladesh, in 1991-92 to study the effect of plant age on nutrient contents of 3 vegetables, lalshak (*Amaranthus Gangiticus A. triclor)*, spinach (*Spinacia oleracea*) and Indian spinach (*Basella alba*). Nutrient content were recorded at 1 month 10 days, 1 month 23 days, 2 month 6 days and 2 months 19 days for lalshak and spinach. One more observation was taken at the age of 27 days for lalshak only. For Indian spinach nutrient contents were recorded at the 2, 3 and 4 months. In lalshak and spinach, the protein, ash, fiber, Ca and P contents increased progressively with the increased in plant age to 2 months 19 days. For Indian spinach, the protein, fat, fibre and P contents increased gradually with the increased in age of the plants from 2 to 4 months.

El- Shinawy *et al.*, (1999) carried out a field trial in lettuces cv. Calona plants grown under nutrient film technique (NFT) conditions supplied with inorganic fertilizer (control), chicken manure, pigeon manure or buffalo manure, for 2 seasons. The electrical conductivity of the nutrient solution was maintained at 1.8-2 mmhos/cm while p H ranged between 5.5 and 6.5. Head fresh and dry weights, chlorophyll content and mineral compositions (total NO_3-N, P, K, Ca, Zn, Mn, Fe and Cu were determined. Yield was highest in the control treatment, followed by chicken manure, pigeon manure and finally buffalo manure. Mineral composition of plants was influenced by treatment. The results suggested that chicken manure, with some modifications, could be used as an organic source under the nutrition film technique system.

Rodrihues and Casali (1998) studied on greenhouse trials; potted seedlings of 11 lettuce cultivars were given mineral or organic fertilizers and the accumulation and utilization of macronutrients. The performance of cultivars in organic fertilizer was correlated with their N utilization efficiency. High K availability reduced the absorption of K and Mg and cultivars, which were more responsive to the organic fertilizer tended to be more efficient in absorption and translocation of Ca and Mg.

Huihe *et al.*, (2003) stated that organic manures decreased root weight and plant height of celery. Pig manure (PM) increases celery yield by 21.1% ($P<0.05$) while peat decreased it by 32.4% ($P < 0.01$). Yields in the other treatments did not differ significantly. Organic manures increased the yield of romaine lettuce by 55.5-132.7% ($P < 0.01$), with greatest increase with rice straw, rape meal and pig manure. Nitrate content of celery was much higher than that of romaine lettuce.

Addition of organic manures on the basis of inorganic fertilizer application increased nitrates on ascorbic acid, soluble sugars and amino acids varied with manure type. Generally speaking, organic manures improved such nutritional indicators in celery and decreased them in romaine lettuce.

Reddy *et al.* (2004) carried out a field study for two years (2001 and 2002) on the farmer's field in Kolar. India, to study the effect of different organic manures on growth and yield of paddy under tank irrigation. Poultry manure and sewage sludge produced better growth components, viz., plant height, and number of tiller per hill, total dry matter per plant and yield components like number of panicles per hill and panicle weight.

Gupta *et al.* (1995) conducted field trials on different organic manures in India and reported that the application of pig manure (10 t ha^{-1}) produced the highest grain yield (4.5 t ha^{-1}) followed by poultry manure and FYM which produced yield of 4.1 and 3.9 t ha^{-1}) of rice grain, respectively. The increase in rice yield with organic manure was 34 to 55% higher over control and 5 to 22% higher over NPK fertilizer.

Babu and Reddy (2000) conducted a field experiment on the effect of NPK fertilizer, FYM and poultry manure on rice. They were given 100: 50: 50 kg NPK ha^{-1} 10 t FYM ha^{-1}, 5 t FYM + 50 kg N as top dressing ha^{-1} or 3 t poultry manure ha^{-1}. The result suggested that the highest grain yield was found with 5 t FYM+ 50 kg N ha^{-1}.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site and Duration

The experiment was carried out at the Research farm and laboratory of the department of Soil Science of Bangabandhu Sheikh Mujibur Rahman Agriculture University (BSMRAU), Gazipur from 1 November 2010 to December 15, 2010. The site is located in the centre of Modhupur Tract (24.9°N latitude and 90.26°E longitude) at 8.4 m above the sea level and about 40 km north to Dhaka. The site was previously under Sal forest and developed later for research purpose (Anon, 1989).

3.2 Climate

The experimental site is situated in the subtropical climatic zone characterized by heavy rainfall during April to September and scanty rainfall during the rest of the year. The monthly average maximum and minimum temperature, relative humidity and monthly rainfall during the field study period are presented in Table 1.

Table 1. Meteorological data of the experimental area from the period of November, 2010 to January, 2011

Month	Air temperature		Relative humidity (%)	Rainfall (mm)
	Max	Min		
November	27.76	23.76	85.66	0.00
December	24.80	16.58	90.77	55.19
January	15.20	11.58	90.80	0.00

3.3 Soil

The soil of the experimental site belongs to Salna series and has been classified as Shallow Red Brown Terrace soil in Bangladesh soil classification system which falls under the order

Inceptisol in soil taxonomy (Brammer, 1978). This soil of Madhupur Tract (AEZ No. 28) is characterized by clay within 50 cm from the surface and is acidic in nature. The soil has poor physical and chemical properties.

3.4 Soil sampling

Before initiation of the experiment, composite samples were collected from 0-30 cm depth of the soil profile. The sample was air dried, ground to pass through 2 mm sieve and used for analysis of physical and chemical properties of soil.

3.5 Physical and chemical properties of soil

3.5.1 Particle-size analysis

Particle-size analysis of the soil sample was done by hydrometer method as outlined by Day (1965) and the textural classes were ascertained using USDA textural triangle.

3.5.2. Bulk density

Bulk density was determined by obtaining a known volume of undisturbed soil cores by using core sampler. It was determined by dividing the oven-dried (105 ^{0}C) mass of the soil core with the inner volume of the sampler (Black, 1965).

3.5.3. Particle density

Particle density of the soil was determined by Pycnometer method as described by Black (1965).

3.5.4. Porosity

Porosity of the soil was calculated by the relation between bulk density and particle density as outlined below:

$$\% \text{ Porosity} = \left(1 - \frac{\text{Bulk density}}{\text{Particle density}}\right) \times 100$$

3.5.5. Soil pH

Soil pH was determined by Glass electrode pH meter in soil – water suspension having soil : water ratio of 1: 2.5 as outlined by Jackson (1958).

3.5.6. Organic carbon

Organic carbon in soil was estimated by wet oxidation method described by Walkey and Black (1935).

3.5.7. Total nitrogen

Total nitrogen was determined by micro-Kjeldahl method following concentrated sulphuric acid digestion and distillation with 40% NaOH. The ammonia evolved was collected in boric acid mixed indicator solution and was titrated against 0.02 N H_2SO_4 (Black, 1965).

3.5.8. Available phosphorus

Extraction for available phosphorus in the soil sample was made with 0.5 M $NaHCO_3$ solution at a nearly constant pH of 8.5 following the method described by Olsen (1965). Spectronic 21D spectrophotometer was used to measure the intensity of the color developed by ascorbic acid (John, 1970).

3.5.9. Exchangeable potassium

Exchangeable potassium was extracted with neutral 1N HN_4OAC as described by Jackson (1973) and was measured by Atomic Absorption Spectrophotometer.

3.5.10. Available sulphur

Available sulphur of the soil was extracted by calcium chloride solution (0.15%) as described by Page *et al*. (1982) and sulphur was determined by spectrophotometer (Hitachi Model 200-20).

Table 2. Physical properties of soil of the experimental site

Soil characteristics	Analytical value
% Sand	17.6
% Silt	47.3
% Clay	35.1
Textural class	Silty clay loam
Bulk density (g/cc)	1.40
Particle density (g/cc)	2.62
Porosity (%)	46.56

Table 3. Some chemical properties of soil of the experimental site

Soil characteristics	Analytical value
Soil pH (soil: water 1: 2.5)	6.1
Organic carbon (%)	0.87
Total N (%)	0.10
Available P (ppm)	12.10
Exchangeable K (meq/100 g soil)	0.56
Total S (ug/g soil)	10.02

3. 6. Land preparation

The field was well prepared by deep ploughing with a tractor followed by harrowing and laddering. Clods were broken and weeds were removed from the field to obtain good tilth. The basal doses of manures and fertilizers were added during final land preparation, after that plots were prepared according to design and layout. Drains were made around each plot and the excavated soil was used for raising the plots about 10 cm high from the soil surface. Ridges were made around each plot to restrict the lateral run-off of irrigation water. Raised plots of size 2 m ×1.75m were made accommodating 56 holes per plot.

3. 7. Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four replications. An area of 15m ×13m was divided into four blocks. Each block was divided into six plots where six treatment combinations were allotted at random. There were 24 unit plots altogether in the experiment. The size of each unit plot was 2m × 1.75m. The space between two blocks and two plots were 1m and 0.5m, respectively.

3. 8. Raising of seedlings

The seeds were dibbled on the 1 November 2010, 2 seeds being placed in each hole (Choudhury et al., 1974). Seeds were used @ 5 kg per hectare (Waseem and Nadeem, 2001). Before dibbling seeds were soaked in water for 48 hrs. Germination was completed within 10 days after dibbling. After the completion of germination thinning was done leaving one seedling in each hole.

3.9. Treatments

Following six treatment combinations were imposed

T_0= No nitrogen

T_1= 50 kg N ha^{-1}

T_2= 75 kg N ha^{-1}

T_3= 100 kg N ha^{-1}

T_4 = 125 kg N ha^{-1}

T_5 = 150 kg N ha^{-1}

3.10. Application of fertilizers

P, K and S were applied from TSP, MOP and gypsum @ 23, 17 and 4 kg ha^{-1}, respectively on being calculated by the methods of BARC (2008). These fertilizers were thoroughly mixed with soil for three days prior to seed sowing and incorporated as well. According to treatment, five nitrogen doses were applied as urea in three splits at 10, 20 and 30 days after sowing as top dressing.

3.11. Plant material

The plant material was red amaranth (*Amaranthus tricolor* cv. BARI lalshak 1). Seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3. 12. Gap filling

Necessary gap filling was done within a week after seedling emergence.

3.13. Intercultural operation

Weeding was done as per requirement. Irrigation was given whenever required. The crop was protected mainly from cut worm by applying Dursban-20 EC. Hand removal of cut worm was also practiced.

3.14 Harvesting

Harvesting of the crop was completed on 15^{th} December, 2010 when the plant growth was maximum for use as vegetable.

3.15 Data Collection

Data on the following parameters were recorded during the course of experiment. All of the data were collected at the harvesting period. Ten plants from each plot were selected randomly in such a way, that the border effect was avoided for the highest precision.

3.15.1. Plant height (cm)

The height of the mean value of randomly selected 10 plants in each plot was measured at 45 days after sowing (DAS). The height was measured in centimeters from the ground level to tip of the highest leaf (in normal condition).

3.15.2. Number of leaves

Number of leaves in each plant was counted from the mean value of randomly selected 10 plants in each plot at 45 days after sowing (DAS) in normal condition and the mean value was calculated.

3.15.3. Leaf breadth

The breadth of the petiole was measured with a slide Calipers from randomly selected ten plants at 45 DAS. The diameter of the petiole breadth was measured in centimeter after harvest at the middle portion of the petiole and the mean value was calculated.

3.15.4. Leaf length

The length of the petiole was measured with a centimeter scale from randomly selected ten plants at 45 DAS and the mean value was calculated.

3.15.5 Root length (cm)

The root length of the randomly selected 10 plants in each plot was measured at 40 days after sowing (DAS). The length was measured in centimeters and the mean value was calculated.

3.15.6 Shoot diameter (mm)

To measure the shoot diameter of a plant a slide calipers was used. The diameter of the plant was measured in centimeter after harvest at the middle portion of the plant and the mean value was calculated.

3.15.7 Fresh root weight (g)

Fresh weight of the roots of ten plants was measured in gram (g) after harvest and averaged as well.

3.15.8 Dry root weight (g)

After *harvest, roots of ten plants were washed with tap water and dried in the oven at* 55^0C *for* 24 hours to remove the outer moisture and measured in gram (g) and averaged as well.

3.15.9 Fresh plant weight (g)

Fresh weight of ten plants was measured in gram (g) after harvest and averaged as well.

3.15.10 Dry plant weight (g)

After harvest, ten plants were washed with tap water and dried in the oven at 55^0C for three days to remove the extra moisture and measured in gram (g) and averaged as well.

3.16. Plant sampling

Destructive samplings were made at 40 DAS. At each sampling five plants were randomly taken form each plot. The plant materials were oven dried at 70^0C for 72 hours to a constant weight and dry weight was recorded. The plant samples were grounded and preserved in a dissector for chemical analysis.

3.16.1. Total nitrogen content

Total nitrogen content in plant samples was determined by micro Kjeldahl method following concentrated sulphuric acid digestion, distillation with 40% NaOH. The ammonium evolved was collected in boric acid indicator and was titrated against 0.02 N H_2SO_4 (Black, 1965).

3.16.2 Total phosphorus, Potassium content and Zinc

Dried plant materials were digested with concentrated HNO_3 and $HClO_4$ mixture as described by Piper (1966) for determination of total phosphorus, potassium content and zinc. Total phosphorus content in the extract was determined by Vanado-Molybdate Yellow color method as described by Jackson (1973). Total potassium and zinc were determined by the Atomic Absorption Spectrophotometer (Model NO. 170-30, Hitachi, Japan).

3.16.3 Total sulphur content in plant sample

The sulphur content was determined by calcium chloride extract method.

3.16.4 Calcium content of the plant sample

Calcium content in plant sample was determined by complex metric method of titration using Na_2EDTA as a complexing agent at pH 12 where calcon was used as indicator (Page et. al., 1982). Exactly 5mL of sample was taken followed by 30mL water, 2mL 10% NaOH solution, 10 drops each of the hydroxyl amine hydrochloride ($NH_2OH.HCl$), potassium ferrrocyanide $[K_2Fe(CN)_6.3H_2O]$ and triethanol amine (TEA), ($C_6H_{15}NO_3$), as masking agent. After the addition of calcon indicator ($C_1H_{13}N_2NaO_5S$) solution, the test sample was titrated against Na_2EDTA (0.01) solution.

3.16.5 Iron content of the plant sample

Iron content of the plant sample was estimated by atomic absorption spectrophotometer at the wavelength of 248 nm. Iron was extracted with DTPA extracting reagent according to the method of PCARR (1983).

Calculation of Fe

Fe mg L^{-1} present in plant sample = Absorbance × total dilution factor × Total curve factor.

3.16.6. Magnesium content of plat sample

Plant materials were digest with concentrated mixture (5:1) of concentrated HNO_3 and $HClO_4$ (Nitric Per-chloric acid) to determine total Mg. Then 5 mL of extract and 1 mL lanthanum chloride in a 50 mL vol. flask and filled up to the mark by distilled water. Concentration of Mg was then measured the Atomic Absorption Spectrophotometer (Model 170-30, Hitachi, Japan) at a wavelength of 285.5 nm.

3.17. Gross yield

A balance was used to record the weight of the harvested plants and weight of the plant was taken in kilogram (kg) from each unit plot and thus yield (t ha^{-1}) was recorded.

3.18. Statistical Analysis

The collected data on various parameters under study were statistically analyzed using MSTAT-C computer package program. The means for all the treatments were calculated and analyses of variances for all the characters were performed by F-variance test. The significance of the differences among the pairs of treatment means was evaluated by Duncan Multiple Range Test (DMRT) at 1% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

CHAPTER-IV

RESULTS AND DISCUSSION

The experiment was conducted to determine the effect of different levels of nitrogen fertilizer (urea) on the growth, yield and yield attributes, N, P, K, Ca, Mg, S, Fe and Zn accumulation both in root and shoot accompanied with their uptake by red amaranth. The growth and yield characters such as plant height, leaf number, leaf size (length and breadth), root length, shoot diameter, plant weight, total plant weight per plot and yield (t ha^{-1}) are presented in tables and graphs. The results of each parameter have been discussed and possible interpretation wherever necessary has been given which are as follows.

4.1 Plant height

Heights of red amaranth plants were recorded from all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments at 45 DAS (Table 4). The application of different doses of N affected plant height significantly ($p<0.01$). The highest plant height (25.93 cm) was recorded in treatment T_5 followed by treatment T_4 (21.77 cm), T_3 (20.99 cm), T_2 (20.78 cm), T_1 (17.15 cm) and T_0 (11.33 cm), respectively. Thus the shortest plant height (11.33 cm) was recorded in T_0. Obtained results on plant height were similar to those reported by Hamid *et al.* (1989) and Roy (2008).

4.2 Leaf number

As shown in Table 4, various levels of N fertilizer induced differences among the number of leaves (per plant) were significant ($p<0.01$). The highest leaf number (24.66) was found in treatment T_5 and the lowest leaf (14.37) number was obtained in T_0. In the current experiment, recorded data on the number of red amaranth leaves (per plant) were in full agreement with those of Talukder (1999).

4.3 Leaf breadth

Among the doses of nitrogen, the breath of the leaves of the plant differed significantly ($p<0.01$) (Table 4). The highest leaf breadth (5.41 cm) was measured in treatment T_5. On the contrary, the lowest leaf breadth (3.29 cm) was found in treatment T_0. In experiments with amaranths, Hossain (1996) and Rajagopal *et al.* (1977) reported the similar range of leaf breadth.

4.4 Leaf length

The effect of different nitrogen treatments on leaf length is shown in Table 4. Considering the treatments, significant ($p<0.01$) variation was recorded in leaf length. The longest leaf length (7.46 cm) of red amaranth was measured in T_5 and that of the lowest (4.12 cm) was recorded in treatment T_0. Hossain (1996) observed that leaf length of different amaranths vary from 7.83 cm to 12.73 cm at 45 DAS. For same growth period, Rajgopal *et al.* (1977) noticed that the breadth of leaves ranges from 9.80 to 10.20 cm. Thus the data of red amaranth leaf length coincided with the findings of Hossain (1996) and Rajgopal *et al.* (1977), respectively.

4.5 Root length

The effect of different nitrogen treatments on root length was not significant (Table 4). Numerically, the longest root length (6.48 cm) was found in treatment T_5 and the lowest (5.76 cm) was recorded in treatment T_0. This sort of N induced variation in the root length of amaranths was reported by Roy (2008).

4.6 Shoot diameter

As shown in Table 4, it is clear that the application of different levels of N influenced shoot diameter significantly ($p<0.01$). The highest shoot diameter (3.94 cm) was observed in T_5 and that of the lowest (2.55 cm) was recorded in T_0. For shoot diameter of red amaranths, similar results were observed by Hossain (1996) and Talukder (1999).

4.7 Fresh and dry root weight

There was significant ($p<0.01$) effect of different treatments on the production of fresh root weight of red amaranth (Table 4). As for fresh weight, the highest value (0.96 g) was observed in T_4 and that of the lowest (0.47 g) was recorded in T_0 and such pattern of fresh root weight production was similar to those of Talukder (1999). In contrast, the trend of dry weight production was insignificant and rugged in all of T_0, T_1, T_2, T_3, T_4, T_5 respectively with the highest dry root weight (0.091 g) in T_5 and that of the lowest (0.041 g) in T_1 coinciding with those of Roy (2008).

Table 4: Effect of N on vegetative growth of red amaranth

Treatment	Plant height (cm)	No. of leaves plant^{-1}	Leaf breadth (cm)	Leaf length (cm)	Root length (cm)	Shoot diameter (cm)	Fresh root weight plant^{-1} (g)	Dry root weight plant^{-1} (g)
T_0	11.33	14.37	3.29	4.12	5.76	2.55	0.47	0.042
T_1	17.15	15.18	3.77	5.10	5.98	2.71	0.71	0.041
T_2	20.78	19.75	4.79	6.62	6.23	2.83	0.87	0.071
T_3	20.99	19.53	4.93	6.21	6.47	3.00	0.90	0.062
T_4	21.77	21.76	5.15	6.63	6.07	3.44	0.96	0.084
T_5	25.93	24.66	5.41	7.46	6.48	3.94	0.89	0.091
CV (%)	9.19	11.24	9.85	6.96	7.05	7.91	3.51	22.26
LSD	3.28	3.92	0.81	0.76	0.79	0.44	0.057	0.057
Level of significance	**	**	**	**	NS	**	**	NS

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg ha^{-1}

CV = Co-efficient of variation

LSD = Least Significant Difference

NS = Non-significant

** = Significant at 1% level of probability

4.8 Fresh and dry plant weight

The effect of different nitrogen treatments on plant fresh weight was significant ($p<0.01$). As shown in Table 5, highest fresh weight (12.07 g) was measured in T_5 and that of lowest (4.88 g) was found in T_0. These sorts of findings indicated that increase in nitrogen doses had a positive effect on the increment of plant fresh weight. On the other hand, increase in nitrogen dose had a significant ($p<0.01$) influence on the increase in plant dry weight too. Namely, a similar trend of highest (0.74 g) and lowest (0.52 g) dry weights were recorded in T_4 and T_0 treatments, respectively. In response to nitrogen fertilization, such patterns of fresh and dry plant weights for red amaranths were reported by Roy (2007).

4.9 Yield /plot

As for yield in red amaranth, different treatments showed significant ($p<0.01$) variation (Table 5). The results indicated that maximum yield (1333.33 g) per plot was observed in T_5 and that of the lowest (350.0 g) was recorded in T_0. These high and low yields could be ascribed for the highest nitrogen dose application followed by that received no nitrogen because N is central element for the growth and development of plant (Roy, 2008).

4.10 Yield /hectare

Yield of red amaranth was positively influenced by various nitrogen treatments (Table 5). However, variation among the treatments corresponding to red amaranth yield per hectare was significant ($p<0.01$). Generalized trend observed for yield was that yield per hectare increased with the increase in nitrogen dose vide T_0, T_1, T_2, T_3, T_4, T_5, respectively. The highest yield (3.33 t/ha) was found in T_5 and the lowest yield (0.87 t ha^{-1}) was recorded in T_0. However, results were in perfect agreement with those of Ara (2005).

Table 5: Effect of N on the yield attributes of red amaranth

Treatment	Fresh weight plant^{-1} (g)	Dry weight plant^{-1} (g)	Yield plot^{-1} (g)	Yield (t ha^{-1})
T_0	4.88	0.52	350.00	0.87
T_1	7.25	0.68	791.66	1.98
T_2	8.89	0.73	966.66	2.41
T_3	10.23	0.81	1100.00	2.75
T_4	11.49	0.88	1200.00	3.00
T_5	12.07	0.74	1333.33	3.33
CV (%)	4.11	10.30	1014	10.14
LSD	0.68	0.14	176.50	0.44
Level of significance	**	**	**	**

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg N ha^{-1}

CV = Co-efficient of variation

LSD = Least Significant Difference

NS = Non-significant

** = Significant at 1% level of probability

4.11 Nutrient content in red amaranth shoot

4.11. 1. Nitrogen concentration (%)

As shown in Table 6, different N treatment combinations showed statistically significant ($p<0.01$) increase in nitrogen (N) content (%) in the order $T_0 < T_1 < T_2 < T_3 < T_4 < T_5$. The highest

(5.11 %) nitrogen concentration was found in T_5 and that of the lowest (4.68 %) was recorded in T_0. These data indicated that increase in nitrogen doses had positive effect on the increment of red amaranth shoot nitrogen content. So such findings could be presumed for two reasons namely, applied nitrogen doses were in accordance with the requirement for the vegetative growth of red amaranth and secondly, it might be speculated for harvesting time and harvested organ since in red amaranth harvested leaves are edible portions and harvesting period was 45 days as N accumulation in plant parts depend on N source and growth period (Rauf *et. al.*, 2009).

4.11. 2. Phosphorus concentration (%)

Phosphorus (P) content of red amaranth after harvest is displayed in Table 6. The trend of phosphorus concentration in red amaranth shoot was remarkable. In other words, nitrogen treatments induced variations in phosphorus content was not significant. Phosphorus concentration varied between 0.27 to 0.32 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.32 %) in T_2. However, such variation of P concentration range in red amaranth shoot lied in the suggestions of Marschner (1990).

4.11.3. Potassium concentration (%)

Data on potassium (K) concentration of red amaranth shoot are shown in Table 6. As for potassium concentration, no remarkable variation among the treatment combinations were observed. Potassium concentration varied between 0.44 to 0.46 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.46 %) in T_2. This sort of K concentration pattern in all of T_0, T_1, T_2, T_3, T_4, T_5 might be credited to the variety used as relations between K accumulation in plant parts and K supply vary from plant to plant (Marschner, 1990).

4.11. 4. Calcium concentration (%)

Determined calcium (Ca) concentrations of red amaranth shoot are shown in Table 6. Treatment induced variation of Ca concentration in red amaranth shoot was significant ($p<0.01$) in all of T_0, T_1, T_2, T_3, T_4, T_5. Further, such calcium concentration varied between 2.46 to 2.28 (%) in all the treatments with the highest concentration (2.46 %) in T_4. However, it remained obscure why such a significant variation lied among T_0, T_1, T_2, T_3, T_4 and T_5 since no relation with the increase in nitrogen doses and that of Ca accumulation exists in plant parts (Carson, 1974).

4.11. 5. Magnesium concentration (%)

Magnesium (Mg) content of red amaranth at harvest is presented in Table 6. The trend of Mg concentration in red amaranth shoot was statistically identical. In other words, treatment combinations induced variations in Mg content was not significant. Magnesium concentration varied between 0.29 to 0.27 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.29 %) in T_5. However, such findings of Mg concentrations fell in the generally agreed range (Marschner, 1990).

4.11. 6. Sulfur concentration (%)

As displayed in Table 6, sulfur (S) content (%) among the treatment combinations showed that it was not increased remarkably. As for sulfur concentration, no treatment affected significant increase was observed. The highest (.26 %) S concentration was found in T_5 and that of the lowest (.22 %) was recorded in T_0. These data indicated that increase in nitrogen doses had no remarkable effect on the increment of red amaranth shoot S content. However, such sorts of variation in S concentrations were in full agreement with those reported by Marschner (1990).

4.11. 7. Iron concentration (%)

Obtained results of iron (Fe) concentration against various treatment combinations in shoot of red amaranth are shown in Table 6. As regards of Fe concentration, no significant variation among the treatments was observed. Namely, Fe concentration varied between 0.13 to 0.17 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.17 %) in T_2. A credible explanation for such variation of iron concentration in red amaranth shoot followed to those reported by Mahideen et al. (1985).

4.11. 8. Zinc concentration (%)

Data as presented in Table 6 showed that Zinc (Zn) concentrations among the treatment combinations varied significantly ($p<0.01$). The highest (83.66 ppm) Zn concentration was found in T_5 and that of the lowest (41.66 ppm) was recorded in T_0. These data indicated that increase in nitrogen doses had positive effect on the increment of red amaranth shoot Zn content and were accordance with reported by Mengel and Kirkby (2001).

Table 6: Effect of N on nutrient content in red amaranth shoot

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (%)	Zn (ppm)
T_0	4.68	0.27	0.45	2.28	0.27	0.22	0.17	41.66
T_1	4.74	0.29	0.46	2.42	0.28	0.23	0.17	44.43
T_2	4.96	0.32	0.45	2.46	0.27	0.24	0.17	49.00
T_3	3.08	0.29	0.46	2.33	0.27	0.24	0.13	73.66
T_4	4.65	0.28	0.44	2.46	0.27	0.26	0.14	76.00
T_5	5.11	0.28	0.44	2.32	0.29	0.26	0.13	83.66
CV (%)	0.63	0.73	3.15	0.49	3.31	6.14	1.34	3.45
LSD	0.057	0.057	0.057	0.057	0.057	0.057	0.057	1.61
Level of significance	**	NS	NS	**	NS	NS	NS	**

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg N ha^{-1}

CV = Co-efficient of variation

LSD = Least Significant Difference

NS = Non-significant

** = Significant at 1% level of probability

4.12. Nutrient content in red amaranth root

4.12. 1. Nitrogen concentration

Nitrogen (N) content (%) among the treatment combinations increased remarkably (Table 7). Treatment affected increase in root N concentration varied significantly ($p<0.01$). The highest (2.95 %) N concentration was found in T_4 and that of the lowest (2.63 %) was recorded in T_0. These data indicated that increase in the application of nitrogen doses had positive effect on the increment of red amaranth root nitrogen content and the results were dissimilar to those of Roy (2008).

4.12. 2. Phosphorus concentration

As shown in Table 7, the trend of phosphorus (P) concentration in red amaranth root was rugged. In other words, treatment combinations induced variations in phosphorus content was not significant. Phosphorus concentration varied between 0.16 to 0.21 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.21 %) in T_2. Such sorts of P concentrations in plant parts were also supported by Munson (1998).

4.12. 3. Potassium concentration

Potassium (K) concentrations of Red amaranth roots are shown in Table 7. However, such potassium concentrations were insignificantly affected by various treatments. Potassium concentration varied between 0.44 to 0.47 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.47 %) in T_5. These sorts of K concentrations in all of T_0, T_1, T_2, T_3, T_4

and T_5 could be attributed to the variety used as relations between K accumulation in plant parts and K supply vary from plant to plant (Marschner, 1990).

4.12. 4. Sulfur concentration

As shown in Table 7, red amaranth root sulfur (S) content (%) among the treatment combinations varied between 0.21 to 0.26 %. Namely, treatment combinations showed no remarkable increase with the increase of nitrogen doses applied. However, the highest (0.25 %) S concentration was found in T_3 and that of the lowest (0.21 %) was recorded in T_4. Thus the different treatment combinations expressed differential effects on red amaranth root sulfur content and were in conformity with those of Marschner (1990).

4.12. 5. Calcium concentration

Calcium (Ca) content of red amaranth root at harvest is presented in Table 7. Treatment combinations induced variations in Ca content was not significant. Calcium concentration varied between 1.21 to 1.43 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (1.43 %) in T_0 and were similar to those of Carson (1974) as this author confirmed that no relation with the increase in nitrogen doses and that of Ca accumulation in plant parts exists.

4.12. 6. Magnesium concentration

As shown in Table 7, data of red amaranth root magnesium (Mg) content did not vary remarkably. Magnesium concentration varied from 0.23-0.24% in all of T_0, T_1, T_2, T_3, T_4, T_5. The highest Mg concentration (0.24%) was observed in T_0, T_2 and T_5, respectively. In other words, a statistically identical Mg concentration was found in various treatments. However, such Mg concentrations coincided with those outlined by Munson (1998).

4.12. 7. Iron concentration (%)

Various treatment affected iron (Fe) concentrations of red amaranth root are shown in Table 7. No remarkable variation for Fe concentration was observed among the treatments. Namely, Fe concentration varied between 0.09 to 0.14 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.14 %) in T_4. Thus the iron concentrations of red amaranth root in various treatments were in conformity with the findings of Mahideen et al. (1985) since the authors clarified with credible explanations why a variation in iron concentration of vegetables exist.

4.12. 8. Zinc concentration (%)

Red amaranth root zinc (Zn) concentration among the treatment combinations varied significantly ($p<0.01$) (Table 6). The highest (71.33 ppm) Zn concentration was found in T_0 and that of the lowest (61.66 ppm) was recorded in T_5. These data indicated that increase in nitrogen doses had no positive effect on the increment of Zn content of red amaranth root and were dissimilar to those reported by Mengel and Kirkby (2001). So it remained to be studied why such a high Zn content was recorded in T_0.

Table 7: Effect of N on nutrient content in red amaranth root

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (%)	Zn (ppm)
T_0	2.63	0.16	0.44	0.22	1.43	0.24	0.09	71.33
T_1	2.82	0.18	0.45	0.23	1.21	0.23	0.11	70.00
T_2	2.89	0.21	0.46	0.24	1.26	0.24	0.11	67.00
T_3	2.58	0.20	0.46	0.25	1.18	0.24	0.14	67.66
T_4	2.95	0.17	0.45	0.21	1.22	0.24	0.14	72.00
T_5	2.74	0.16	0.47	0.26	1.36	0.23	0.09	61.66
CV (%)	1.01	1.26	2.42	1.50	1.67	1.25	7.32	3.11
LSD	0.057	0.057	0.057	0.058	0.057	0.057	4.92	3.86
Level of significance	**	NS	NS	NS	**	NS	NS	**

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg N ha^{-1}

CV = Co-efficient of variation

LSD = Least significant Difference

NS = Non-significant

** = Significant at 1% level of probability

4.13 Nutrient uptake

There is no doubt that plants need a certain level of each essential nutrient in its tissues for proper growth and development. However, nutrient level is different for each of the nutrient in plant tissues. Usually macronutrients are present in much higher concentration than the micronutrients. Nitrogen fertilization based nutrient uptake of red amaranth is presented below:

4.13. 1. Nitrogen uptake

Nitrogen (N) uptake of red amaranth is presented in Table 8. Treatments induced variations in N uptake was statistically significant ($p<0.01$) for all of T_1, T_2, T_3, T_4 and T_5, respectively. However, N uptake varied between 41.03 to 170.45 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest uptake 170.45 (kg ha^{-1}) in T_5 and were in full agreement with those of Marschner (1990).

4.13. 2. Phosphorus uptake

The trend of phosphorus (P) uptake in red amaranth was remarkable. In other words, data presented in Table 8 indicated that N treatments induced variations in P uptake was significant ($p<0.01$). Further, such P uptake varied between 2.42 to 9.41 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest uptake (9.41 kg ha^{-1}) in T_5. As for plants, evidence of such kind of P uptake has been detailed by Mengel and Kirkby (2001).

4.13. 3. Potassium uptake

Potassium (K) uptake in red amaranth is shown in Table 8. However, the potassium uptake was significantly ($p<0.01$) affected by various treatments. Potassium uptake varied between 3.98 to 14.62 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest uptake (14.62 kg ha-

^{1}) in T_5. Such K uptake in red amaranth could be attributed to the variety used as relations between K uptake in plant parts and K supply vary from plant to plant (Marschner, 1990) and source of N applied (Roy, 2008).

4.13. 4. Sulfur uptake

As presented in Table 8, sulfur (S) uptake (kg ha^{-1}) in red amaranth among the treatment combinations showed remarkable variation. Sulfur uptake among the treatments was statistically significant ($p<0.01$). It varied between 1.95 to 8.66 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest uptake (8.66 kg ha^{-1}) in T_5. Thus the applied nitrogen doses had a positive effect on the increment of red amaranth S uptake. However, such variations in S uptake were in full agreement with those of Marschner (1990).

4.13. 5. Calcium uptake

The trend of calcium (Ca) uptake in red amaranth was remarkable for all the treatments (Table 8). In other words, treatment combinations induced variations in Ca uptake was significant ($p<0.01$). Further, such calcium uptake varied between 19.95 to 77.50 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest uptake (77.85 kg ha^{-1}) in T_5. For Ca uptake in plants, similar findings were postulated by Hanson (1984).

4.13. 6. Magnesium uptake

Magnesium (Mg) uptake of red amaranth at harvest is presented in Table 8. The significant ($p<0.01$) trend of Mg uptake in red amaranth was in the order of $T_0<T_1<T_2<T_3<T_4<T_5$. In other words, treatment combinations of N doses applied had a positive effect on Mg uptake varying between 2.41 to 9.66 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake

9.66 (kg ha^{-1}) in T_5. However, such range of Mg uptake lied in the suggestions of Kirkby and Mengel (1986).

4.13. 7. Iron uptake

Obtained results of iron (Fe) uptake against various treatment combinations in red amaranth are shown in Table 8. As regards of Fe uptake, significant ($p<0.01$) variation among the treatments was observed. Namely, Fe concentration varied between 1.55 to 4.39 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest concentration 4.39 (kg ha^{-1}) in T_4. A well clarified explanation for such Fe uptake in plants is detailed by Mengel and Kirkby (2001).

4. 13. 8. Zinc uptake

Data as presented in Table 8 showed that Zinc (Zn) uptake among the treatment combinations varied significantly ($p<0.01$). The highest (0.18 kg ha^{-1}) Zn uptake was found in T_2 and that of the lowest (0.07 kg ha^{-1}) was recorded in T_0. These data indicated that increase in nitrogen doses had a positive effect on the increment of red amaranth Zn uptake and were in agreement with those of Mengel and Kirkby (2001).

Table 8: Effect of N on nutrient uptake of red amaranth

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Ca (kg ha^{-1})	Mg (kg ha^{-1})	S (kg ha^{-1})	Fe (kg ha^{-1})	Zn (kg ha^{-1})
T_0	41.03	2.42	3.98	1.95	19.95	2.41	1.55	0.07
T_1	93.93	5.85	9.11	4.51	47.98	5.61	3.50	0.14
T_2	119.98	7.87	10.99	5.71	59.55	6.63	4.30	0.18
T_3	84.96	7.87	12.72	6.58	64.03	7.60	3.81	0.13
T_4	139.83	8.50	13.39	7.83	73.70	8.29	4.39	0.13
T_5	170.45	9.41	14.62	8.66	77.50	9.66	4.29	0.14
CV (%)	11.81	10.22	8.97	13.43	10.35	10.26	10.31	10.33
LSD	6.25	5.81	5.44	1.43	1076	1.25	0.68	0.057
Level of significance	**	**	**	**	**	**	**	**

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg N ha^{-1}

CV = Co-efficient of variation

LSD = Least Significant Difference

NS = Non-significant

** = Significant at 1% level of probability

4.14 Economic performance of red amaranth

The partial budget analysis on the effect of nitrogen doses applied on red amaranth production is presented in Table 9. The highest gross return (Taka 39,960.00 ha^{-1}) was obtained from the treatment T_5 which received N (150 kg ha^{-1}), followed by the treatment T_4 (Taka 36,000.00 ha^{-1}) which received N (125 kg ha^{-1}), T_3 (Taka 33000.00 ha^{-1}) which received N (100 kg ha^{-1}), T_2 (Taka 28,900.00 ha^{-1}) which received N (75kg ha^{-1}) and T_1 (Taka 23, 760.00 ha^{-1}) which received N (50 kg ha^{-1}). All the treatments resulted in higher gross return over the control (Taka 10,440.00 ha^{-1}). On the other hand, highest variable cost (Taka 10,980.00 ha^{-1}) was required in the treatment T_5 which received N (150 kg ha^{-1}) and that of the lowest (Taka 7479.00) was needed in T_0 which received no nitrogen fertilizer. The highest cost benefit ratio (3.66) was recorded in T_4 which was followed by T_5 (3.64).

Table 9: Effect of nitrogen on economic performance of red amaranth cultivation

Treatment	Gross return (Tkha^{-1})	TVC (Tkha^{-1})	Gross margin (Tkha^{-1})	BCR
T_0	10440.00	7479.00	2961.00	1.40
T_1	23760.00	8507.00	15235.00	2.79
T_2	28920.00	9211.00	19709.00	3.14
T_3	33000.0	9544.00	23456.00	3.46
T_4	36000.00	9826.00	26174.00	3.66
T_5	39960.00	10980.0	28980.00	3.64

T_0 = 0 kg N ha^{-1}, T_1 = 50 kg N ha^{-1}, T_2 = 75 kg N ha^{-1}, T_3 = 100 kg N ha^{-1}, T_4 = 125 kg N ha^{-1}, T_5 = 150 kg N ha^{-1}

TVC= Total Variable Cost

BCR= Benefit Cost Ratio

4.15 Relationship between N doses and yield and nutrient uptake

4.15. 1. Yield and N dose

The relationship between yield and applied N doses is presented in Figure 1. The regression analysis indicated that the yield of red amaranth was linearly and positively correlated to the applied N doses. It was also evident from the regression equation that increase in N dose resulted in the increase in yield and thus coincided with those of Roy (2008).

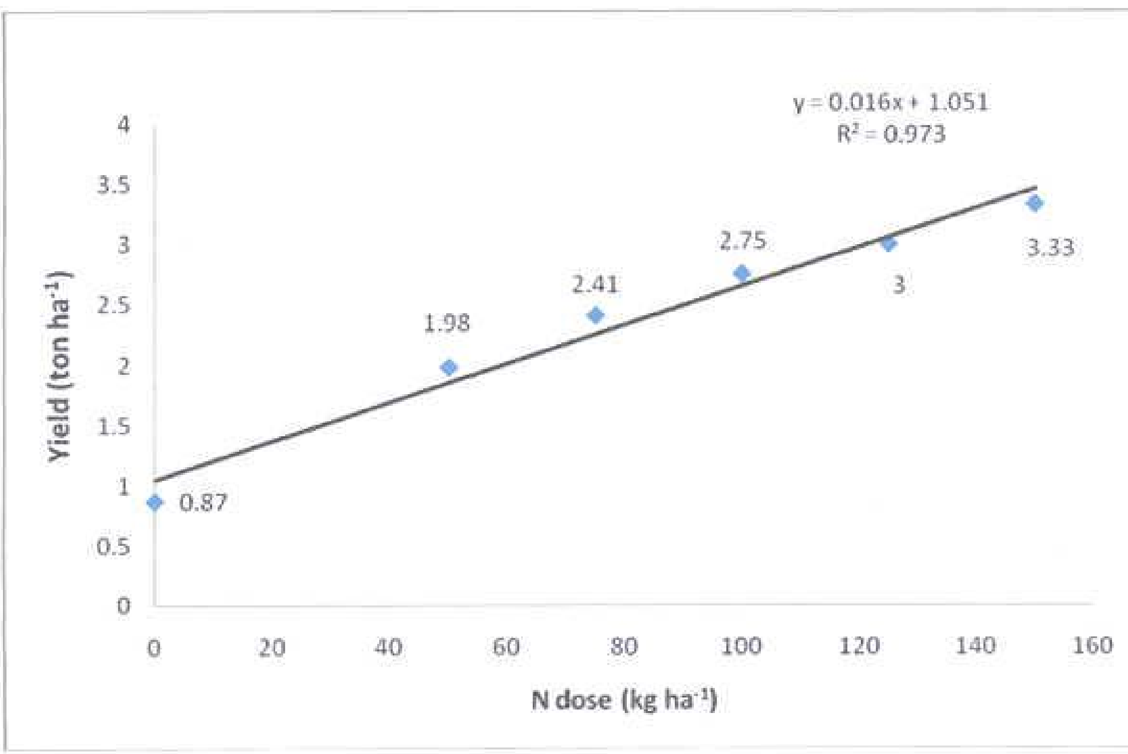

Figure 1 : Relationship between N level / dose and yield of red amaranth

4.15. 2. N uptake and N dose

The relationship between N uptake and applied N dose is presented in Figure 2. From regression line it was clear that increase in N dose resulted in the increase in N uptake and thus coincided with those of Marschner (1990) and Ara (2005).

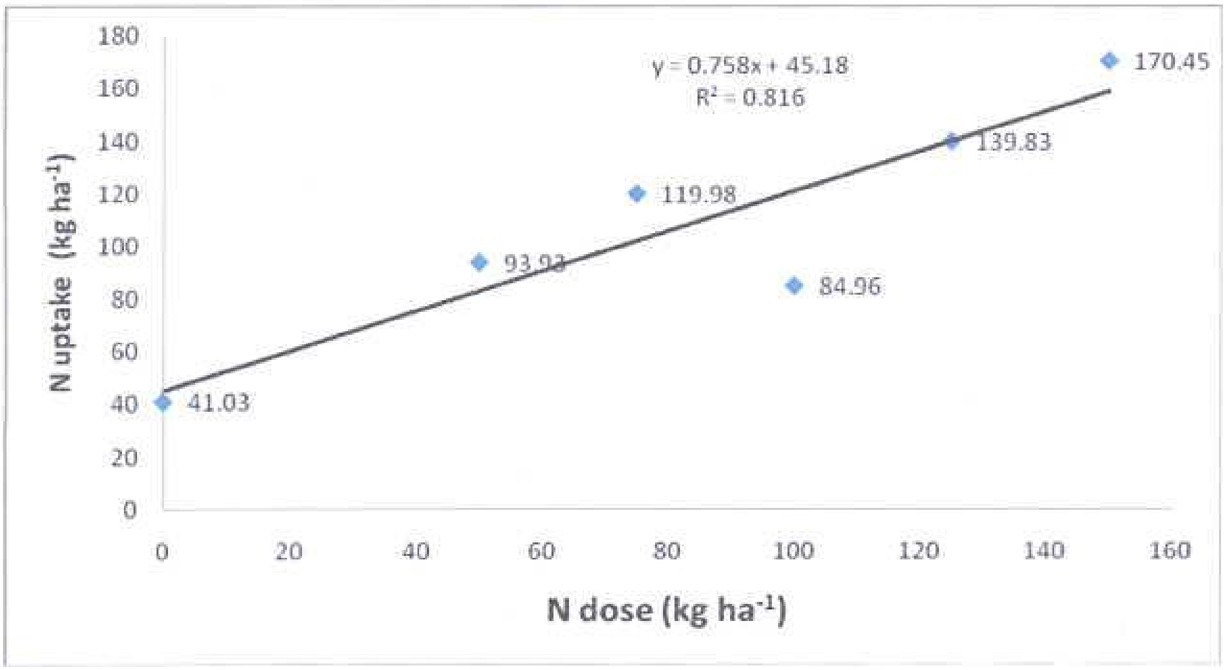

Figure 2: Relationship between N dose and uptake

4.15. 3. P uptake and N dose

The relationship between P uptake and applied N dose is presented in Figure 3. From regression line, it was clear that increase in N dose resulted in the increase in P uptake up to T_5 (150 kg N ha^{-1}) application. So it was evident that the relationship between P uptake and applied N doses was positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment. Further P uptake trend was similar to that of N uptake. In experiments with amaranths, similar results were also reported by Roy (2008).

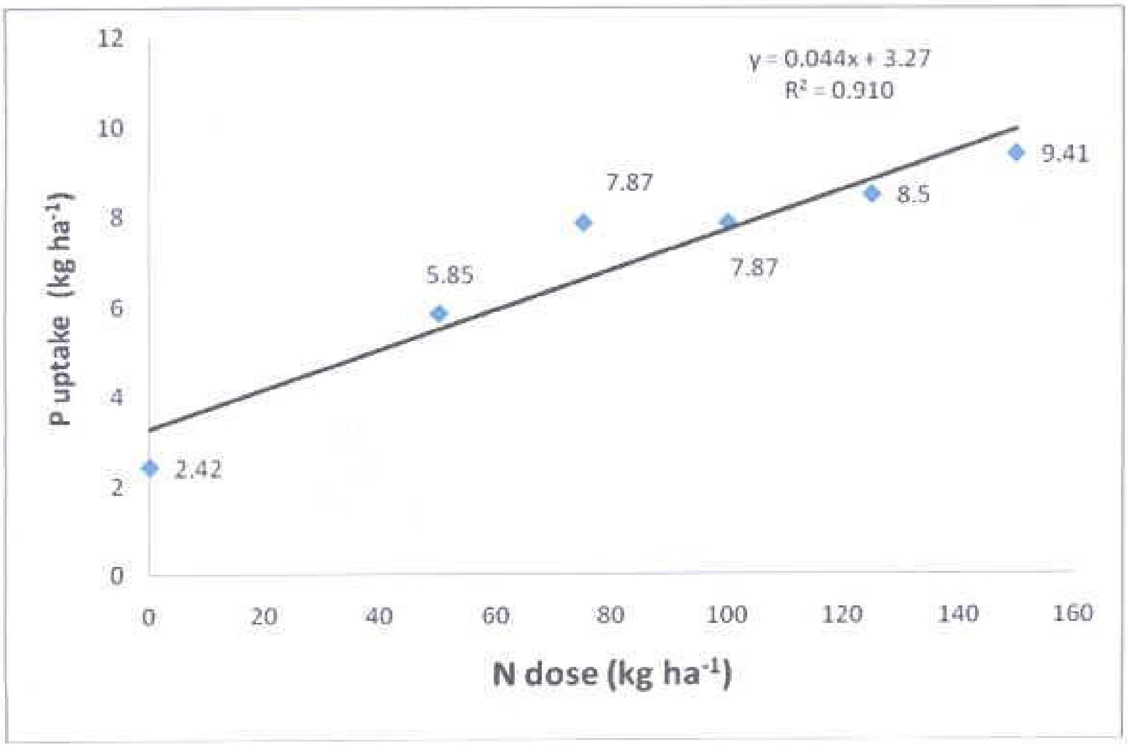

Figure 3 : Relationship between N dose and P uptake

4.15. 4. K uptake and N dose

The relationship between K uptake and applied N dose is shown in Figure 4. From regression line, it was evident that the relationship between K uptake and applied N doses was positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations. Further K uptake trend was similar to those of N and P uptake. In experiments with amaranths, similar results were also reported by Roy (2008).

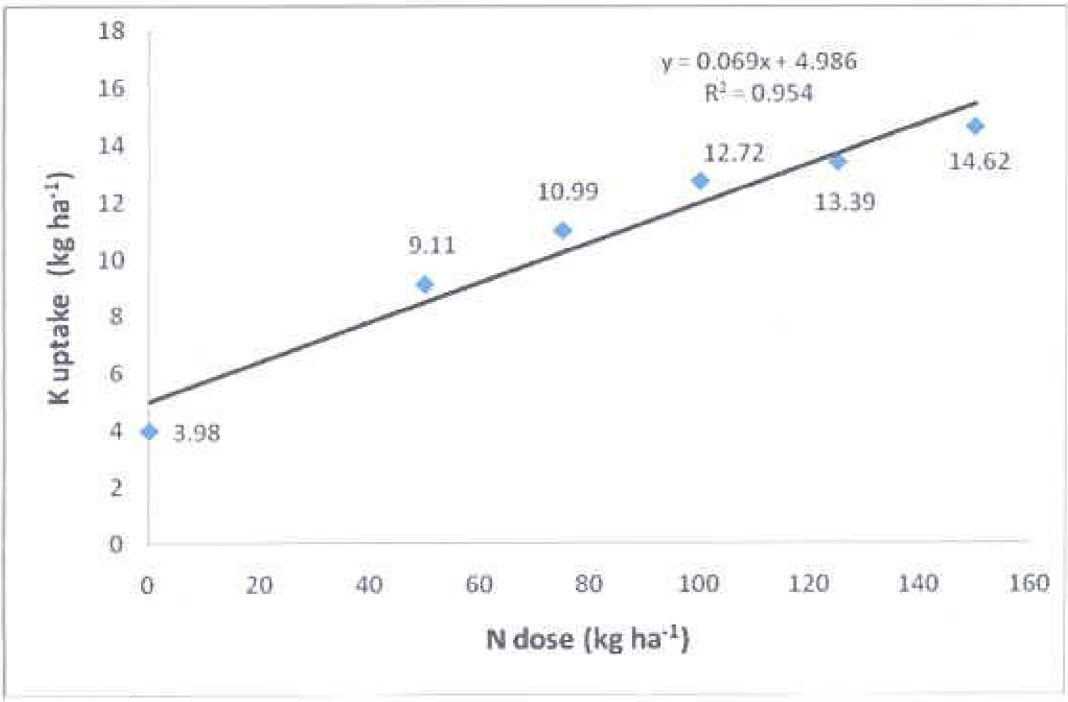

Figure 4 : Relationship between N dose and K uptake

4.15. 5. S uptake and N dose

The relationship between S uptake and applied N dose is displayed in Figure 5. From regression line, it was clear that S uptake increased up to T_5 (150 kg N ha^{-1}) application. So the relationship between S uptake and applied N doses was positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations and pattern of S uptake was similar to those of N, P and K uptake. In experiments with amaranths, similar results were also reported by Mahideen et al., (1985) and Roy (2008).

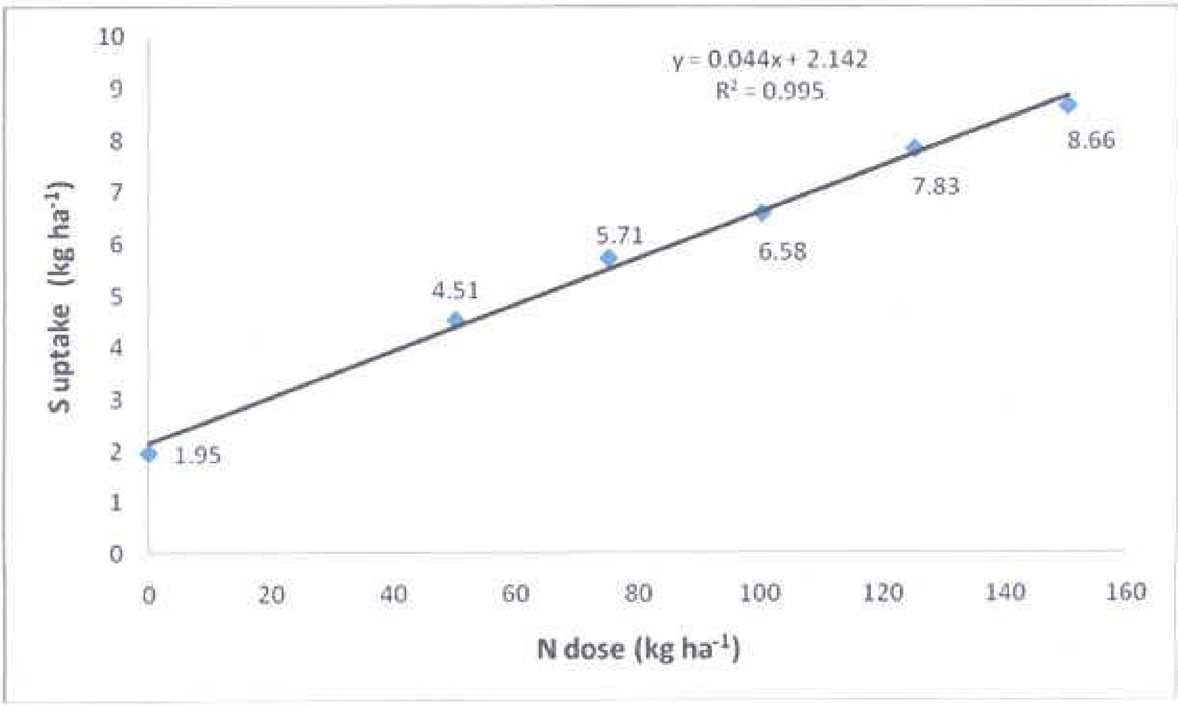

Figure 5 : Relationship between N dose and S uptake

4.15. 6. Ca uptake and N dose

The relationship between Ca uptake and applied N dose is presented in Figure 6. From regression line, it was clear that Ca uptake increased up to T_5 (150 kg N ha^{-1}) application. Thus applied N doses was positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations and pattern of Ca uptake was similar to those of N, P, K and S uptake. In experiments with amaranths, similar results were also reported by Mahiden et al., (1985) and Roy (2008).

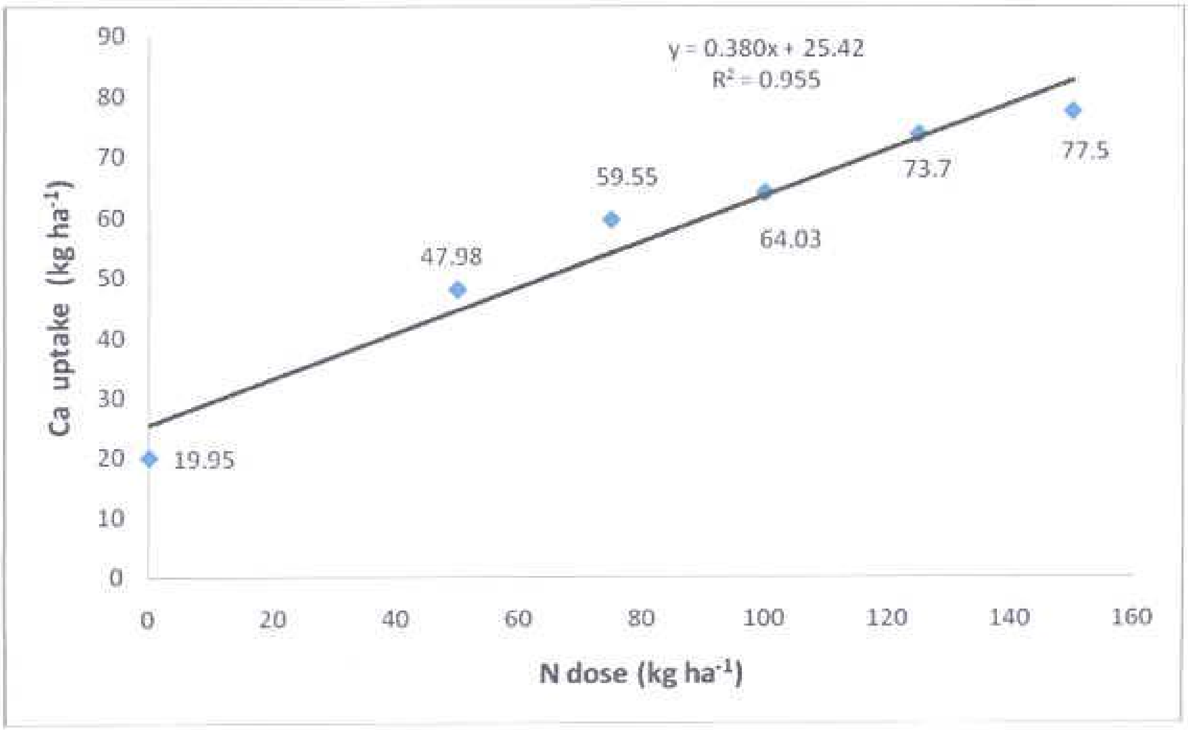

Figure 6: Relationship between N dose and Ca uptake

4.15. 7. Mg uptake and N dose

The relationship between Mg uptake and applied N dose is shown in Figure 7. From regression line, it was clear that Mg uptake increased up to T_5 (150 kg N ha^{-1}) application. So the relationship between Mg uptake and applied N doses was positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations and pattern of Mg uptake was similar to those of N, P, K, S and Ca uptake. In experiments with amaranths, similar results were also reported by Mahiden *et al.*, (1985) and Roy (2008).

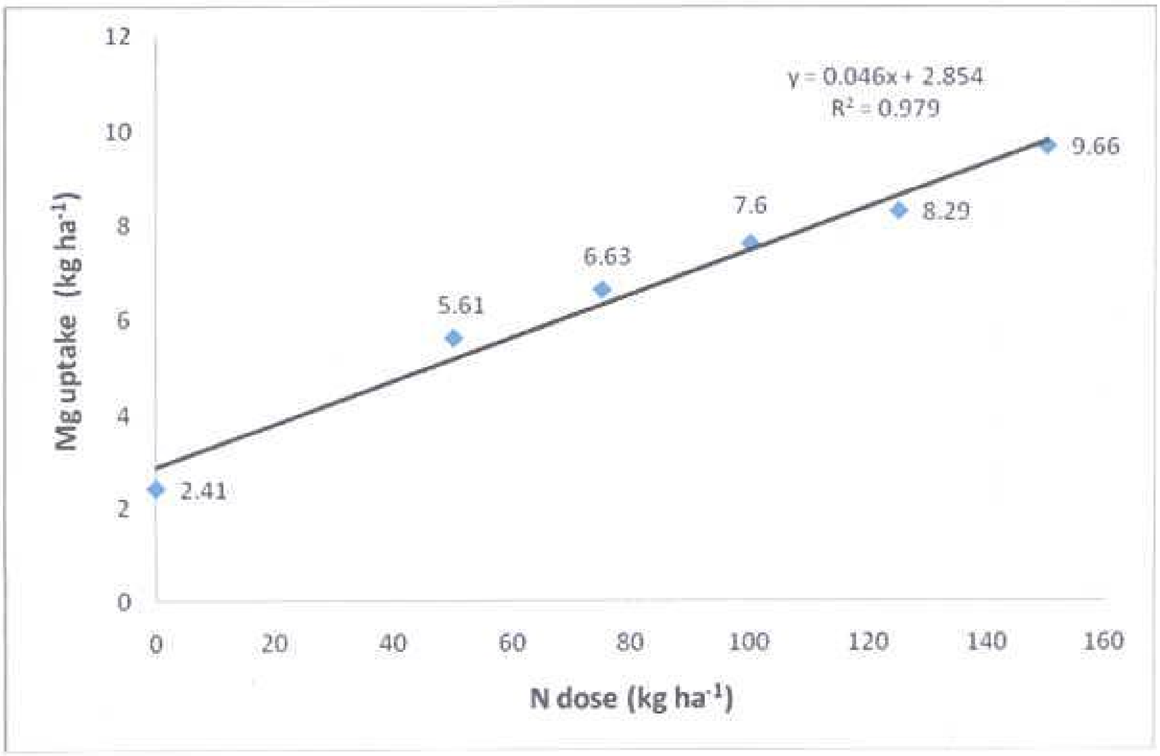

Figure 7 : Relationship between N dose and Mg uptake

4.15. 8. Fe uptake and N dose

The relationship between Fe uptake and applied N dose is shown in Figure 8. From regression line, it was clear that Fe uptake increased up to T_4 (125 kg N ha^{-1}) application. After that there was a decline in Fe uptake with the increase in N doses. So the relationship between Fe uptake and applied N doses was not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations and pattern of Fe uptake was dissimilar to those of N, P, K, S, Ca and Mg uptake. In experiments with amaranths, similar results were also reported by Roy (2008).

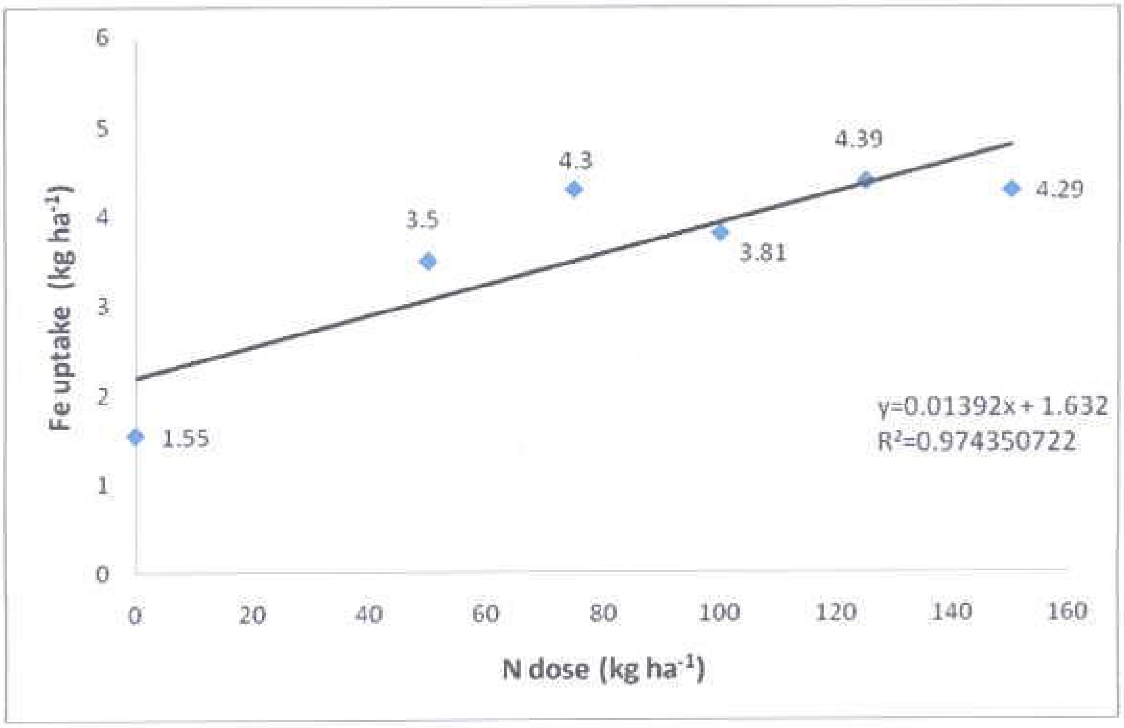

Figure 8 : Relationship between N dose and Fe uptake

4.15. 9. Zn uptake and N dose

The relationship between Zn uptake and applied N dose is presented in Figure 9. From regression line, it was clear that Zn uptake increased up to T_3 (100 kg N ha^{-1}) application. After that there was a decline in Zn uptake. So the relationship between Zn uptake and applied N doses was not positively correlated with all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations and pattern of Zn uptake was dissimilar to those of N, P, K, S, Ca, Mg and Fe uptake. In experiments with amaranths, similar results were also Roy (2008).

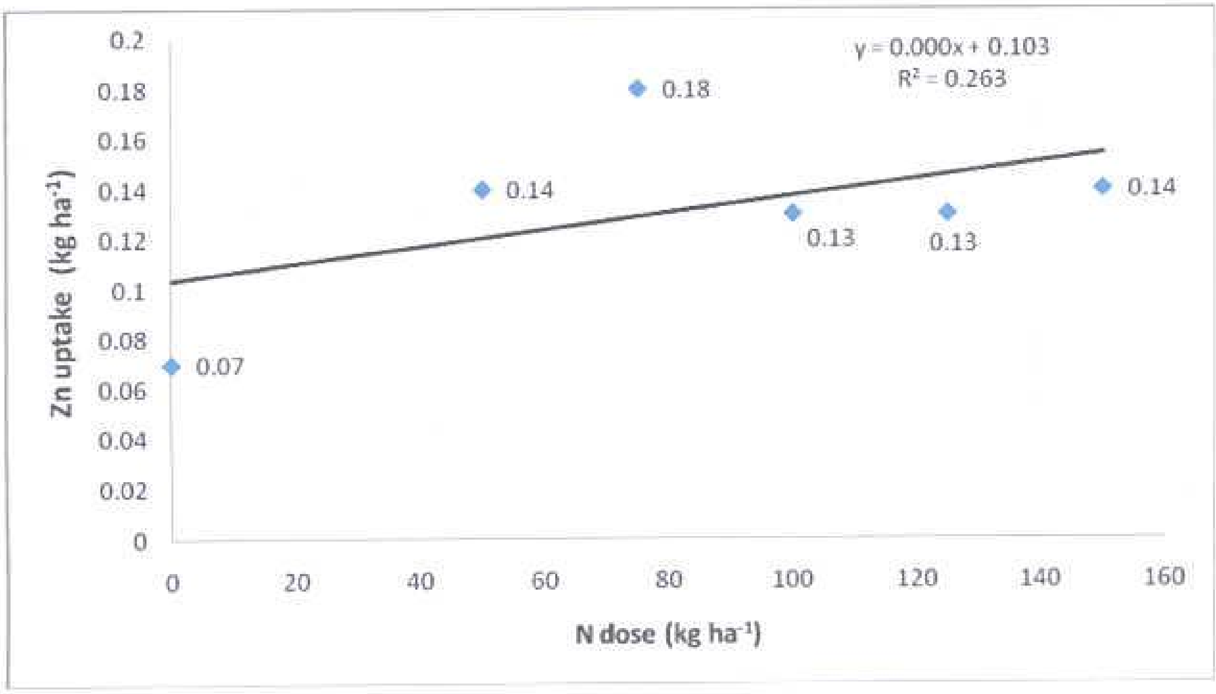

Figure 9 : Relationship between N dose and Zn uptake

CHAPTER V

SUMMARY AND CONCLUSIONS

The study was conducted at the farm of BSMRAU, Gazipur during the period of November to December, 2010 to enhance the production of red amaranth (BARI lalshak 1) through the improvement of growth and yield by optimizing the appropriate levels of nitrogen fertilizer.

The experiment was laid out in a Randomized Complete Block Design (RCBD) comprising six treatments with four replicates each. The treatment combinations were T_0 (0 kg N ha^{-1}), T_1 (50 kg N ha^{-1}), T_2 (75 kg N ha^{-1}), T_3 (100 kg N ha^{-1}), T_4 (125 kg N ha^{-1}) and T_5 (150 kg N ha^{-1}), respectively. Amounts of N, P, K and S applied from urea, TSP, MOP and gypsum were 68, 23, 17 and 4 kg ha^{-1}, respectively on being calculated by the methods of BARC (2008). Plants were harvested after 45 days of dibbling. After harvest, data on different plant parameters namely, plant height, leaf number, leaf breadth, leaf length, root length, shoot diameter, fresh and dry weight of root and plant, yield (ha^{-1}), N, P, K, Ca, Mg, S and Fe accumulation both in root and shoot followed by their uptakes were recorded. Additionally, relationship among various N doses (kg ha^{-1}), yield (t ha^{-1}) and N, P, K, Ca, Mg, S, Fe and Fe uptake were studied followed by economic analysis. The data were statistically analyzed and their means were evaluated by LSD (Least Significant Difference). Highest plant height (25.93 cm), leaf number (24.66) along with widest leaf breadth (5.41 cm) and longest leaf length (7.46 cm), longest root length (6.48 cm), highest shoot diameter (3.94 cm) and dry root weight (0.091 g plant $^{-1}$) were recorded in T_5. Highest fresh weight (12.07 g plant $^{-1}$), and yield (3.33 t ha^{-1}) were also recorded in T_5. But highest fresh dry root weight (0.96 g plant $^{-1}$) was recorded in T_4. However, plant height, leaf number along with length, breadth and shoot diameter encompassing fresh weight and dry weight of root, yield, accumulation of N, P, K, Ca, Mg, S, Fe and Zn both in root and shoot accompanied with their uptakes in all of T_0, T_1, T_2, T_3 , T_4 and T_5 were statistically significant ($p<0.01$). As regards of nutrient accumulation in shoot, highest N content (5.11 %) was recorded in T_5 followed by T_2 (4.96 %), T_1 (4.74%), T_4 (4.65%), T_0 (4.68%) and T_3 (3.08 %), respectively. As for P content, highest (0.32%) was observed in T_2 with a rugged accumulation pattern. Mean while, K accumulation also showed a rugged pattern with highest K (0.46 %) recorded in T_1 and T_3, respectively with the lowest (0.44%) in T_5. In case of Ca accumulation, highest (2.46 %) was quantified in T_2 and T_4 with the lowest (2.28%) in T_0. Accumulation patterns of Mg, S and Fe, in all of T_0, T_1, T_2, T_3, T_4, and T_5 were statistically identical. However, as for Zn, highest (83.66 ppm) was found in T_5 with that of the lowest (41.66 ppm) in T_0 showing. Mean while, accumulation patterns of N, Ca and Zn were significant ($p<0.01$) in all of T_0, T_1, T_2, T_3, T_4, and T_5 treatment combinations.

On the contrary, for root, a significant ($p<0.01$) N accumulation pattern with the highest N (2.95%) in T_4 was noticed in all of T_0, T_1, T_2, T_3, T_4, and T_5 treatment combinations. Simultaneously insignificant P and K accumulations coupling highest P (.21%) and K (0.47%) in T_2 and T_5 treatments were observed. Relevantly insignificant S and significant ($p<0.01$) Ca accumulations were recorded. The highest S (0.25%) and Ca (1.43%)

determined in T_3 and T_0 treatment combinations. However, Mg and Fe accumulations were statistically identical. Mean while Zn accumulation with the highest (72.00 ppm) in T_4 was significant ($p<0.01$) in all of T_0, T_1, T_2, T_3, T_4, and T_5 treatment combinations.

. As for nutrient uptake, all of N, P, K, S, Ca, Mg, Fe and Zn with the highest N (170.45 kg ha^{-1}), P (9.41 kg ha^{-1}), K (14.62 kg ha^{-1}), S (9.66 kg ha^{-1}), Ca (8.66 kg ha^{-1}), Mg (77.50 kg ha-^{1}) and Zn (0.18 kg ha^{-1}) recorded in T_5 showed a significant ($p<0.01$) uptake pattern in all of T_0, T_1, T_2, T_3, T_4, and T_5 treatment combinations. But Fe uptake was significant in all of T_0, T_1, T_2, T_3, T_4, and T_5 treatment combinations with the highest (4.39 kg ha^{-1}) in T_4. Focused on benefit cost ratio (BCR), highest BCR (3.66) was found in T_4 with that of the lowest BCR (1.40) in T_0.

The results indicated that N doses had a positive impact on the growth parameters of red amaranth like plant height, leaf number, fresh and dry weight of plant. Additionally applied nitrogen had also significant effect on N, P, K, Ca, Mg, S, Zn and Fe accumulation both in root and shoot followed by highest red amaranth yield (3.33 t ha^{-1}) in T_5. Noticeable fact was that significant ($p<0.01$) N, P, K, Ca, Mg, S, Zn and Fe uptake was found in T_5. But highest (4.39 kg ha^{-1}) Fe uptake was found in T_4. Even BCR was highest (3.66) in T_4 followed by BCR (3.64) in T_5. Based on data obtained from the current investigation it can therefore be concluded that increasing nitrogen doses played an important role on the growth, nutrient accumulation and yield of red amaranth. But comparative results of various parameters studied in the present investigation suggested that T_5 was the best treatment because yield was highest (3.33 t ha^{-1}) in T_5 and related

BCR in both of T_4 and T_5 treatment combinations were 3.66 and 3.64, respectively with no considerable difference.

However, the present study was conducted in winter season of 2010 at BSMRAU research farm only. Therefore, recommendation of T_5 (N 150 kg ha^{-1}) as fertilizer dose necessitates both regional and multi location trials. Finally, data based findings on growth parameter, nutrient accumulation and yield followed by BCR suggest that treatment T_5 had the potentials to be recommended as suitable N dose for red amaranth cultivation. Moreover, this study highlighted the possibility of conducting physiological experiment. Namely, it would be interesting for one to see what type of relation exists between N content and that of the gross protein in plant parts when red amaranth is grown with T_5 as sole N source because both N accumulation and uptake were high in T_5. Additionally, this finding also revealed that further experiments on red amaranth production with 150 kg N ha^{-1} should be conducted to verify the whether the application of N at 150 kg could sustain its productivity or not when tried at multi location as the experiment was carried out in one season and only in one location namely at BSMRAU farm.

CHAPTR VI

REFERENCES

Ali, M.M., Shaheed S.M., and Kubota A. 1997. Soil degradation during the period of 1997-1995 in Agriculture Research, New Dehli, 3-5.

Agele, S. O., Adeosun, S. and Oluwader, D. 2004. A lysimeter study of nutrient release, leaching losses and growth responses of amaranths resulting from the application of organic and inorganic nitrogen sources. Environ. Helsinki, Finland ; World Food Ltd., **2**: 301-306.

Anon, 1989. Annual weather report. BSMRAU, Meteorological station, Gazipur, Bangladesh.

Anon, 1997. Fertilizer Recommendation Guide published by BRAC, Dhaka, Bangladesh.

Ara, R. 2005. Effect of nitrogen and harvesting frequencies on yield and quality of spinach. MS Thesis, Dept. of Hort., BSMRAU, Gazipur, Bangladesh.

Babu, B.T.R. and Reddy, V.C. 2000. Effect of nutrient sources on growth and yield of direct seeded rice. Crop Res. Hisar. 19(2): 189-193. Bangaladesh. II Selected chemical characters. *Soil Sci. Plant Nutr.*, **43**: 879-890.

Bangladesh Agricultural Research Council (BARC), 2008. Fertilizer Recommendation Guide, BARC, Farm gate, Dhaka, Bangladesh.

BBS, 2010. Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Burea of Statistics. Statistics Division, Ministry of Bangladesh. Dhaka, Bangladesh, pp. 100-109.

Begume, R.A. 2005. Assesment of water and soil pollution and its impact on rice and amaranth.

Black, G. R. 1965 a. Bulk Density. In "Methods of Soil Analysis". Part I, Ed. C. A. Black. Am. Soc. Agron., Madison, USA, Wisconsin, pp. 374-390.

Brammer, H. 1978. Soils of Bangladesh. In "Soils and Rice". Manila, The Philippines, The Rice, 35-55.

Carson, E. W. 1974. Plant roots and its environment. pp. 507-525, Univ. Press of Virginia, Charlottesvile, USA.

Chaudhury, B. 1967. Vegetables. National Book Trust: NewDelhi. India. pp. 195.

Choudhury, A. R., Rashid, M. M., Hossain, A. 1974. A study on the effect of different spacing and nitrogen levels on the yield of spinach. *Bangladesh Horticulture*, **2**: 39-43.

Day, P.R. 1965. Particle fractionation and particle size analysis. In "Methods of Soil Analysis". Part I, Ed. C. A. Black. Am. Soc. Agron., Madison, USA, Wisconsin, pp. 562.

El-Shinway, M. Z., Hadid, A. L. and Tuncay, O. 1999. The use of organic of manure for lettuce plants grown under NTF condition. Proc. Intl. Symp. on green house management for better yield and quality in mild winter climates, Antalya, Turkey, 491: 315-318.

Food and agriculture Organization (FAO). 1972. Food composition table for use in East Asia. UN and US Department of Health, Education and Welfare. pp. 11-15.

Freeze, B.S., Webber, C. Landwall, C.W. and Domar, J.F. 1993. Risk simulation of the economics of manure application to restore eroded wheat crop land *Can. J. Soil. Sci.*, **73**: pp. 267-274.

Gomez, K.A. and A.A. Gomez. 1984. Statistical Procedure for Agricultural Reaserch, John Willey and Sons, New Uork.

Grunhage, L. and Jagar, H. 1985. Effect of heavy metal on growth and heavy metal contents of Allium porrum. *Angew botanic,* **59**: 11-27.

Gupta, R.P., Sharma, V.P. Singh. D.K. and Srivastava, K.J. 1995. Effect of organic manures inorganic fertilizers on growth, yield and quality of onion variety Agrifound Dark Red. News Letter National Hort. Res. Dev. Foundation. **19** (2-3): 7-11.

Hamid, M.M., N.U. Ahmed and S.M.M. Hossain. 1989. Performance of some local and exotic germplasm of amaranth. *Agril. Sci. Digest* **9**: 202-204.

Hanson, J. B. 1984. The function of calcium in plant nutrition. In "Advances in Plant Nutrition". Praeger, New York, pp. 149-208.

Hossain, S.I. 1996. A comparative study on yield and quality of some *Amaranth* genotype. MS thesis, IPSA, Salna, gazipur, pp. 41-44.

Huihe, Li, Wange-Zhengyin, Zhang-Hao, Li-Baozhen, Li-H.H., Wang, Z.Y. Zhang, H., Li, BZ. 2003. Effect of organic manures on the nutritional quality of foliage vegetables in soilless culture. *J. Southwest Agril. Univ.* **25** (1):66-69.

Jackson, M.L. 1958. Soil Chemical Analysis. Prantice hall of india Pvt. Ltd., p538.

Jackson, M.L. 1973. Soil Chemical Analysis. Prantice hall of india Pvt. Ltd., p498.

Jingxue, Y. E., Wu, C., Shen, L., Xang, X., Zhang, G., and Song, Y. 2004. Effect of combined aplication of organic manure and fertilizer on Chinese cabbage yield and quality. *J. Jillin. Agric. Univ.*, **26**: 155-157.

John, M. K. 1970. Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Sci.*, **109**:214-220.

Karim, Z., M., Miah, M. U. and Razia, S. 1994. Fertilizer in the national economy and sustainable environmental development. *Asia Pac. J. Environment Dev.*, **1**: 48-67.

Kirkby, K and Mengel, E. A. 1986. The role of magnesium in plant nutrition. Z. Pflafanzenernaher, Bodenkd, **139**: 209-222.

Latiff, M. A. and Maraiker, S. 2003. Studies on the performance of some vegetable crops in organic farming system. Annals of the Srilanka, Dept. of Agri., **5**:141-146.

Mahideen, M.K., Subramanian, A. S. and Raagopal, A. 1985. Effect on transplanting on growth, flowering and seed yield in amaranthus (*Amaranthus spp*). *South Indian Hort.* **23**: 87-90.

Marschner, H. 1990. Mineral nutrition of higher plants. Academic Press, London. pp195-269

Materechera, S.A. and Mukwevho, T.N. 2007. Response of leaf Amaranth (*Amaranthus cruentus*) to nitrogen from chicken manure and defoliation frequency in a semi- arid environment of South Africa Crop Science Department, North-West University (Mafikeng Campus), Mmabatho, South Africa. *Acta-Horticulturae*. 2007; **752**: 499-504

Mengel, K. and Kirkby, E. A. 2001. Principles of plant nutrition. pp. 213-234.

Monira, U. M. 2007. Nutrient status in tomato grown on organic manure treated soil. MS thesis, Dept. of Soil Science, BSMRAU, Salna, Gazipur.

Munson, R. D. 1998. Principles of plant analysis. In Hand Book of Reference Methods for Plant Analysis. Kalra, Y. P (ed), Soil and Plant Analysis Council. CRC Press, pp. 1-24.

Muthukrisna, C.R. and I. Irulappan. 1986. Amaranthus. p. 670-679. In: T.K. Bose and M.G. Som (eds.) Vegetable crop indian. Naya Prokash, Calcutta-Six. India.

Nuruzzaman, M., S.M. Ullah, A. Islam, S. Rahman and H. Rashid. 1993. Effect of industrial waste on soil properties and crop growth. Regional workshop on "Environmental impacts from fertilizers, Agrochemicals and industrial wastes. Under the project Chemical Research Needs (REN)".

Olsen, S. R. 1965. Methods of Soil Analysis. Part I, Ed. C. A. Black. Am. Soc. Agron., Madison, USA, Wisconsin, p1035.

Page, A.L., Miller, R.H. and Keeney, D. R. 1982. Methods of Soil analysis. Part 2, American Soc. Agron., Inc. madi, USA.

PCARR (1983), Philippine Council of Agriculture and Resources Research.

Piper, G. 1966. Soil and Pant Analysis. Adelaide University Press, Australia.

Rajgopal, A., C.R. Muthukrishan, M.K. Mohideen and S. Syed. 1977. 2 amaranths-An early vigorous variety. *South Indian J. Agric. Sci.* **50(2)**: 183-186.

Rauf, M. A., Karim, A. J. M., Zpoebich, S., and Hassan, J. 2009. Potential of industrial sludge as a source of nitrogen and its partitioning, uptake and its use efficiency in red amaranth. *Intl. J. Bio Res.*, **7**: 474-480.

Reddy, V.C., Ananda, M.G. and Murthy, K.N.K. 2004. Effect of different nutrient sources on growth and yield of paddy (Oryza sativa L.). *Environ . Ecol.* **22**: 622-626.

Rodrihues, E. T. and Casali, V. W. 1998. Response of lettuce to organic fertilizer. II-Concentration, content and utilization of macronutrients in cultivars. Revesta Ceres, **45**: 437-447.

Roy, P. K. 2008. Effect of organic manures on growth and yield in stem amaranth. MS thesis, Dept. of Soil Science, BSMRAU, Gazipur.

Shahidullah, M., Karim, M. Islam, K. R., Das, U. K and Chaudhury, K. 1997. Effect of age of plants on nutrient content of three vegetables. *Bangladesh J. Sci. Inds., Res.,* **32**: 212-215.

Shanmugavelu, K.G. 1989. Amaranthus. In: production Technology of vegetables Crops. Oxford and IBH Publishing Co Pvt. Res. Cent. USDA, Albary, California, USA.

Singh, H., Singh, S. and Sing, V. 1996. Research of onion to nitrogen and sulphur. *Ann. Agric. Res.* **17**:441-444.

Suchoroska, J. 1992. Effect of fertilizer with Nowmin on the yield and quality of vegetables cultivated in rotation. Rozpray, Akademica rolnica, W. Szezeccicinic,, **142**: 109-172.

Talukder, M.S.A. 1999. Effect of plant density on green yield and seed production in different Thesis, BSMRAU, Salna, Gazipur.

Teutonico, R.A and D. Knorr. 1985. Amaranth composition, Properties and application of a reddish covered food crop: Food technology. **39**: 49-61.

Walkey, A. and Black, A.L. 1935. An examination of the different method for determining soil organic matter and a proposed modification of the chronic and titration method. *Soil Sci.* **37**: 29-38.

Wasem, K. and Nadeem, A. 2001. Enhaance of spinach production by varying sowing dates, row spacing and frequencies of cuttings. On line J. Bio. Sci., Asian Network for Scientific Information, **1**: 92-94.

Yamazaki, H. and Roppongi, K. 1998. The effect of organic matters application for leaf vegetable yield and quality. Bulletin of the Saitama Hort. *Expet. Stn.* **21**: 7-20.