SPINACH GROWTH IN RESPONSE TO NITROGEN FERTILIZATION

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CERTIFICATE

This is to certify that the thesis entitled "SPINACH 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 *bona fide* research work carried out by MD. MAHBUBUL ALAM, Registration. No. 04-1408, 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

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ABSTRACT

The study was conducted at the farm of BSMRAU, Gazipur during the period of November to December, 2010 to enhance the production of spinach (*Beta vulgaris* cv. BARI spinach 1) through the improvement of growth and yield of spinach 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 (1 50 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 $ha\text{-}^{1}$, 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 has a positive effect on the short term growth and yield of spinach. Further relationship found between N, P, K, S, Ca, Mg, Fe and Zn uptake and applied N doses followed by the study of highest BCR (benefit cost ratio) indicated that nitrogen fertilizer applied at the rate of 75 kg N ha^{-1} has a better potential for the production of spinach.

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CHAPTER I

INTRODUCTION

Spinach (*Beta vulgaris* cv. BARI Spinach 1) locally called *palong sak* is an annual dioecious plant belonging to the family Chenopodiaceae. Spinach is one of the most important highly nutritious green leafy winter vegetables grown in Bangladesh on a large scale (Rashid, 1999). In general for spinach, the area of production and total yield are 5668 ha and 27000 metric tons (MT), respectively (Anon., 1998). Though spinach is a winter crop it may be grown through out the year (Ahmed, 1995).

The leafy vegetables are emphasized in every plan for better nutritional standards, and spinach and cabbage are the leaders among those that are cooked. Spinach ranks high in minerals and vitamins (Work, 1997). Spinach is a very rich source of vitamin A (9000 – 10000 IU/100 g). It also contains appreciable amount of vitamin C (30 – 60 mg/100 g) and iron (10 – 16 mg/100 g) (Rashid, 1999). Hundred (100) g leaves supply as much essential amino acids as 100 g of any non-vegetarian food like meat and fish as reported by Nath (1976). Spinach also has some medicinal values (Pandita and Lal, 1993). Considering its potentialities spinach is a major vegetable crop but it is still a less advanced crop.

Bangladesh today is almost self-sufficient in matter of food grains. However, self-sufficiency in the true sense can be achieved only when each individual of the country is assured of balanced diet. Fruits and vegetables are the only natural sauces of protective food as they supply nutrients, vitamins and minerals. The annual production of vegetable is 1.56 million tons (Anon., 1998), which is far below its actual requirement of 8.13

million metric tones. The average per capita vegetable consumption in Bangladesh is only 50 g, against the FAO recommendation of 200 g (Anon., 1991) which is the lowest among the countries of South and South East Asia (Rekhi, 1997). There is a big gap between the need and supply of vegetables in Bangladesh. The shortage of vegetables is about 6.83 million metric tons (Anon., 1998). As in a developing country, malnutrition is a common feature of Bangladeshi people. Thousands of children of this country die annually because of malnutrition. Availability is the major constraint of consumption and the availability of vegetables may be increased by enhancing production and minimizing post harvest losses.

Palong sak is a leafy vegetable which requires more of nitrogen for crown (leaves) growth and higher yield (Pandita and Lal, 1993). The yield is closely related to available nitrogen and it was increased by applied nitrogen in combination with potash (Cervato 1969 and Stanilova *et al.* 1972). Nitrogen application also influenced the yield of spinach under saline condition (Pandita and Lal, 1993).

The quality of spinach is also influenced by fertilization. Nitrogen application increased the protein, β-Carotene, reducing sugars, ascorbic acid (Pandita and Lal, 1993) and oxalic acid contents in spinach (Leskove and Dobersekurbance, 1972; Macreke, 1973).

In Bangladesh, 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 meristematic activity when applied in optimum quantity. Available data indicate that the fertility of most of our soils has been deteriorated over years (Kader, 1992 and Anelli *et al.*, 1985) which is responsible for stagnation and in some cases, even decline crops yield (Cervato, 1969). 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).

So economically beneficial, technically sound and eco-friendly use of nitrogen fertilizers is needed to minimize the environmental risks and to secure the optimal physical, chemical and biological properties of soil for crop production as well. These facts suggest that there is ample scopes of increasing spinach yield per unit area with appropriate use of nitrogen fertilizers. Thus the economic and eco-friendly use of nitrogen fertilizers particularly urea encompassing the profitable vegetable yield and unacceptable loss to the soil environment is a long waited demand both in agriculture and horticulture. Aside, information on the use of urea doses with particular reference to short term spinach cultivation under diversified agro-climatic conditions is not well developed so far. So the objectives of the current investigation were as follows:

1. To measure the variations in plant height with different nitrogen doses during the growing period
2. To quantify the yield of spinach related to short term growth period
3. To determine the nutrient accumulation in leaves, stem and root of spinach

CHAPTER II

REVIEW OF LITERATURE

Studies on growth, yield, and nutrition of spinach have been conducted in different parts of the world. Among the research works on nutrition relevant to short term growth and yield of spinach against nitrogen fertilization is scanty so far. Some of the information relevant to the study is cited in this chapter under the following headings.

2.1 Nitrogen and the yield and yield contributing characters of spinach

As spinach is a leafy vegetable it requires more nitrogen for crown (leaves) growth. Various recommendations on maturing and fertilization have been made by different workers. According to Pandita and Lal (1993) the average leaf yield of spinach rose with increasing N rate from 20.4 ton/ha at zero N to 41.2 ton/ha at the highest N rate of 90 kg/ha as urea.

Pandia and Lal (1993) reported that in cultivar Dark Green Bloomsdale and Matador, application of N as calcium ammonium nitrate with PK basal dressing at 100:100 kg/ha increased yield with increasing N rates to 150 kg/ha and then in some cases it declined.

Thompson and Doerge (1995) conducted three field experiments using subsurface trickle irrigation with various rates of target soil water tension (SWT) and N fertilizer application during 1990-93. The experiments were conducted with the leafy vegetables collard [Kale] cv. Vates, mustard (Brassica juncea) cv. Southern Giant and spinach cv. Indian summer. The interactive affects of water and N treatments on crop yield, N uptake and unutilized fertilizer N were studied. Yields of all crops increased with increasing rate of N fertilizer.

In general, excessive irrigation (SWT <5.6 kPa) resulted in reduced yields and N uptake and high rates of unutilized fertilizer N. optimum SWTs were 9 KPa for collard, 8 kPa for spinach and 6-10 kPa for mustard.

An experiment was conducted by Nashrin, *et al.*,(2002) at horticultural farm, Bangladesh Agricultural University, Mymensingh, Bangladesh to study the effect of different levels of nitrogen on the Growth and Yield of Gimakalmi, *Ipomoea retans* Poir. The experiment revealed number of leaves was significantly influenced by different levels of nitrogen applied. They reported that number of leaves increased with the increasing levels of nitrogen. The highest rate of nitrogen (60 kg N/ha) gave the highest number of leaves (158.67) and the lowest (139.03) was given by 0 N i.e., the treatment where no nitrogen was applied. Again the maximum fresh weight of leaves was obtained from the application of 60 kg N/ha and the lowest was from the control i.e., 0 kg N/ha and the lowest yield 7.13 t/ha in control where no nitrogen was applied.

The enhancement of spinach production was evaluated by varying sowing dates, row spacing and frequency of cuttings by Waseem and Nadeem (2001). The data were checked on two aspects of spinach i.e. fresh foliage yield and dried foliage yield (kg/ha). The analysis of the trial did not show any significant variations in case of different sowing dates. However, the maximum fresh foliage as well as dried weight was obtained from October sowing (2082.78 and 207.78 kg/ha, respectively) while both the other factors i.e. row spacing and different cuttings revealed significant differences for fresh and dried yield of spinach. Broadcast and third cuttings gave the highest fresh foliage yield (2157.59 and 2329.44 kg/ha, respectively). Maximum dried weight of spinach (212.37 and 222.61 kg/ha) was also obtained from these two levels.

2.2 Nitrogen and the quality of spinach

Turkott and Hejnak (2001) conducted experiment on spinach, variety Pavana F1, in micro-plot trials in neutral soil (pH > 6.5) and in acid soil (pH <4.5). They concluded that the graduated rates of nitrogen fertilization (50 and 100 kg N/ha) increased the energy contents as many as 2, 39 kJ/g of dry matter compared with control variant without nitrogen fertilizer. The total formation of dry matter during vegetative period, spinach yield and the total accumulation of net energy by spinach plants were higher in neutral soil than in acid soil. The total quantity of produced dry matter and the total accumulated energy by spinach plants increased by graduated rates of nitrogen fertilizer.

Biemond, *et al.* (1996) examined effects of nitrogen on accumulation and partitioning of dry matter of spinach cv. Trias. Greenhouse and field experiments (the latter on a sandy soil) were carried out with different amounts and dates of N application. Frequent measurements were carried out on dry matter and N accumulation in leaf blades, petioles and stems. Increasing N application increased yield of dry matter and N accumulation, whereas splitting N applications had much smaller effects. However, the partitioning of dry matter and N proved insensitive to N treatments. Harvest indices for dry matter (about 0.67) or N (about 0.74) of crops at a marketable stage were fairly constant over treatments and experiments. Increasing or splitting the N application affected N accumulation more than dry matter production resulting in large effects on N concentrations. The lack of variation in response to N for different N regimes facilitate the development of N application techniques aimed at high yield, high quality and reduced emissions. The organic N concentration of leaf blades and petioles decreased with leaf age, although in most experiments this decrease was smaller at higher leaf numbers. The nitrate-N concentration decreased with increasing leaf number at any sampling date; it was higher when N was abundant. High yields in autumn crops were associated with high nitrate concentrations but also with potentially high losses of N.

The quality of spinach is influenced by fertilization. Nitrogen application increased the protein, β-Carotene, reducing sugars (Pandita and Lal, 1993), ascorbic acid and oxalic acid (Leskove and Dobersekurbanc, 1972; Macreke, 1973) contents in spinach. Nitrogen in combination with phosphorus and potash increased dry matter, crude protein and vitamin C content in spinach as reported by Stanilova *et al.* (1972).

Spinach and komatsuna on an Ando soil were supplied with 0, 10, 15 or 30 g N/m^2. Nitrate-N contents increased with the N application rate, reaching 1.14 and 1.26 g/kg fresh weight (FW) in spinach and komatsuna leaf petioles (at harvest), respectively, with 30 g N/m^2. In both crops, sucrose content was highest with 0 g N/m^2, glucose content was highest w3ith 10 g N/m^2 and both decreased with increasing N application. Total ascorbic acid content was decreased by increasing N application, from 0.74 g/kg FW at 0 g N/m^2 to 0.51 g/kg FW at 30 g N/m^2 in spinach and from 1.00 g/kg FW at 0 g N/m^2 to 0.48 g/kg Fw at 30 g N/m^2 in komatsuna. In spinach, the total (water- soluble plus water- insoluble) oxalic acid content was increased in the leaf blades and decreased in the leaf petioles by increasing N application but whole-leaf contents were not affected. High plant sucrose and ascorbic acid contents were associated with low yield and N content and high DM content. It was concluded that in terms of crop quality, the low N application rates are preferable, but not at the expense of growth and yield (Takebe *et al.*, 1995).

Effect of nitrogen on yield and quality of spinach was studied by Anac, *et al.*, 1999. In a Turkish field trial, N was applied at 80 or 160 kg/ha. Leaf yields were highest at the higher fertilizer rater but ascorbic acid contents were higher at the lower N rater.

The effects of the absence of nitrogen and all nutrients on the contents of components related to spinach quality were investigated during the late stage of growth under hydroponics culture (Yoshida *et al,* 1998). Spinach plants were grown in a standard solution containing 100 mg NO_3-N/litre until plant height reached about 25 cm, and then transferred to either the standard solution without N (-N solution) or groundwater for 10 days. At 8 days, the sugar and ascorbic acid contents were increased about 2-4 times and 1.3-2 times, respectively compared with plants grown in the standard solution . The nitrate content decreased by 75-90% compared with that in plants in the standard solution after 8 days, but oxalic acid content was not affected. With regard to spinach quality, culture in groundwater was more effective than that in the-N solution.

Zhang, *et al.* (1990) reported the effect of nitrogen concentration in the nutrient solution on the growth and nutrient contents of hydroponically grown spinach. Spinach cv. Daidan was grown in nutrient solutions with 3.3, 5.3, 8 or 16 meq nitrate- N and 1.3 meq ammonium- N /liter. With the lowest rate of nitrate-N, FW was 10% lower than with higher concentrations, and leaves were pale in color. Ascorbic acid and sugar contents increased as nitrate-N decreased, with the total sugar content at the lowest nitrate-N rate being 1.7 times that with the highest nitrate-N rater. Nitrate and oxalate contents decreased as the nitrate-N rate decreased, with the lowest nitrate concentration being 7.8 mg/100 g FW. For production of high-quality spinach, a rater of 6.5 meq nitrate-N/litre is recommended which would give about 5% N in DM

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^{o}N latitude and 90.26^{o}E longitude) at 8.4 m above the sea level and about 40 km north of 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.

Meteorological data of the experimental area doing the period of November, 2010 to January, 2011.

Table-1. Meteorological data of the experimental area.

Month	Air temperature (^{0} C)		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 hydrometermethod 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 (1973).

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 indicator 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 HNO_3 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

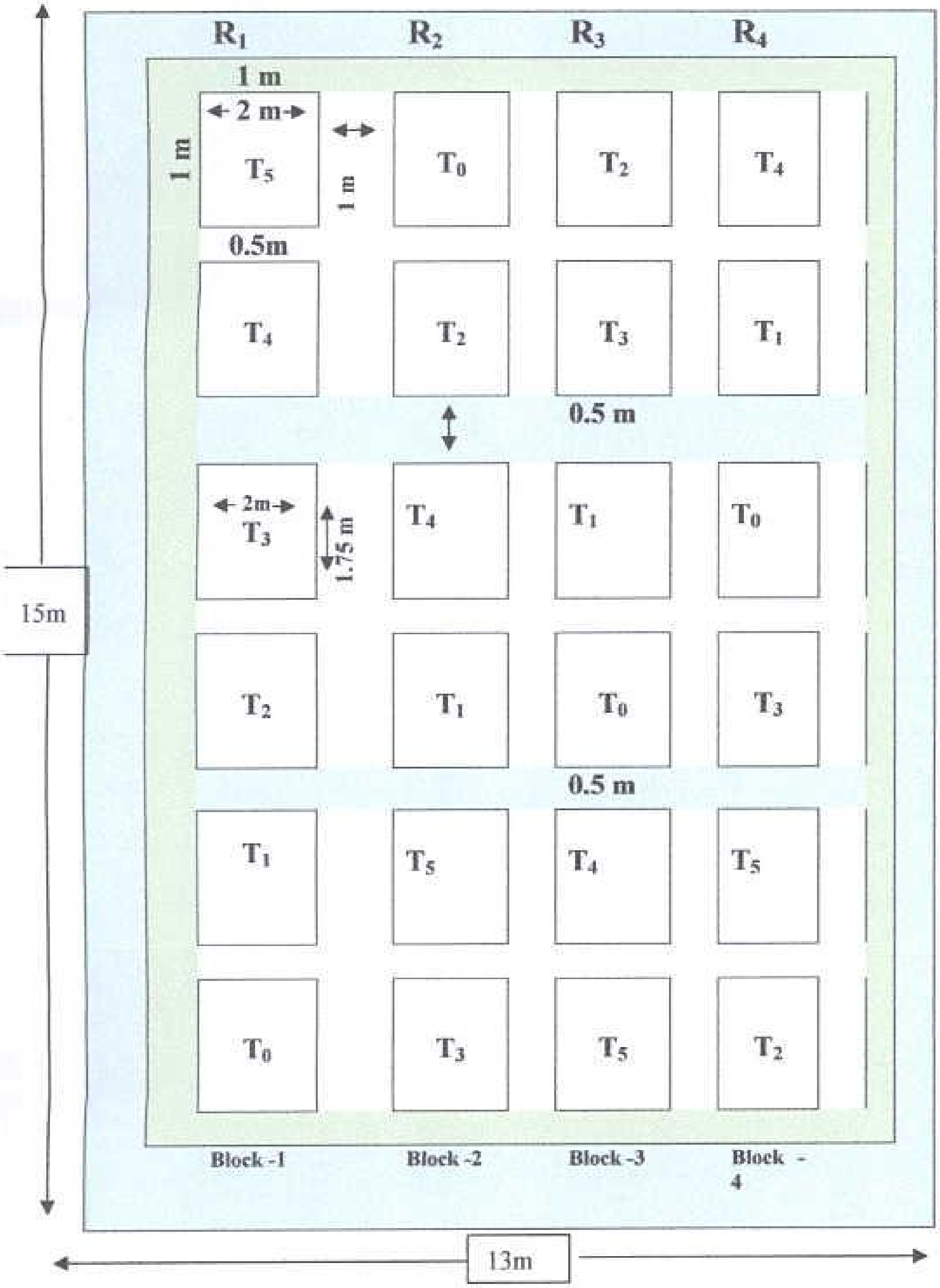
Soil characteristics	Analytical value
Soil pH (soil: water 1: 2.5)	6.1
Organic carbon (%)	0.87
Total N (%)	0.10
Available P (ppm)	12.10
Exchangeable K (meq/100 g soil)	0.56
Available S (µg/g soil)	10.02

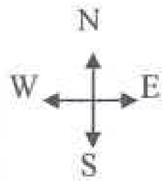
3. 6. Land preparation

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. 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. The layout of the experiment is shown in Figure 1.





Plot size: 2.m x 1.75m

Plot spacing: 0.5m

Between replication: 1.0m

Treatment:

$T_0 = N_0$ (No nitrogen dose)

$T_1 = N_{50}$ (A nitrogen dose of 50 kg ha^{-1})

$T_2 = N_{75}$ (A nitrogen dose of 75 kg ha^{-1})

$T_3 = N_{100}$ (A nitrogen dose of 100 kg ha^{-1})

$T_4 = N_{125}$ (A nitrogen dose of 125 kg ha^{-1})

$T_5 = N_{150}$ (A nitrogen dose of 150 kg ha^{-1})

Figure 1. Lay out of the experiment

3. 8. Raising of seedlings

The seeds were dibbled on 1st 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

$T_0 = N_0$ (No nitrogen dose)

$T_1 = N_{50}$ (A nitrogen dose of 50 kg N ha^{-1})

$T_2 = N_{75}$ (A nitrogen dose of 75 kg N ha^{-1})

$T_3 = N_{100}$ (A nitrogen dose of 100 N kg ha^{-1})

$T_4 = N_{125}$ (A nitrogen dose of 125 N kg ha^{-1})

$T_5 = N_{150}$ (A nitrogen dose of 150 N kg ha^{-1})

3.10. Application of fertilizers

Amount 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). Other than urea fertilizers were thoroughly mixed with soil for three days prior to seed sowing. According to treatment, five nitrogen doses were applied in three splits at 10, 20 and 30 days after sowing as top dressing.

3.11. Plant material

The plant material was Spinach (*Beta vulgaris* cv. BARI Spinach1). Common characteristics of this variety are production of uniform tender leaves, providence of multiple cuttings at 15 to 20 days interval, furnishes a heavy yield of 125 quintal green leaves and in winter, it produces seed stalk in 75 days. 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 15th 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 mean value of height randomly selected 10 plants in each plot was measured 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 randomly selected 10 plants in each plot after 45 days of sowing (DAS) in normal condition and the mean value was calculated.

3.15.3. Petiole 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. Petiole 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 after 45 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 upper, middle and lower 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, root of ten plants was washed with tap water and dried in the oven at 55^0C 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 outer 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.

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 and zinc content. 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 complexometric titration method using Na_2EDTA as a complexing agent at pH 12 where calcon was used as a 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 ferrocyanide [$K_4Fe(CN)_6.3H_2O$] and triethanol amine (TEA), ($C_6H_{15}NO_3$), as masking agent. After the addition of calcon indicator 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

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

3.17. Gross yield of plant

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.

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 5% level of probability (Gomez and Gomez, 1984) for the interpretation of results.

Chapter IV

Results and Discussion

The plant material used in the current experiment was Spinach (*Beta vulgaris* cv: BARI Spinach-1). The experiment was conducted to compare the effect of various nitrogen doses on the growth, yield, yield attributes including the nutrient concentrations and their uptake by spinach. Nitrogen dose effect was determined by gross yield of the plant.

4.1 Plant height

Spinach plants grew well during the growing period in all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments. Plant height was measured after harvest. Plant height did not differ significantly among the various treatments imposed (Table 3). However, highest plant height (17.2 cm) was recorded at T_3 and that of the lowest (11.87 cm) was measured at T4. Noticeably the highest plant height (17.2 cm) at T_3 differed significantly ($p<0.01$) from that of T_0. This finding suggested that nitrogen (N) dose at T_3 played a role on spinach growth and N doses below or above T_3 did not bring any remarkable effect on plant growth. The results also indicates that plants grown with higher nitrogen doses received higher amount of nitrogen element from the soil and thus attained higher plant height and those grown with lower nitrogen doses showed lower plant heights with the reception of lower amount of nitrogen from the soil. Similar findings were also reported by Islam et al. (1984) and Hamid et al. (1986), respectively.

4.2 Average leaf number per plant

As for Nitrogen doses, no significant effect on the average leaf number per plant was observed (Table 3). However, among different nitrogen doses, the highest average number of leaves (13.93) was obtained from T_3. All other treatments showed statistically similar performance of the various nitrogen doses applied. The lowest number of leaves (10.67) was found from T_0 (control: no nitrogen). From this result it was clear that the leaf number increases with increasing nitrogen doses and the inference is similar to those reported by Roy (2008).

4.3 Leaf breadth

In the present experiment, average petiole breadth increased with the increase in nitrogen doses (Table 3). The highest leaf breadth (6.79 cm) was found in T_5 and that of the lowest (4.92 cm) was recorded in T_0. The highest petiole breadth in T_5 differed significantly ($p<0.01$) when compared with T_0 but was statistically similar to those of T_1, T_2, T_3, T_4, respectively. Such findings are indications of nitrogen dose effect on the leaf breadth enhancement of spinach (Ara , 2005 and Roy , 2008).

4.4 Leaf length

On an average, nitrogen doses had a positive effect on the leaf length enlargement (Table 3). The longest leaf length (10.12 cm) was observed in T_5 followed by 9.58 cm, 8.79 cm and 8.70 cm in T_3, T_2 and T_4, respectively and the T_1 produced the shortest leaves (8.00 cm) in spinach. However, all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments showed statistically *identical* performance in respect of average leaf length enhancement. These findings suggested that no significant effect on the leaf length of spinach was found even at higher nitrogen doses.

4.5 Root length

The effect of different treatments on root length was significant ($p<0.01$). The highest root length (9.56 cm) was recorded in T_5 and that of the lowest (6.15 cm) was found in T_1. The highest root length in T_5 was significant ($p<0.05$) only over that of the lowest. These highest and lowest root length of spinach lie in the generalized agreement that nitrogen fertilization has a positive effect on root length enhancement. However, root length in T_0, T_1, T_2, T_3, T_4 showed statistically identical performance (Table 3).

4.6 Shoot diameter

As shown in Table 3, shoot diameter in spinach varied significantly ($p<0.01$) in respect of the various nitrogen doses imposed. Namely, the highest shoot diameter (3.18 cm) was obtained in T_5 and that of the lowest (2.27 cm) was measured in T_0. Based on the shoot diameter recorded, one could say that different nitrogen dose induced variable shoot diameter indicated that nitrogen doses had a considerable effect on shoot diameter enlargement.

4.7 Fresh and dry root weight

There was no significant effect of different treatments on the production of fresh and dry root weight of spinach, respectively (Table 4). As for fresh weight, the highest value (1.23 g) was observed in T_5 and that of the lowest (0.67 g) was recorded in T_0. All of T_0, T_1, T_2, T_3, T_4 and T_5 treatments showed statistically identical performance in respect of fresh weight production. A similar trend of dry weight production was found in all of T_0, T_1, T_2, T_3, T_4, T_5.

Table 4: Effect of N on vegetative growth of spinach

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	11.87	12.05	4.92	8.70	6.35	2.27	0.67	0.15
T_1	15.83	13.15	5.16	8.00	6.15	2.45	0.90	0.14
T_2	14.86	11.87	5.67	8.46	6.17	2.85	0.95	0.15
T_3	17.26	13.93	5.39	9.58	6.74	2.92	0.88	0.14
T_4	14.59	10.67	5.97	8.79	7.51	2.65	0.85	0.14
T_5	14.72	12.30	6.79	10.12	9.56	3.18	1.23	0.15
CV (%)	14.73	13.48	11.83	19.54	21.08	12.64	1.59	6.70
LSD	4.046	3.022	1.216	3.180	2.722	0.625	2.294	0.057
Level of significance	**	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

4.8 Fresh and dry plant weight

The effect of different treatments on plant fresh weight was significant ($p<0.01$). As shown in Table 5, highest plant height (13.42 g) was measured in T_5 that was statistically significant to all other treatments of T_0, T_1, T_2, T_3, T_4 respectively. Conversely, lowest plant height (7.10 g) was recorded in T_0. These sorts 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 an influence on the increase in plant dry weight too. Namely, a similar trend of highest (1.10 g) and lowest (0.660g) dry weights were recorded in T_5 and T_0 treatments, respectively. However, such nitrogen dose effect on plant dry weight was not significant (Table 5).

4.9 Yield /plot

Data as shown in Table 4, yielded significant ($p<0.01$) results on spinach yield per plot. Spinach yield per plot increased with the increase in nitrogen dose vide T_1, T_2, T_3, T_4 and T_5, respectively. The maximum yield (1493.33 g) per plot was found in T_5. Sequentially, the next measured highest yields 1366.67, 1200, 866.67, and 480.0 g per plot were observed in T_4, T_3, T_2 and T_1, respectively. However, the minimum yield (275.00 g) was recorded in T_0 (Table 4).

4.10 Yield /hectare

Yield of spinach was positively influenced by various treatments (Table 5). However, variation among the treatments corresponding to spinach yield per hectare was not significant. Generalized trend observed for yield was that yield per hectare increased with the increase in nitrogen dose vide T_1, T_2, T_3, T_4 and T_5 respectively. The highest yield (3.73 t/ha) was found in T_5 and the lowest yield (2.13) was recorded in T_0. Although the experiment was carried out only for one season but results were in perfect agreement with those reported by Ara (2005).

Table 5: Effect of N on the yield attributes of spinach

Treatment	Fresh weight (plant^{-1})(g)	Dry weight (plant^{-1}) (g)	Yield (plot^{-1}) (g)	Yield (t ha^{-1})
T_0	7.10	0.66	275.00	2.13
T_1	9.50	0.73	480.00	2.43
T_2	11.93	0.76	866.67	2.54
T_3	12.10	0.75	1200.00	3.00
T_4	12.79	0.81	1366.67	3.42
T_5	13.42	1.10	1493.33	3.73
CV (%)	0.30	2.62	8.37	8.73
LSD	0.057	2.945	144.10	5.263
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 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 spinach shoot

4.11. 1. Nitrogen concentration (%)

As shown in Table 6, nitrogen (N) content (%) among the treatments showed that it was increased remarkably with increasing the N doses. As for nitrogen concentration, treatments showed statistically significant ($p<0.01$) increase in various treatments. The highest (4.28 %) nitrogen concentration was found in T_5 and that of the lowest (3.92 %) was recorded in T_0. These data indicated that increase in nitrogen doses had positive effect on the increment of spinach 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 spinach and secondly, it might be speculated for harvesting time and harvested organ since in spinach 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 spinach at harvest is presented in Table 6. The trend of phosphorus concentration in spinach shoot was identical. In other words, treatments induced variations in phosphorus content was not significant. Phosphorus concentration varied between 0.20 to 0.22 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.22 %) in T_3. However, the range 0.21 to 0.22 (%) lied in the generally agreed range suggesting these dose were appropriate for spinach growth and development (Marschner, 1990).

4.11. 3. Potassium concentration (%)

Data of spinach shoot potassium (K) concentration are shown in Table 6. As for potassium concentration, no remarkable variation among the treatments was observed. Potassium concentration varied between 0.45 to 0.47 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, with the highest concentration (0.47 %) in T_3. This sort of constant K concentration 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) concentration of spinach shoot are shown in Table 6. The trend of Ca concentration in spinach shoot is identical in all treatments. In other words, treatments induced variations in Ca content are not significant. Further, such calcium concentration varies between 1.35 to 1.42 (%) in all of T_0, T_1, T_2, T_3, T_4 and T_5, with the highest concentration (1.42 %) in T_4 which does not vary significantly ($p<0.01$) when compared to T_0, T_1, T_2, T_3, T_5, respectively. However, it remains obscure why such variations lie among T_0, T_1, T_2, T_3, T_5 since no relation with the increase in nitrogen doses and Ca accumulation in plant parts exists (Carson, 1974).

4.11. 5. Magnesium concentration (%)

Magnesium (Mg) content of spinach at harvest is presented in Table 6. The trend of Mg concentration in spinach shoot is identical. In other words, treatments induced variations in Mg content are not significant. Magnesium concentration varied between 0.27 to 0.28 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5 with the highest concentration (0.28 %) in T_1. However, the range 0.27 to 0.28 (%) lies in the acceptable range (Marschner, 1990).

4.11. 6. Sulfur concentration (%)

As shown in Table 6, sulfur (S) content (%) among the treatments not increased remarkably. As for sulfur concentration, treatments showed no statistically significant increase. The highest (.25 %) S concentration was found in T_5 and that of the lowest (.23 %) was recorded in T_4. These data indicate that increase in nitrogen doses has positive effect on the increment of spinach shoot S content to some extent. However, such sorts of variations in S concentration are in full agreement with those reported by Marschner (1990).

4.11. 7. Iron concentration (%)

Obtained results of iron (Fe) concentration against various treatments in shoot of spinach are shown in Table 6. As regards Fe concentration, no remarkable variation among the treatments was observed. Namely, Fe concentration varied between 0.19 to 0.22 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.22 %) in T_4. Such variation of iron concentration in spinach shoot is similar to those reported by Mohideen et al. (1985).

4.11. 8. Zinc concentration (%)

Data as presented in Table 6 shows that Zinc (Zn) concentrations among the treatments varies significantly ($p<0.01$). The highest (96.00 ppm) Zn concentration was found in T_6 and that of the lowest (86.67 ppm) was recorded in T_0. These data indicate that increase in nitrogen doses has positive effect on the increment of spinach shoot Zn content. Similar findings were also reported by Mengel and Kirkby (2001).

Table 6: Effect of N on nutrient content in spinach shoot

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (%)	Zn (ppm)
T_0	3.92	0.20	0.45	1.33	0.27	0.23	0.19	91.00
T_1	3.93	0.22	0.45	1.38	0.28	0.24	0.19	90.83
T_2	3.95	0.22	0.45	1.36	0.27	0.24	0.20	92.33
T_3	3.50	0.22	0.47	1.35	0.27	0.24	0.19	86.67
T_4	4.28	0.21	0.45	1.42	0.27	0.21	0.22	95.67
T_5	4.28	0.22	0.45	1.38	0.27	0.25	0.21	96.00
CV (%)	0.18	2.29	2.23	4.82	3.15	5.12	3.50	2.26
LSD	0.057	0.057	0.057	0.12	0.057	0.057	0.057	3.750
Level of significance	**	NS	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 spinach root

4.12. 1. Nitrogen concentration (%)

Nitrogen (N) content (%) among the treatments increased remarkably (Table 7). Treatment affected increase in root N concentration varied significantly ($p<0.01$). The highest (2.71 %) N concentration was found in T_3 and that of the lowest (2.44 %) was recorded in T_5. These results are similar to those of Roy (2008) where the author clearly stated that no N application in vegetable production encourages remarkable root growth for nutrient N search and thereby paving the way of better uptake.

4.12. 2. Phosphorus concentration (%)

As shown in Table 7, the trend of phosphorus (P) concentration in spinach root was rugged. In other words, treatments induced variations in phosphorus content was not significant. Phosphorus concentration varied between 0.14 to 0.21 (%) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest concentration (0.21 %) in T_3. Nutrient concentrations in plant parts generally correlates with the availability of nutrient in soils which was observed in the present study as well. Such findings were also supported by Munson (1998).

4.12. 3. Potassium concentration (%)

Spinach root potassium (K) concentrations are shown in Table 7. However, these potassium concentrations were insignificantly affected by various treatments. Potassium concentration varied between 0.46 to 0.48 (%) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest concentration (0.4 8 %) in T_3 and 0.46% K only in T_4. These sorts of constant K concentration in all of T_0, T_1, T_2, T_3, T_5 could be due 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, spinach root sulfur (S) content (%) among the treatment combinations showed a steady pattern. Namely, treatments showed no remarkable increase with the increase of nitrogen doses. However, he highest (.26 %) S concentration was found in T_3 and that of the lowest (.20 %) was recorded in T_4. Thus the different treatment combinations expressed differential effects on spinach root sulfur content and were in conformity with those of Marschner (1990).

4.12. 5. Calcium concentration (%)

Calcium (Ca) content of spinach root at harvest is presented in Table 7. Treatments induced variations in Ca content was not significant. Calcium concentration varied between 0.55 to 0.61 (%) in all of T_0, T_1, T_2, T_3, T_4 and T_5, respectively with the highest concentration (0.61 %) in T_3 and with those of Roy (2008).

4.12. 6. Magnesium concentration (%)

As shown in Table 7, data of spinach root magnesium (Mg) content did not vary remarkably. Magnesium concentration varied from 0.24-0.25% in all of T_0, T_1, T_2, T_3, T_4 and T_5. The highest Mg concentration (.25%) was observed in all the treatments other than T_2. In other words, a constant Mg concentration was found in various treatments. However, such Mg concentrations lied in the normal range (Munson, 1998).

4.12. 7. Iron concentration (%)

Various treatment affected iron (Fe) concentrations of spinach root are shown in Table 7. No remarkable variation for Mg concentration was observed among the treatments. Namely, Fe concentration varied between 0.13 to 0.15 (%) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentration (0.15 %) in T_5. A credible explanation for the variation of such iron concentration in vegetables was given by Mohideen et al. (1985).

4.12. 8. Zinc concentration (%)

As shown in Table 7, spinach root zinc (Zn) concentrations among the treatments varied significantly ($p<0.01$). The highest (118.00 ppm) Zn concentration was found in T_5 and that of the lowest (106.80 ppm) was recorded in T_0. These data indicated that increase in nitrogen doses had a positive effect on the increment of spinach root Zn content and were similar to those reported by Mengel and Kirkby (2001).

Table 7: Effect of N on nutrient content in spinach root

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (%)	Zn (ppm)
T_0	2.66	0.17	0.48	0.55	0.25	0.23	0.13	106.80
T_1	2.68	0.18	0.47	0.56	0.25	0.23	0.13	107.20
T_2	2.67	0.19	0.48	0.56	0.24	0.24	0.13	107.20
T_3	2.71	0.21	0.48	0.61	0.25	0.26	0.15	115.33
T_4	2.41	0.17	0.46	0.56	0.24	0.20	0.14	118.00
T_5	2.44	0.14	0.48	0.57	0.25	0.25	0.15	118.00
CV (%)	0.45	1.91	2.22	1.25	3.10	2.35	3.78	0.85
LSD	0.058	0.058	0.057	0.057	0.057	0.058	0.057	1.65
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 that the micronutrients. Nitrogen fertilization based nutrient of spinach is detailed below:

4.13. 1. Nitrogen uptake

Nitrogen (N) uptake of spinach is presented in Table 8. Treatment combinations induced variations in N uptake was statistically significant in all of T_1, T_2, T_3, T_4, T_5, respectively. However, N uptake varied between 51.44 to 104.98 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake 104.98 (kg ha^{-1}) in T_3 and were in full agreement with those of Marshner (1990).

4.13. 2. Phosphorus uptake

The trend of phosphorus (P) uptake in spinach was remarkable. In other words, data presented in Table 8 indicated that treatments induced variations in P uptake was significant ($p<0.01$). Further, such P uptake varied between 2.52 to 6.69 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake (6.69 kg ha^{-1}) in T_3 which varied significantly ($p<0.01$) when compared to T_0, T_1, T_2, T_4, T_5, respectively. Evidence of this kind of work has been provided by Mengel and Kirkby (2001).

4.13. 3. Potassium uptake

Potassium (K) uptake in spinach is shown in Table 8. However, the potassium was significantly ($p<0.01$) affected by various treatments. Potassium uptake varied between 5.5 to 11.65 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake (11.65 kg ha^{-1}) in T_2. Such K uptake in spinach 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).

4.13. 4. Sulfur uptake

As shown in Table 8, sulfur (S) uptake (kg ha^{-1}) among the treatments showed remarkable variation. Sulfur uptake variation among the treatments was statistically significant ($p<0.01$). It varied between 2.58 to 7.31(kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake (7.31 kg ha^{-1}) in T_3. These data indicated that increase in nitrogen doses had a positive effect on the increment of spinach S uptake. However, such variations in S uptake are in full agreement with those reported by Marschner (1990).

4.13. 5. Calcium uptake

The trend of calcium (Ca) uptake in spinach was remarkable for all the treatments (Table 8). In other words, treatments induced variations Ca uptake was significant ($p<0.01$). Further, such calcium uptake varied between 17.03 to 39.78 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake (39.78 kg ha^{-1}) in T_3. However, these sorts of findings were similar to those reported by Hanson (1984).

4.13. 6. Magnesium uptake

Magnesium (Mg) uptake of spinach at harvest is presented in Table 8. The trend of Mg uptake in spinach is significantly ($p<0.01$) correlated to the treatment. In other words, treatments is highly effective to induce variations in Mg uptake . Magnesium uptake varied between 3.30 to 8.12 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest uptake 8.12 (kg ha^{-1}) in T_3. However, the range 3.30 to 8.12 (kg ha^{-1}) lied in Kirkby and Mengel (1976).

4.13. 7. Iron uptake

Obtained results of iron (Fe) uptake against various treatments in spinach are shown in Table 8. As regards of Fe uptake, significant ($p<0.01$) variation among the treatments was observed. Namely, Fe concentration varied concentration varied between 2.66 to 5.79 (kg ha^{-1}) in all of T_0, T_1, T_2, T_3, T_4, T_5, respectively with the highest concentrationing 5.79 (kg ha^{-1}) in T_3. A credible 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 treatments varied significantly ($p<0.01$). The highest (3.77 kg ha^{-1}) Zn uptake was found in T_5 and that of the lowest was (0.66 kg ha^{-1}) recorded in T_0. These data indicated that increase in nitrogen doses had a positive effect on the increment of spinach Zn uptake. Similar findings were also reported by Mengel and Kirkby (2001).

Table 8: Effect of N on nutrient uptake of spinach

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	80.16	4.85	9.70	27.95	5.79	4.96	3.85	0.66
T_1	91.73	5.30	11.13	33.19	6.77	5.90	4.47	1.15
T_2	97.42	5.71	11.65	34.24	7.01	6.10	5.09	2.08
T_3	104.98	6.69	14.11	39.78	8.12	7.31	5.79	2.60
T_4	51.44	2.52	5.50	17.03	3.33	2.58	2.66	2.48
T_5	92.81	4.70	9.75	29.90	5.91	5.42	4.55	3.77
CV (%)	9.29	8.71	9.99	9.36	9.64	10.88	10..	9.76
LSD	14.73	0.84	7.69	5.41	1.14	1.12	0.81	1.32
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 spinach

The partial budget analysis on the effect of nitrogen doses applied on spinach production is presented in Table 9. The highest gross return (Taka 30000.00 ha^{-1}) was obtained from the treatment T_3 which received N (100 kg ha^{-1}), followed by the treatment T_2 (Taka 25400.00ha^{-1}) which received N (75 kg ha^{-1}) and T_1 (Taka 24300.00 ha^{-1}) which received N (50 kg ha^{-1}). All the treatments recorded higher gross return over the control. On the other hand, highest variable cost (Taka 10,608.00 ha^{-1}) was recorded in the treatment T_5 which received N (150 kg ha^{-1}) and that of the lowest was observed in T_0 which received no nitrogen fertilizer. The highest cost benefit ration (3.32) was recorded in T_3 which was followed by T_1 (2.93) and T_1 (2.89).

Table 9: Effect of nitrogen on economic performance of spinach cultivation

Treatment	Gross return ($Tkha^{-1}$)	TVC ($Tkha^{-1}$)	Gross margin ($Tkha^{-1}$)	BCR
T_0	21300.00	7479.00	13821.00	2.85
T_1	24300.00	8307.00	15993.00	2.93
T_2	25400.00	8811.00	16589.00	2.88
T_3	300000.00	9044.00	20956.00	3.32
T_4	12000.00	9826.00	2174.00	1.22
T_5	21700.00	10609.00	11091.00	2.05

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 among yield, nutrient uptake and N doses

Yield and N dose

The relationship between yield and applied N doses is presented in Figure 2. The regression analysis indicates that the yield of spinach is linearly and positively correlated to the applied N doses. It is also evident from the regression equation that the increase in N dose results in the increase in yield and thus it coincides with the findings of Takebe et al. (1995).

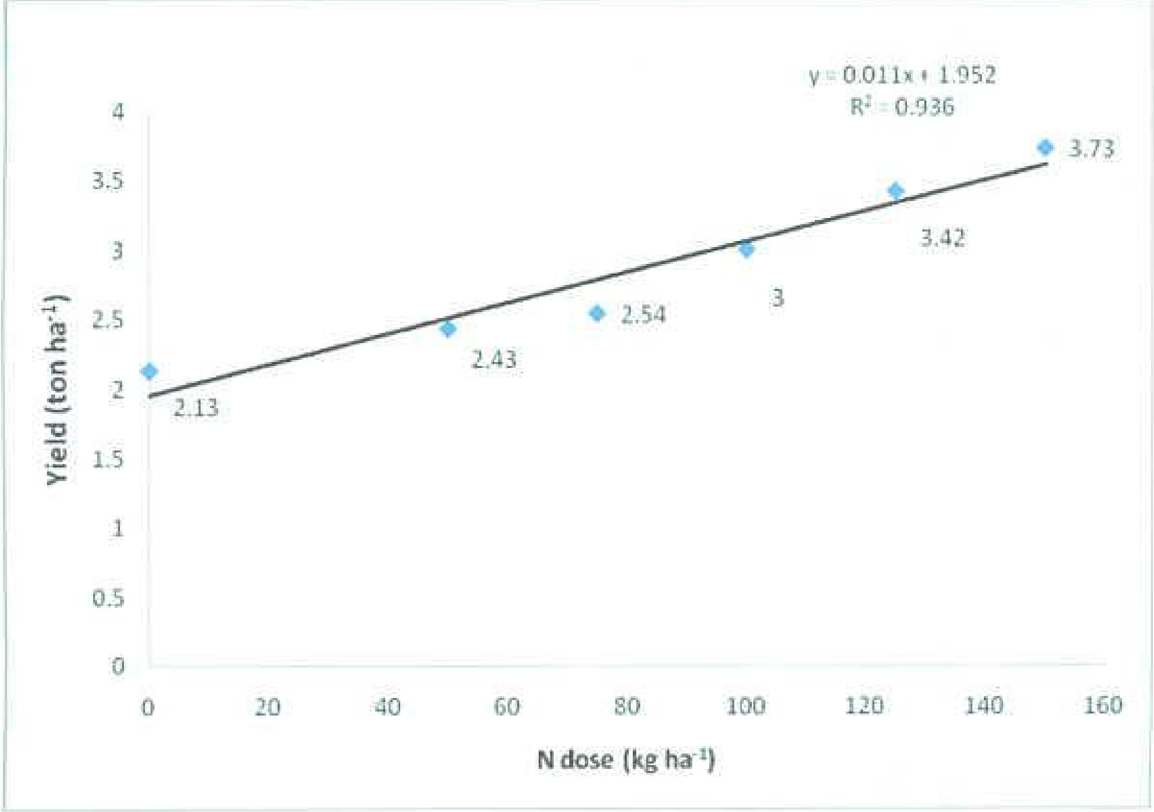


Figure 2: Relationship between N and yield of spinach

4.15. 1. N uptake and N dose

The relationship between N uptake and applied N dose is presented in Figure 3. From regression line it is clear that N uptake increases up to T_3 (100 kg N ha^{-1}) application only. So it is clear that the relationship between N up take and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments. In experiments with amaranths, similar findings were also reported by Takebe et al., (1995) and Roy 2008). Due to draught and other adverse condition the result of T_4 showed no resemblance with other treatments. So the result of T_4 is not showed in the figure.

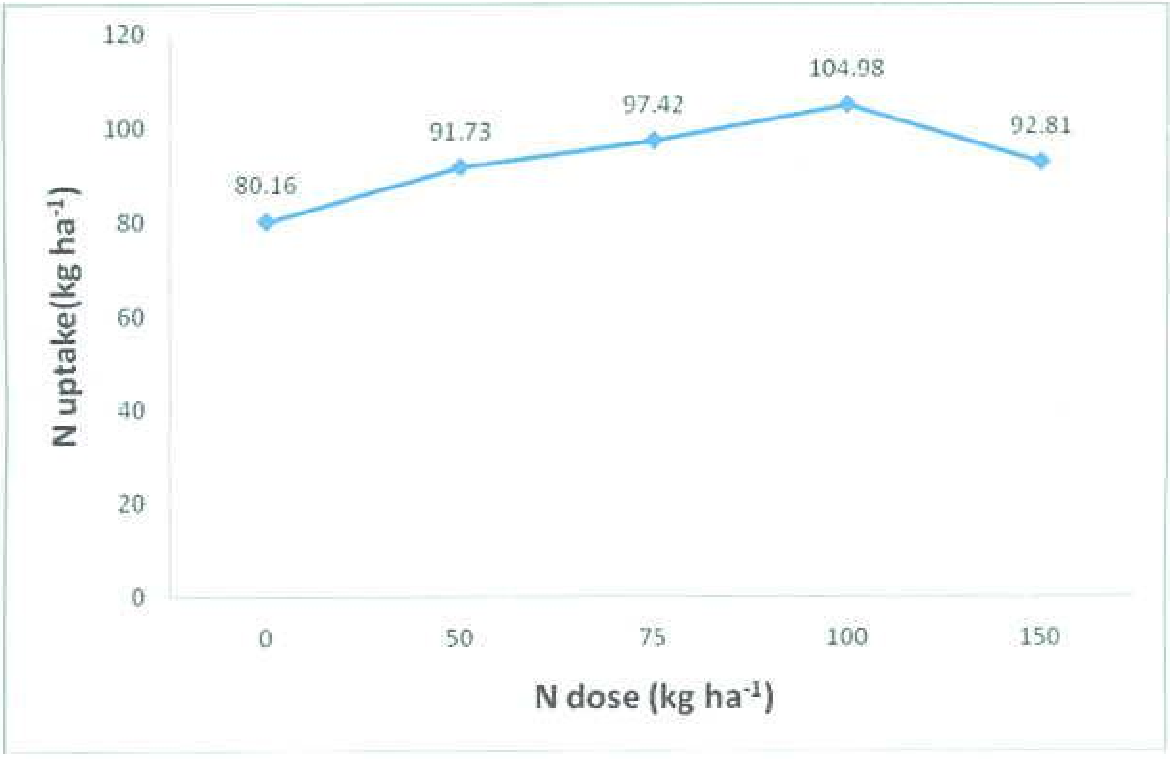


Figure 3: Relationship between N dose and uptake

4.15. 2. P uptake and N dose

The relationship between P uptake and applied N dose is presented in Figure 4. From regression line, it is clear that P uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in P uptake with the increase in N doses. So it is evident that the relationship between P up take and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment combinations. P uptake trend is rather similar to that of N uptake. In experiments with amaranths, similar findings were also reported by Takebe *et al.* (1995) and Roy 2008). The result of T_4 showed no resemblance with other treatments due to draught and other adverse condition. For that reason it is not mentioned in the figure.

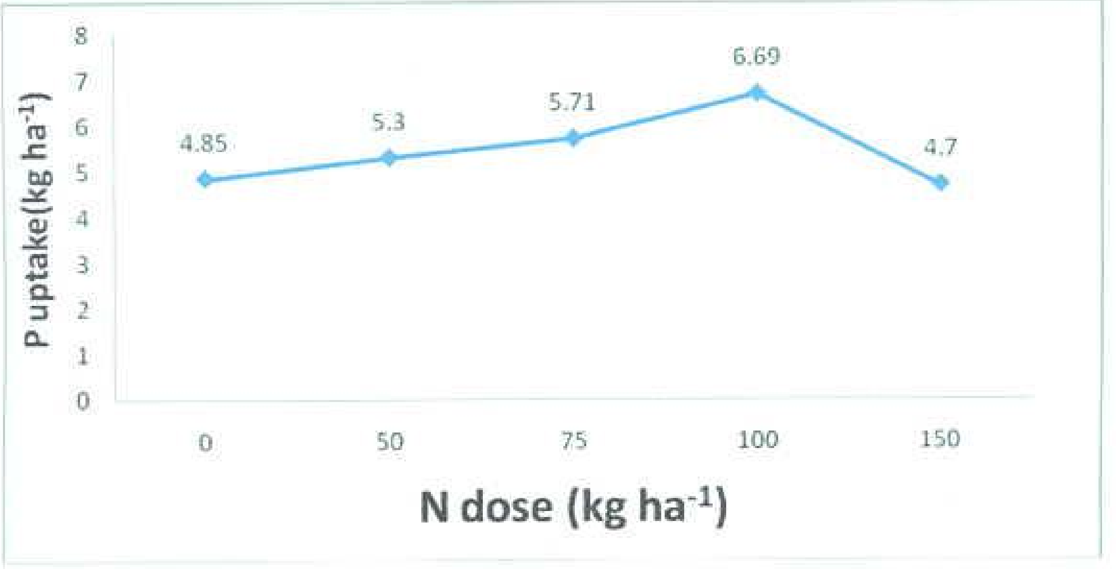


Figure 4: Relationship between N dose and P uptake

4.15. 3. K uptake and N dose

The relationship between K uptake and applied N dose is shown in Figure 5. From regression line, it is clear that K uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in K uptake with the increase in N doses. So the relationship between K uptake and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments and the pattern of K uptake is similar to that of N and P uptake. In experiments with amaranths, similar results were also reported by Takebe *et al.* (1995) and Roy 2008). Due to some unfavorable condition in the field, T_4 showed a wide variation in comparison with other treatments. That's why the result of T_4 is not presented in the figure.

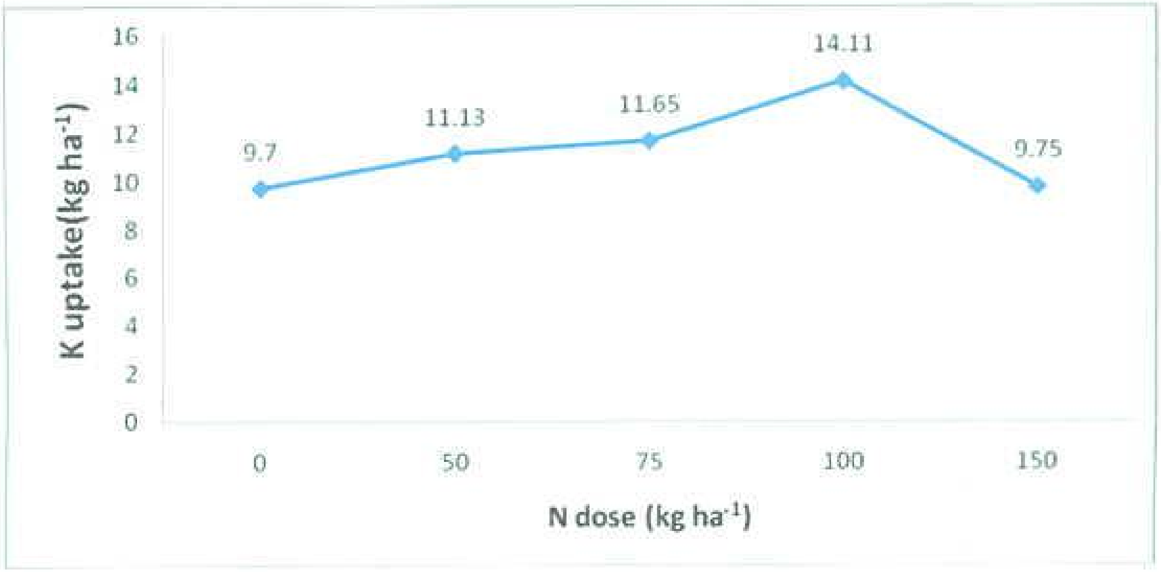


Figure 5 : Relationship between N dose and K uptake

4.15. 4. S uptake and N dose

The relationship between S uptake and applied N dose is displayed in Figure 6. From regression line, it is clear that S uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in S uptake with the increase in N doses. So the relationship between S uptake and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatment and pattern of S uptake is similar to those of N, P and K uptake. In experiments with amaranths, similar results were also reported by Takebe *et al*. (1995) and Roy 2008). Due to draught and other adverse condition the result of T_4 showed no resemblance with other treatments. So the result of T_4 is not shown in the figure.

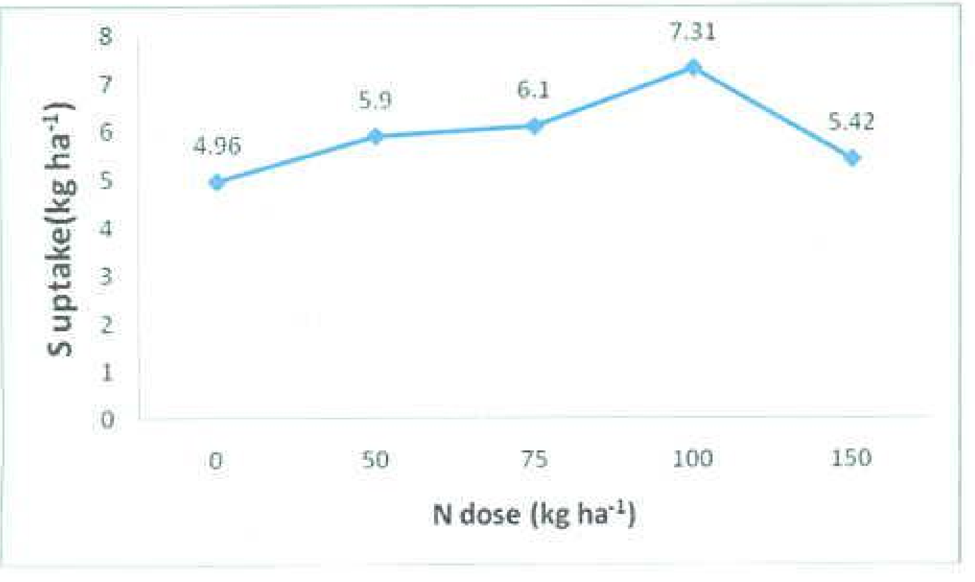


Figure 6 : Relationship between N dose and S uptake

4.15. 5. Ca uptake and N dose

The relationship between Ca uptake and applied N dose is presented in Figure 7. From regression line, it is clear that Ca uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in Ca uptake with the increase in N doses. So the relationship between Ca uptake and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments and pattern of Ca uptake is similar to those of N, P, K and S uptake. In experiments with amaranths, similar results were also reported by Takebe *et al.* (1995) and Roy 2008). Due to some unfavorable condition in the field, T_4 showed a wide variation which can't be possible in normal condition. That's why the result of T_4 is not presented in the figure.

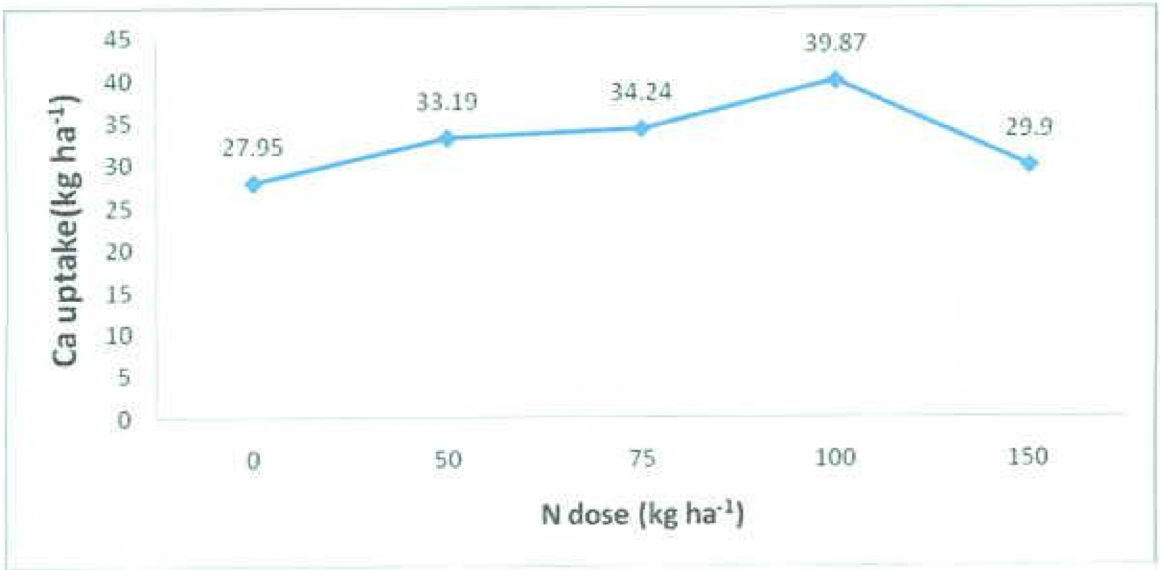


Figure 7: Relationship between N dose and Ca uptake

4.15. 6. Mg uptake and N dose

The relationship between Mg uptake and applied N dose is shown in Figure 8. From regression line, it is clear that Ca uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in Mg uptake with the increase in N doses. So the relationship between Mg uptake and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments and pattern of Mg uptake is similar to those of N, P, K, S and Ca uptake. In experiments with amaranths, similar results were also reported by Takebe *et al.* (1995) and Roy 2008). The result of T_4 showed no resemblance with other treatments due to draught and other adverse condition. For that reason it is not mentioned in the figure.

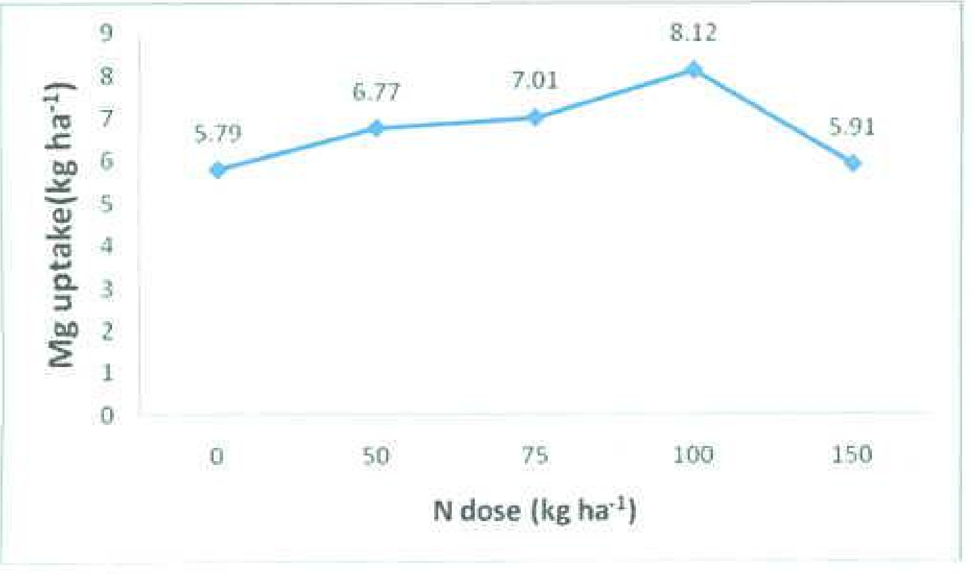


Figure 8 : Relationship between N dose and Mg uptake

4.15. 7. Fe uptake and N dose

The relationship between Fe uptake and applied N dose is shown in Figure 9. From regression line, it is clear that Fe uptake increases up to T_3 (100 kg N ha^{-1}) application. After that there is a decline in Fe uptake with the increase in N doses. So the relationship between Fe uptake and applied N doses is not positively correlated for all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments and pattern of Fe uptake is similar to those of N, P, K, S, Ca and Mg uptake. In experiments with amaranths, similar results were also reported by Takebe *et al.* (1995) and Roy 2008). Due to some unfavorable condition in the field, T_4 showed a wide variation which can't be possible in normal condition. That's why the T_4 is not presented in the figure.

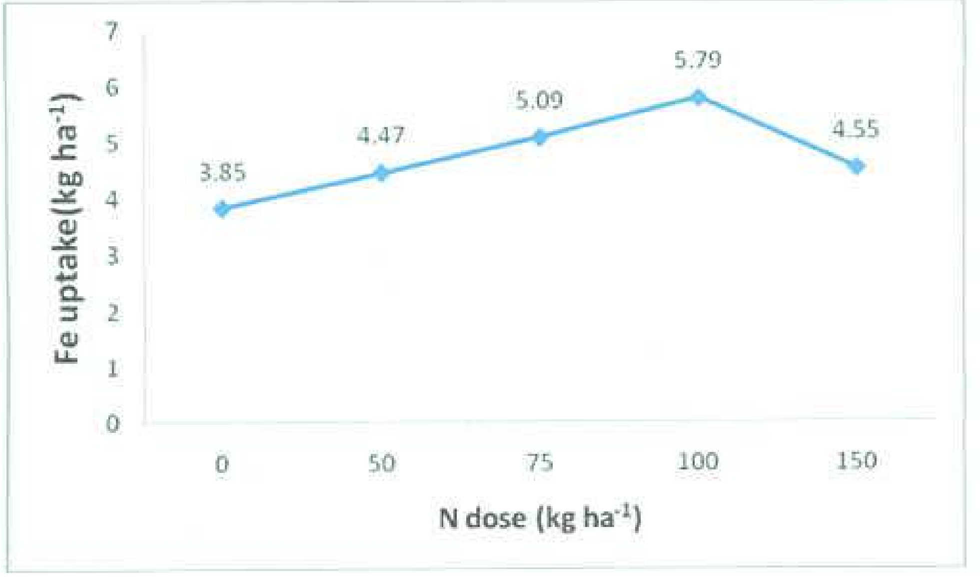


Figure 9 : Relationship between N dose and Fe uptake

4.15. 8. Zn uptake and N dose

The relationship between Zn uptake and applied N dose is presented in Figure 10. From regression line, it is clear that Zn uptake increases up to T_5 (150 kg N ha^{-1}) application. So the relationship between Zn uptake and applied N doses is positively correlated with all of T_0, T_1, T_2, T_3, T_4 and T_5 treatments and pattern of Zn uptake is disimilar to those of N, P, K, S, Ca, Mg and Fe uptake. In experiments with amaranths, similar results were also reported by Takebe *et al.* (1995) and Roy (2008). The result of T_4 showed no resemblance with other treatments due to draught and other adverse condition. For that reason it is not shown in the figure.

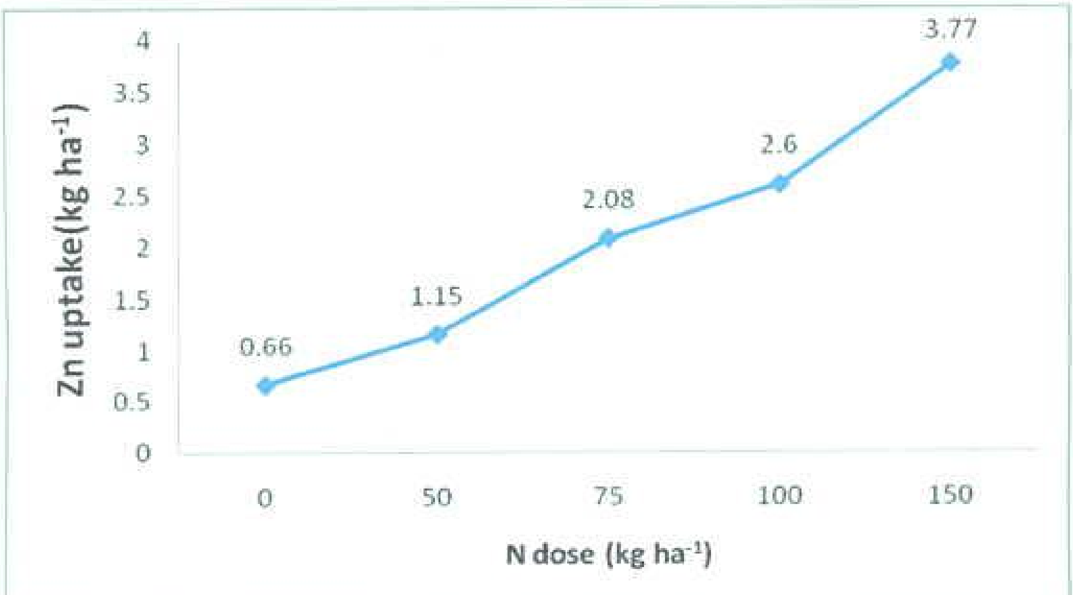


Figure 10 : Relationship between N dose and Zn uptake

Chapter V

SUMMARY AND CONCLUSION

The study was conducted at the farm of BSMRAU, Gazipur during the period of November to December, 2010 to enhance the production of spinach (BARI spinach 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 treatments 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 (1 50 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, Fe and Fe accumulation 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 (17.26 cm), leaf number (13.93) were found in T_3. Widest petiole breadth (6.79 cm) and longest petiole (10.12 cm), longest root length (9.56 cm), highest shoot diameter (3.18 cm) and fresh root weight (1.23 g plant $^{-1}$) were measured in T_5. Highest fresh weight (13.42 g plant $^{-1}$), dry weight (1.10 g plant $^{-1}$) and yield (3.73 t ha^{-1}) were also recorded in T_5. However, dry root weight in all of T_0, T_1, T_2,

T_3 , T_4 and T_5 were statistically identical. As regards of nutrient accumulation in shoot, highest N (4.28 %) was recorded in T_5 followed by T_4 (4.28%). T_3 (3.50 %) and T_2 (3.95 %), respectively. As for P, highest (0.22 %) was observed in T_2 which was followed by T_3 and T_5, respectively. Mean while, highest K (0.47 %) was recorded in T_3 and the lowest (0.45%) was found in all of T_0, T_1, T_2, T_4 and T_5 (0.45%). In case of Ca accumulation, highest (1.42 %) was quantified in T_5 and the lowest (1.33%) was observed in T_0. In case of Mg, S and Fe, all of T_0, T_1, T_2, T_3, T_4 and T_5 showed the identical pattern of accumulation. However, as for Zn, highest (96 ppm) was found in T_5 with that of the lowest (90.83 ppm) in T_2.

As for Fe, it ranged from 0.19 to 0.22%. On the contrary, for root , highest N(2.17%), P (.21%), K (0.48%) , Ca (.61 %), Mg (.25%), S (.26%), Fe (.15%) were accumulated in T_3. However, in case of Zn, highest (118.00 ppm) was accumulated in T_5. As for nutrient uptake, highest N (1.098 kg ha^{-1}), P (6.69 kg ha^{-1}), K (14.11 kg ha^{-1}), Ca (39.87 kg ha^{-1}), Mg (8.12 kg ha-^{1}), S (7.31 kg ha^{-1}), Fe (5.79 kg ha-^{1}) and Zn (3.77 kg ha^{-1}) were recorded in T_3. Focused on benefit cost ration (BCR), highest BCR (3.32) was found in T_3 with that of the lowest BCR (2.05) in T_5.

The results indicated that N doses had a positive impact on the growth parameters of spinach like plant height, leaf number, fresh and dry weight of plant. Applied nitrogen had also significant effect on N, P, K, Ca, Mg, S, Zn and Fe accumulation both in root and shoot and the spinach yield although the highest yield (3.73 t ha^{-1}) was recorded in T_5. Noticeable fact is that highest N, P, K, Ca, Mg, S, Zn uptake is found in T_3. In contrast, highest Fe uptake was found in T_5. Even BCR was highest (3.32) in T_3. Based on data obtained from the current investigation it can therefore be concluded that increasing nitrogen doses play an important role on the growth, nutrient accumulation and yield of spinach. But comparative study of various parameters in relation to their respective treatments followed by the BCR study revealed that T_3 was the best treatment.

However, the present study was conducted in winter season of 2010 at BSMRAU research farm only. Therefore, recommendation of T_3 (N 100 kg ha^{-1}) as fertilizer dose necessitates both regional and multi location trials. Finally, data based findings on growth parameter, nutrient accumulation, yield and BCR suggest that treatment T_3 has the potential to be recommended as suitable N dose for spinach cultivation. Moreover, this study also highlights 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 spinach is grown with T_3 as sole N source. Additionally, this finding revealed that further experiments on spinach production with 100 kg N ha^{-1} should be conducted to verify whether the application of N at 100 kg can 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.

Chapter VI

References

Ahmed, K. U. 1995. Ful Fol O Sak Sobji (in Bengali). Kall-kwik printing Ltd. 149/A, Old Airport Road, Baitush Sharaf Complex, Dhaka, 1207.

Anac, D., N. Eryuce, O. Gurbuz, B. Eryuce, C. Kilic, M. Tutam and P. Martin Prevel. 1999. Effect of combined N and K nutrition on yield and quality of spinach-Improved crop quality by nutrient management, Ege University, Faculty of Agriculture, Soil Dept 35100 Bornova, Izmir, Turkey. pp. 39-41.

Anelli, G., F. Mencarelli and F. Guaraldi. 1985. Short storage of *Brassica oleracea* L. and *Brassica campestis* L. in different types of modified atmospheres. *Acta Hort.* 154: 77-84.

Anon, 1989. Annual weather report. Bangabandhu Sheikh Mujibut Rahman Agricultural University (BSMRAU). Meteorological Station, BSMRAU, Gazipur -1706, Bangladesh.

Anon, 1991. Basat Barite Sobji Utpadon (in Bengali). Bangladesh Agricultural Research Institute, Gazipur, Bangladesh. 239 p.

Anon, 1997. Fertilizer Recommendation Guide. BARC, Farm gate, Dhaka, Bangladesh.

Anon, 1998. Year Book of Agricultural Statistics of Bangladesh, 1997. Bangladesh Bureau of statistics, Statistics Division, Ministry of Planning, Peoples' Republic of Bangladesh, Dhaka.

Ara, R. 2005. Effect of nitrogen and harvesting frequencies on yield and quality of spinach. MS Thesis, Dept. of Horticulture, BSMRAU, Gazipur-1706.

BARC (Bangladesh Agricultural Research Council), 2008. Fertilizer Recommendations Guide.

Biemond, H., j. Vos, and P.C. Struik. 1996. Effects of nitrogen on accumulation and partitioning of dry matter and nitrogen of vegetables. Netherlands Journal of Agricultural Science. 44 (3): 227-239.

Black, G. R. 1965 a. Bulk Density. In Methods of Soil Analysis. Part I, Ed. C. A. Black, Am. Soc. Agron. Inc., Madison, Wisconsin, USA, pp374-390

Brammer, H. 1978. Rice Soils of Bangladesh. In "Soils and Rice." Manila, The Philippines, The Rice, pp35-55Soil Resources.

Carson, E. W.1974. Plant roots and its environment. pp-507-524. Univ. Press of Virginia, Charlottesvile.

Cervato, A. 1969. *Annali Della Facolta di agrarian, University Catholica del S. Cuore, Milano.* 10: 989-421.

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

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedure for Agricultural Research (2nd Edn.), John Willey and Sons, New York, pp-28-92

Hamid, M. M., M. C. Saha, A. K. M. M. Rahman and S. M. M. Hossain, 1986.Effec of nitrogenous fertilizer on growth and yield of Spinach. *In:* Horticulture Research Report of Vegetable Seedlings. BARI, Joydevpur, Gazipur, pp: 36.

Hanson, J. B. 1984. The function of calcium in plant nutrition. In " Advances in plant nutrition."pp 1449-208, Praeger, New York.

Islam, A. B. M. Z., M. A. Siddique and M. M. Hossain. 1984. The influence of palnting material and dose of nitrogen on the yield of Kang Kong (*Ipomoea aquatica).* Thai. J. Agric. Sci. 17: 87-87.

Jackson, M. L. 1973. Soil Chemical Analysis. Prantice Hall of India Pvt. Ltd., p498

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

Kader, A. A. 1992. Post harvest Technology of Horticultural Crops. Division of Agriculture and Natural Resources, University of California. 6701., San Pablo Avenue, Okland, California 94608-1239, pp. 15-17.

Kirkby, E. A. and Mengel, K. 1976. The role of magnesium in plant nutrition.Z. Pflazenernaehr, Bodenkd, 139, 209-222.

Leskovec, E. and A. Doversekurbanc. 1972. *Zbornic Biotechniske Fakultete Univerze, v Ljubljani, Kmetijstvo.* 19: 101-109.

Macreke, D. Van. 1973. *Medudelingen van de Faclteit Landbouwwetenschappen, Rijsuniversitetit Gent.* 38: 173-199.

Marschner, H. 1990. Mineral nutrition of higher plants. Academic Press, Harcourt Brace Jovanovich Publishers, London. Mengel, K. and Kirkby, E. A. 2001. Principles of plant nutrition. pp-213-234.

Mohideen, M. K., Rangawswami, P., Metha, V., Shanmugaluvu, V. A. K. G. and Muthukrishan, 1985. A note on 3 Amaranths. Spouth Indian Hort., 33, 127-128.

Monira, U. S. 2007. Nutrient status in tomato grown on organic manure treated soil. MS thesis, Faculty of Agriculture, BSMRAU, Gazipur.

Munson, R. D. 1998. Principles of plant analysis. In Handbook of reference methods for plant analysis.

Nashrin, S. A., A. M. Farroque, M. K. Siddiqua, M. M. Rahman and M. R. Khanam. 2002. Effect of nitrogen and spacing on the growth and yield of gimakalmi, *Ipomoea retans* Poir. Online J. Bio. Sci. Asian Network for Scientific Information. 2 (3): 170-174.

Nath, P. 1976. Vegetables for the tropical region. India Council for Agricultural Research, New Delhi. Page, A. L., Miller, R. H. and Keeney, D. R. 1982. Methods of Soil Analysis, Part II, Am. Soc. Agron. Inc., Madison, USA.

Pandita, M. L. and S. Lal. 1993. Spinach beet and spinach, *In:* Vegetable crops. Bose, T. K., M. G. Som and J. Kabir. (ed). Naya Prokash, 206, Bidhan Sharani, Cacutta, India. pp. 753-777.

Page, A.L., Miller,R.H. and Keenely, D.R. 1982. Metods of Soil Analysis, Part II, Am. Soc. Agron. Inc., Madision, USA.

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

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

Rashid, M. M. 1999. Sobjibiggan (in Bengali). Rashid Publishing House, 94, OLd DOHS, Dhaka- 1206.pp. 474-480.

Rauf, M. A., Karim, A. J. M. S., Zoebich, M. A. and Hasan, J. 2009. Potential of industrial sludge as a source of nitrogen and its partitioning, uptake and its use efficiency in red amaranth production. Intl. J. Bio Res., 7, 59-65.

Rekhi, S. S. 1997. Vegetable imporvement and seed production. Paper presented in the National Swminar on Vegetable Improvement and Seed Production held at BARI during 3-4 March, 1997, Gazipur, Bangladesh.

Roy, P. K. 2008. Effect of organic manure on growth and yield of stem amaranth. MS Thesis, Dept. of Soil Science, BSMRAU, Gazipur-1706.

Stanilova, O., D. Boboshevska and G. Vitanova. 1972. *Nauchni Trudove, Vissh Selskostopanski Institut 'Georgi Dimitrov.' Obshcho Zemledelie.* 24: 35-46.

Takebe, M., T. Ishihara, K. Matsuno, J. Fujimoto and T. Yoneyama. 1995. Effect of nitrogen application on the contents of sugar, ascorbic acid, nitrate and oxalic acid in spinach (*Spinacia oleracea* L) and Komatsuna (*Brassica campeatris* L.). Japanese Journal of Soil Science and Plant Nutrition. 66 (3): 238-246.

Thompson, T.L. and T. A. Doerge. 1995. Nitrogen and water rates for subsurface trickle-irrigated collard, mustard, and spinach. HortScience. 30 (7): 1382-1387.

Walkey, A. C. and Black, T. A. 1935. Estimation of soil organic carbon by chromic acid titration method. Soil Sci., 47, 29-38.

Waseem, K. and A. Nadeem. 2001. Enhancement of spinach production by varying sowing dates, row spacing and frequency of cuttings. Online J. Bio. Sci. Asian Network for Scientific Information. 1 (10): 902-904

Work, P. 1997. Spinach. *In:* Vegetable production and marketing. Biotech Books, 1123/74, Tri Nagar, Delhi- 110035. pp. 514-522.

Yoshida, A., K. Harada, A. Sugawara and T. Tadano. 1998. Effects of the asence of nitrogen and all nutrients at the later growth stage on the contents of sugars, ascorbic acid, nitrate and oxalic acid in spinach (*Spinacia oleracea* L) under hydroponic culturing. Japanese Journal of Soil Science and Plant Nutrition. 69 (2): 178-184.

Zhang, C. L., Y. Watanable and N. Shimada. 1990. The effect of nitrogen concentration in the nutrient shloution on the growth and nutrient contents of hydroponically grown spinach. Technical Bulletin of the Faculty of Horticulture, Chiba University, Faculty of Horticulture, Chiba University, Matsudo, Chiba 271, Japan. No. 43, pp. 1-5.