INFLUENCE OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF CARROT

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CERTIFICATE

*This is to certify that thesis entitled **"INFLUENCE OF NITROGEN AND SULPHUR ON GROWTH AND YIELD OF CARROT"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **SHOAIB RAHMAN, Registration no. 14-06049** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2021
Place: Dhaka, Bangladesh

Prof. Dr. Md. Ismail Hossain
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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

The present investigation entitled "Influence of nitrogen and sulphur on growth and yield of carrot" was conducted from January, 2019 to February, 2020 at the horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factor A: Four levels of nitrogen fertilizer (0 kg N/ha, 40 kg N/ha, 80 kg N/ha and 120 kg N/ha) and Factor B: Three levels of sulphur (0 kg S/ha, 5 kg S/ha and 10 kg S/ha) of carrot. The experiment was laid out in a Randomized Complete Block Design with three replications. In case of nitrogen fertilizer application, the highest plant height, number of leaves, length of leaves, fresh weight of plant, dry weight of plant, length of root, diameter of root, dry weight of root and yield were recorded and lowest percent of cracked roots per plot and lowest percent of rotten roots per plot were recorded of carrot in case of application of nitrogen @ 120 kg N/ha. In case of different levels of sulphur, the highest plant height, number of leaves, length of leaves, fresh weight of plant, dry weight of plant, length of root, diameter of root, dry weight of root and yield were recorded and lowest percent of cracked roots per plot and lowest percent of rotten roots per plot were recorded of carrot in case of application of sulphur @ 10 kg S/ha. Again, the highest plant height, number of leaves, length of leaves, fresh weight of plant, dry weight of plant, length of root, diameter of root, dry weight of root and yield (22.21 ton/ha) were recorded and lowest percent of cracked roots per plot and lowest percent of rotten roots per plot were recorded of carrot in case of combined effect of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha applying in the carrot field.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	**Full meaning**
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization of United Nations
gm	Gram
Ha	Hectare
CRSP	Collaborative Research Support Project
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
N	Nitrogen
%	Percent
RCBD	Randomized Complete Block Design
S	Sulphur
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

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CHAPTER I

INTRODUCTION

Carrot (*Daucus carota* L.) is a winter crop belongs to the family Apiaceae and is one of the important root vegetable crops cultivated throughout the world. It is well distributed throughout the temperate, tropical and subtropical part of the world. Its fleshy edible roots are used as human food and animal feed (Salunkhe and Kadam, 1998). Carrot is rich in beta-carotene and is an excellence source of iron, calcium, phosphorus and folic acid and vitamin B. It is also rich in sugar content and some important medicinal values (Sadhu, 1993; Yawalker, 1992). Carrot is also an excellent source of vitamins A, C, K, B1, B2, B6, calcium, dietary fiber and protein (Mateljan, 2007 and Atkins, 1999). It is used as salad and as cooked vegetable in soups, stews, curries, etc. and is also used for the preparation of pickles, jam, and sweet dishes (Kabir *et al*., 2000). Carrots are a very important vegetable crop, widely used in human (especially children) diet due to their high nutritional (Heinonen, 1990) and medicinal value, and their role in disease prevention (Arscott and Tanumihardjo, 2010; Zhang *et al*., 2009; Gallichio *et al*., 2008).

Carrot is cultivated in total area of 4368 acres and total production of 15679 MT (BBS, 2017) in Bangladesh. Nitrogen application above 110 kg/ha decreases the yield and quality due to root cracking (Balvoll, 1995). Large nitrate concentration in soil tends to improve shoot: root ratio (Raynal-Lacroix, 1994).

Carrot plants need micronutrients for cell and chlorophyll production. From a physiological standpoint, the yield of carrot depends on the production and translocation of carbohydrates from the leaves to the roots (Wafaa, 2013). Being nitrophilous vegetables showing a tendency to accumulate nitrates, carrots require nitrogen fertilization, as one of the most important management practices (Ahmadi *et al*., 2010; John *et al*., 2003). Nitrogen is one of the most important yield-limiting nutrients for plants (Xia *et al*., 2011; Ekbic *et al*., 2010). Nitrate accumulation is affected not only by the type of nitrate fertilizer used, but also by nitrogen rates, variety, environment, harvesting date and other agronomical factors (Gajewski *et al*., 2009; Kòňa, 2006; Amr and Nadidi, 2001; Gutezeit, 2000; Cserni and Prohaszka, 1988). About 85-90% of nitrogen is absorbed by carrot during the growth stage of plant; while in the first and last quarter of its growth only 10-15% of nitrogen is absorbed. Split applications of fertilizers, especially nitrogen, improve carrot yield (Balvoll, 1995).

Wiebe (1987) obtained the best result of carrot yield with 80 to 140 $kgha^{-1}$ of nitrogen, whereas Markovic *et al*. (2002) reported the highest yield at the application rate of 100 $kgha^{-1}$. As high nitrogen rates cause accumulation of harmful nitrates in the plants (Mubashir *et al*., 2010; Ahmadi *et al*., 2010; Anjana *et al*., 2007; Chen *et al*., 2004; John *et al*., 2003; Gutezeit, 1999), it is essential to use genotypes which accumulate a low content of this nutrient. The consumption of foods and beverages high in nitrates is very dangerous to human health since it causes a large number of diseases, most commonly carcinogenic diseases (Mozafar, 1993). The toxic effects of nitrate are due to its endogenous conversion to nitrite, which is related to methaemoglobinaemia, gastric cancer and other diseases (Santamaria, 2006). The concentration of ß-carotene increases with increasing nitrogen rates. Hocmuth *et al*. (1999) used nitrogen rates of 0 to 220 kg/ha and obtained the highest content of ß-carotene (55 mg/kg) with 160 kg/ha. Chenard *et al*. (2005) found that ß-carotene content was affected by increasing nitrogen rates.

Several studies revealed the importance of sulphur achieve high carrot yield (Anjaiah and Padmaja, 2006). Root yield and quality parameters increased with increasing levels of sulphur. Sulphur played a key role in increasing the root TSS value. The effect of sulphur amendment on soil properties is directly associated with considerable variation on oxidation- reduction processes in soil. The oxidation of elemental sulphur to sulphate results in acidification of the soil. The acid produced from the oxidation process helps in reducing soil alkalinity (Cox and Koenig, 2010). Also, Sulphur is one of the essential elements needed for plant growth and development. It is immobile in plants and being a constituent of proteins, it is vital for the synthesis of the sulphur-containing amino acids- cysteine, cystine and methionine. The amino acids are indicators of the protein quality in plant (Scherer *et al*., 2008 and Abdallah *et al*., 2010).

The present study was conducted to evaluate the influence of nitrogen and sulphur on growth and yield of carrot (*Daucus carota* L.). Different levels of nitrogen increases the vegetative growth of carrot and different levels of sulphur also increases the quality of carrot root. Aiming this factors some objectives are undertaken for this study and they are-

i. To study the growth and yield responses of carrot in relation to different levels of nitrogen and sulphur application.

ii. To find out optimum level of nitrogen and sulphur for growth and yield of carrot.

CHAPTER II

REVIEW OF LITERATURE

Carrot draws much attention to the researchers throughout the world to develop its production technology. Use of nitrogen and sulphur fertilizers are to important factors for maximum yield and quality of a crop. Like many other root and tuber crops, the growth and yield of carrot are largely influenced by these two factors. A number of factors like emergence, soil moisture and temperature, plant growth and yields of the crop are closely related with these factors. Optimum dose of nitrogen and sulphur are necessary to ensure the quality and high yield of the crop. Although many research works have been done on various cultural aspects of carrot in different countries, unfortunately literature regarding studies on nitrogen and sulphur level under Bangladesh conditions is scanty. For this reason, available literature on carrot and other root crops related to present research work are reviewed in this chapter.

2.1. Literatures on nitrogen

Maurya and Goswami (1985) revealed that, nitrogen fertilizer application during growth stage of carrot increases plant height of carrot. Beside this it also increased the leaf number of carrot. After the application of over dose of nitrogen the length and diameter of carrot root was increased (Sarker, 1999; Batra and Kallo, 1990).

Sarker (1999) showed that nitrogen treatments significantly increased yield of carrot per hectare.

Nitrogen had significant influence on the growth and yield of carrot. The tallest plants (47.36 cm), highest number of leaves (11.61), highest root length (16.17 cm), maximum fresh weight of leaves (145.1 g), maximum dry matter content of leaves (11.66%), maximum dry matter content of root (15.90%), maximum fresh weight of root (68.33

g), maximum gross yield of root (22.55 t/ha) and maximum marketable yield of root (20.67 ton/ha) were found in 100 kg N per ha. Therefore, from the present study it may be concluded that, 100 kg N per ha were suitable for optimum growth and yield of carrot (Moniruzzaman *et al*., 2013).

A review by Mozafar (1993) summarizes the effects of N fertilization on the vitamin content of plants, including carrot. Fertilization with N, especially at high rates, decreases the concentration of vitamin C and increases the concentration of carotenes.

Musa *et al*. (2010) reported that the applied nitrogen significantly elevated ß-carotene content at maturity, while no significant variation was recorded at fruiting.

Nitrate accumulation in carrot root was measured from the carrot root which were grown in the Central European region, the values range from 50 to 500 mg NO_3kg^{-1} fresh weight FW) (Pokluda, 2006; Gutezeit, 1999; Mazur, 1992).

Increasing fertilizer rates increased nitrate accumulation over control in carrot (John *et al*., 2003). With 180 $kgNha^{-1}$ supply, a higher nitrate accumulation in carrot is possibly due to a greater uptake of nitrate than its utilization in plant physiological processes (Cantliffe, 1973).

Hartmann (1983) found increased soil nitrate concentrations and nitrate accumulation in plants under drought and inadequate watering conditions. Similar results were obtained by Augustin *et al*. (1977), who reported a two-fold increase in nitrate content due to insufficient irrigation.

Allaire-Leung *et al*. (2001) found that nitrate leaching was positively correlated to soil NO_3-N content but was not correlated to irrigation depth, irrigation uniformity, or deep percolation.

Van Der Boon *et al*. (1988) determined that increased soil and air temperatures reduce nitrate reductase activity consequently leading to an increase in nitrate content, as confirmed by the results of Calatayud *et al*. (2008).

The carrot genotypes tested had a significant effect ($P<0.05$) on nitrate content in the root. Lower nitrate content was found in the hybrid Almaro in both years, which was expected considering the genetic predisposition of the hybrid to reduce nitrate accumulation (Gutezeit and Fink, 1999; Lee *et al*., 1992; Anikeenko and Vintsunas, 1986; Cserni *et al*., 1983).

Amr and Nadidi (2001) reported a statistically significant effect of cultivar ($P\leq 0.05$) on the nitrate content in vegetables grown under both greenhouse and open field conditions. The distribution of accumulated nitrates in carrot roots in both years was uneven, gradually decreasing from the top to the bottom of the root. Higher nitrate levels were measured in the upper part of the root (332.5 mg NO_3kg^{-1} FW in 2005, that is, 524.1 mg NO_3kg^{-1} FW in 2006), which was statistically significant as compared to the lower part (247.5 mg NO_3kg^{-1} FW in 2005, that is, 262.8 mg NO_3 kg^{-1} FW in 2006). Similar nitrate distribution within carrot root was previously reported by Steer (1982), who found 90% of totally accumulated nitrate in the upper third of the root, that is, just below the top.

The physiological role of vitamin C is to produce protective effects in vegetables by decreasing nitrosoamine levels (Mc Knight *et al*., 1999; Beyers and Peery, 1992).

Stefanelli *et al*. (2010) reported that increased N applications resulted in increased vegetative growth and larger fruits, suggesting that the decline in ascorbic acid could, in part, be due to a dilution effect.

Cieślik (1994) found that the vitamin C content was highest at the lowest nitrate content, whereas Lisiewska and Kmiecik (1996) reported a decrease in vitamin C content as induced by the nitrogen rate increase from 80 to 120 kg/ha.

Lee and Kader (2000) associated the low vitamin C level in treatments with increased nitrate rates with rapid plant growth which provoked biological dilution of vitamin C. Cultivar Nantes had a statistically higher vitamin C level than Almaro, as expected by the genetic variability between these two genotypes.

Zushi and Matsuzoe (1998) reported a variable effect of water deficiency on vitamin C content. Vitamin C content is reduced by low water tension (Rudich *et al.*, 1977) as well as by PRD (Partial Root Zone Drying) (Du *et al.*, 2008). In view of the physiological importance of vitamin C, the use of high rates of nitrogen fertilizers should be avoided in carrot cultivation.

The level of ß-carotene in carrot roots was found to increase upon treatment with higher rates of nitrogen, which was in agreement with a previous study conducted by Chenard *et al*. (2005) and Cserni and Prohaszka (1988).

A lower carotene content was obtained by Evers (1989) using the nitrogen rate of 150 kg/ha, which had no effect on carotene content as compared to the 80 kg/ha rate.

Previous studies reported few data on the effect of water deficiency on ß-carotene content, except in tomatoes. Matsuzoe *et al*. (1998) found that water deficiency resulted in an increase in ß-carotene content in three cherry tomato cultivars and produced no effect in one cultivar. Zushi and Matsuzoe (1998) suggested that water stress had no effect on ß-carotene content in tomatoes, which is in agreement with the results of the present study on carrot.

The carrot genotypes tested showed a statistically significant difference in ß-carotene level in both years. Genetic variability regarding this quality trait was determined by Kalt (2005), Alasalvar *et al*. (1998, 2001) and Hart and Scott (1995).

Boskovic-Rakocevic *et al*. (2012) conducted a study and concluded that, the effect of increasing nitrate fertilization rates on the vitamin C and ß-carotene content of the root in two carrot genotypes suggest that: Nitrate accumulation in carrot roots was directly affected by nitrogen rate, with nitrate level being statistically different ($P<0.05$) at all rates applied. The highest level of vitamin C was found in non-fertilized soil with significant differences between the increasing rates of nitrogen. ß-carotene content increased with increasing rates of nitrogen and was found to be statistically significant even at 120 and 180 $kgNha^{-1}$, as compared to both the control and 60 $kgNha^{-1}$ rate.

2.2. Literatures on sulphur

Singh *et al*. (2016) conducted an experiment on carrot to evaluate the effect of sulphur nutrient on carrot and observed that, the application of sulphur up to 30 and 45 kg/ha significantly increased the edible root yields and dry matter production of carrot and radish , respectively.

Wafaa (2013) conducted an experiment and showed that the dry mass of carrot had increased significantly with the increase of sulphur fertilizer rates. The highest sulphur rate (400 kg fed^{-1}) produced carrot dry mass significantly more as compared to those plants that received control or sulphur at a rate of 100 and 200 kg fed^{-1}. The differences between 100 and 200 kg fed^{-1}were found to be not-significant. He also found that in the case of sulphur treatment, the total soluble, solid, sugar contents and protein content of carrots tended to be greater than where no sulphur was applied. The total soluble solid, sugar contents and protein contents significantly affected by sulphur application to soil. The highest of these parameters were observed with S_{400} treatment.

Kaya *et al*. (2009) reported that increased application of sulphur and sulphur-containing waste led to a significant increase in copper content of plants.

Elemental sulphur is biologically oxidized to H_2SO_4 in soil under aerobic conditions. The oxidation of S to H_2SO_4 is particularly beneficial in alkaline soils to reduce pH, make micronutrients more available and reclaim soils. They also reported a significant positive correlation between the $SO^{=}_4$-S content and electrical conductivity (EC) of tomato greenhouse soils. The generated soil salinity was high with increasing sulphur applications, which indicates that plants might be subjected to high salinity problems. High rates of elemental sulphur should be avoided, especially in soils with high EC level. Soil properties (especially EC and pH) and cultivated plant species should be taken into consideration in the recommendations for sulphur application to soils. Previous studies indicated that while the soil pH was decreased, soil EC was increased in soil by sulphur Orman and Kaplan (2011).

Wafaa (2013) concluded that initial soil EC before sulphur treatments is highly important. Therefore, this should be taken into consideration when making recommendation for sulphur applications to lower pH of soils, especially of high salt content. Non - saline soil may become slightly saline and also, a slightly saline soil may become moderately or highly saline due to sulphur applications.

Kaya *et al*. (2009) reported that the application of sulfur and sulfur-containing waste resulted in decrease in soil pH, but it also increased the concentrations of nutrients available to plants, such as Zn, Cu and Mn. Sulphur decreased soil pH and increases

EC of soil, availability and mobility of heavy metals (Cui *et al*., 2004 and Martinez and Motto, 2000).

Decreases in values of soil pH were accompanied by increases in the extractable Fe and its availability to plants. Fe is also strongly affected by oxidation-reduction reactions which largely depend on the soil moisture content (Nube and Voortman, 2006 and Kabata-Pendias, 2004).

Sulphur fertilization had significant effect on changes in the Cu content of soil. This could result from changes in soil pH. In a study carried out by Takáč *et al*. (2009), the content of mobile Cu in the soil was not significantly affected by soil pH. Soil pH is known to regulate bioactivity and availability of nutrients to plants, because H+ protons are involved in chemical equilibrium. Vicente *et al*. (2009) and Jaggi *et al*. (2005) claimed that the availability of copper to plants, as with other trace minerals, markedly decreases as pH value rises. At high pH value copper is strongly adsorbed to clays, iron and aluminum oxides, and organic matter.

Elemental sulphur fertilization increased Mn concentrations in the soil, in comparison with the control. The application of 400 kg sulphur contributed to an increase in Mn content (5.41mgkg^{-1}), compared with other sulphur doses. One of the adverse effects of sulphur contamination is an increase in Mn solubility and the mobilization of heavy metals from both natural and anthropogenic sources (Abdou *et al*., 2011).

Kayser *et al*. (2001) demonstrated that the application of elemental sulphur increased zinc solubility in the soil and utilization by plants. Different results were obtained by Abdou *et al*. (2011) who did not observe an increase in zinc availability to plants as a result of elemental sulfur fertilization.

Vicente *et al*. (2009) claim that the availability of copper to plants, as with other trace minerals, markedly decreases as pH value rises above save. At high pH value copper is strongly adsorbed to clays, iron and aluminum oxides, and organic matter. Of the micronutrients required by plants, Cu often has the lowest total concentration in soil.

CHAPTER III

MATERIALS AND METHOD

This chapter deals with the materials and methods that were used in carrying out the experiment.

3.1 Location of the experiment field

The experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during January 2019 to February 2020. The location of the experimental site was at 23°75' N latitude and 90°34' E longitude with an elevation of 8.2 meter from sea level (Anon., 1989).

3.2 Climate of the experimental area

The experimental area is characterized by subtropical rainfall during the month from May to September and scattered rainfall during the rest of the year. Information regarding average monthly, soil temperature as recorded by Bangladesh Meteorological Department (climate division) Agargoan, Dhaka, during the period of study have been presented in Appendix I.

3.3 Soil of the experimental field

Soil of the study site was salty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with PM 5.8-6.5, ECE-25.28 (Haider *et al.*, 1991). The analytical data of the soil sample collected from the experimental area were determined in the soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Planting materials

The seeds of carrot cv. New Kuroda (a Japanese verity) were used in the experiment. The seeds of Snow Brand Co. Ltd., Tokyo, Japan were collected from Nadim Seed Store, Siddique Bazar, Dhaka.

3.5 Treatments of the experiment

The experiment was a two factorial designed to study the effect of different levels of nitrogen and sulphur on growth and yield of carrot. The experiment consisted of the following treatments:

Factor A: Nitrogen level

N_0= 0 kg N/ha

N_1= 40 kg N/ha

N_2= 80 kg N/ha

N_3= 120 kg N/ha

Factor B: Sulphur level

S_0= 0 kg S/ha

S_1= 5 kg S/ha

S_2= 10 kg S/ha

There were 12 (4×3) treatments combination such as N_0S_0, N_0S_1, N_0S_2, N_1S_0, N_1S_1, N_1S_2, N_2S_0, N_2S_1, N_2S_2, N_3S_0, N_3S_1 and N_3S_2.

3.6 Experimental design and layout

The experiment was conducted in Randomized Complete Block Design (RCBD) having two factors with three replications. The total area of the experimental plot was 82.2 m^2 (13.7m × 6m) which was divided into three equal blocks and each block was divided into 12 unit plots. The size of each plot was 1m × 0.6 m. Thus, there were 36 (12 × 3) unit plots altogether in the experiment. The distance between blocks were 1.0 m and 0.5 m wide drain was made between the plot to facilities different intercultural operations.

The complete layout of the experimental plot has been shown in figure 1:

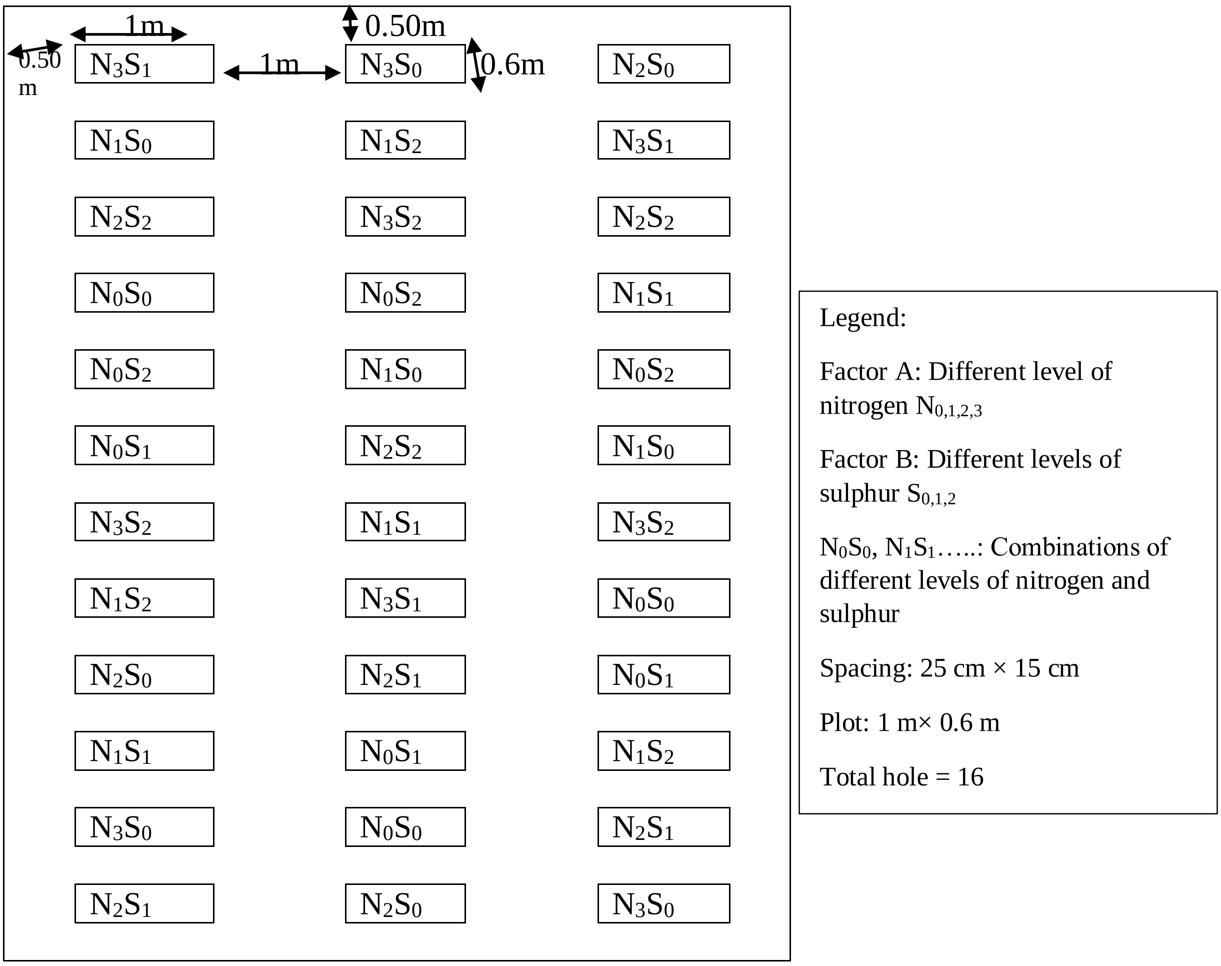


Figure 1: Field layout of the two factors experiment in the Randomized Complete Block Design (RCBD)

3.7. Cultivation procedure

3.7.1. Land preparation

The soil was well prepared and good tilth was ensured for commercial crop production. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready.

3.7.2. Application of manure and fertilizers

The following doses of manures and fertilizers recommended by Rashid, (1999) were applied to the experimental plots to grow the crop as below:

Manure/Fertilizers	Dose/ha	Dose/plot*
Cow dung	10 tons	1.50 kg
Urea	As per treatment	
TSP	125 kg	18.75 g
MoP	125 kg	18.75 g
Sulphur	As per treatment	

*= Unit plot size was 1m × 0.6m = 0.6 m^2

Nitrogen was applied at the rate of 0, 40, 80 & 120 Kg N per hectare in the form of urea as factor A and sulphur was applied at the rate of 0, 5 and 10 kg S per hectare in the form of gypsum as factor B. The entire amount of cow dung was applied at the time of initial land preparation and the total amount of TSP and MoP were applied during the final land preparation. Nitrogen and sulphur as per treatment schedule were top-dressed at 30 days after sowing the seeds.

3.8 Seed soaking

Before sowing, the seed were soaked in water for 24 hours and then wrapped with a piece of thin cloth prior to planting. Then the moistened seeds were spread over polythene sheet for two hours to dry out the surface water, this operation was to facilitate for quick germination of seeds.

3.9 Sowing of seeds

The soaked seeds @ 3 Kg/ha (Rikabdar, 2000) were sown on 30 January, 2019. Shallow furrows with 1.5 cm depth were made at a distance of 15cm along the rows spaced at a distance of 25 cm. There were 16 holes in each unit plots and four to ten seeds were placed in each hole and immediately after sowing covered with loose soil.

3.10 Intercultural operations

3.10.1 Thinning

Emergence of seedlings started after 6 days from the date of sowing. Seedlings were thinned out two times. First thinning was done after 20 days of sowing (DAS), leaving four seedling in each hill .The second thinning was done after 10 days from first thinning, keeping one, two & three healthy seedling in each hill as per requirement.

3.10.2. Weeding

Weeding was done as and necessary to keep the crop free from weeds, for better soil aeration and to break the crust and to achieve good quality of carrot roots. Generally weeding was done four times.

3.10.3 Irrigation

The field was irrigated five times during the whole period of plant growth. Just after sowing light watering was done with fine watering cane at first time. Surface crust was broken after each irrigation, The second, third, fourth and fifth watering were done at 20 , 35, 55 .and 75 days after sowing of seeds respectively.

3.11 Plant protection

3.11.1 Insect pest

The crop was infested with cut warm (*Agrostis ipsilon*), mole cricket, field cricket during the early stage of growth of seedlings. These insects were controlled by spraying Dursban 20 EC at the contrition of 0.2% at 15 days interval for three times starting from 20 days after sowing.

3.11.2 Diseases

At early growth stage some of the plants affected by foot root disease which was controlled by Ridomil MZ 72 WP at the rate of 2.5 g/L of water.

3.12 Harvesting

The crop was harvested on 15 May, 2019 after 105 days from seed sowing when the foliage turned pale yellow (Bose and Som, 1990). Rikabdar (2000) suggested that carrots should be harvested in Bangladesh within 90-105 days after sowing for maximum yield and quality. The crop was harvested plot wise carefully by hand. The soil and fibrous roots and hearing to the roots were cleaned with cloth. Ten plants were selected at random and uprooted very carefully from each unit plot at the time of harvest and mean data on the following parameters were recorded.

3.13 Parameters assessed

Growth stage

1. Plant height

2. Number of leaves per plant

3. Length of leaves per plant

4. Fresh weight of plant

5. Dry weight of plant

Yield parameter

6. Length of root

7. Diameter of root

8. Cracked roots per plot

9. Rotten roots per plot

10. Dry weight of root

11. Gross yield/ha

3.14 Collection of data

Five plants per plot were sampled in the middle rows and marked by bamboo stick for collection of per plant data while the crop of whole plot was harvested to record per plant data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random sampling to avoid the border effect.

3.14.1 Plant height

In order to measure the plant height, a centimeter (cm) by a meter scale at 45,60,75 and 90 days after sowing (DAS) from the point of the attachment of the leaves to the root (ground level) up to the tip of the longest leaf.

3.14.2 Number of leaves per plant

Number of leaves per plant of 10 sampled hills were counted at 45, 60, 75 and 90 DAS. All the leaves of the plants were counted separately. Only the smallest young leaves at the growing point of the plant were excluded from the counting.

3.14.3 Length of leaves per plant

The average length of the leaves was recorder in cm by a meter scale from the point of attachment of the leaves (proximal end) to the last point of the leaves (distal end) in each treatment combination.

3.14.4 Length of root per plant

The average length of the root was recorder in cm by a meter scale from the point of attachment of the leaves (proximal end) to the last point of the root (distal end) in each treatment combination.

3.14.5 Diameter of root per plant

The average diameter of the root was measured at the thickest portion of the root at harvest with the help of a slide caliper.

3.14.6 Fresh weight of plant

Plants were detached by a sharp knife and 100 g fresh weight was recorded in gram (g).

3.14.7 Dry weight of plant

Plants were detached by a sharp knife and 100 g dry weight was recorded in gram (g).

3.14.8 Cracked roots per plot

At the time of harvest, the number of cracked roots were counted. Cracked root percentage was calculated by using the following formula—

Cracked root (%) = $\frac{Number\ of\ cracked\ roots}{Number\ of\ total\ roots} \times 100$

3.14.9 Rotten roots per plot

At, harvest the number of rotten roots were counted and the result was calculated on percentage basis as per the following formula-

Rotten root (%) = $\frac{Number\ of\ rotten\ roots}{Number\ of\ total\ roots} \times 100$

3.14.10 Dry weight of root

Roots were detached by a sharp knife and 100 g dry weight was recorded in gram (g).

3.14.11 Total yield of roots per hectare

The yield of roots per hectare was computed from the per plot yield and was recorded in tones.

3.15 Statistical analysis

The data collected from the experimental plots were statistically analyzed according to final out the variation(s) by MSTATC. The significance of difference between pair of means were performed by Duncan's Multiple Range Test (DMRT) test at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the present study have been presented and discussed in this chapter. To achieve the stated objectives of the study two different phases as mentioned earlier are presented separately. Data on different parameters were analyzed statistically and the results have been presented in Tables and Figures for easy discussion. The results of each parameter have been discussed and interpreted in this chapter:

4.1. Plant height

Statistically significant variation was recorded among different nitrogen level on the plant height of carrot (App. III). Data revealed that, the maximum plant height (28.33 cm) was showed at the applying nitrogen fertilizer @ 120 kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum plant height (18.33 cm) was showed at not applying nitrogen fertilizer @ 0 kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al.* (2013) and Stefanelli *et al.* (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

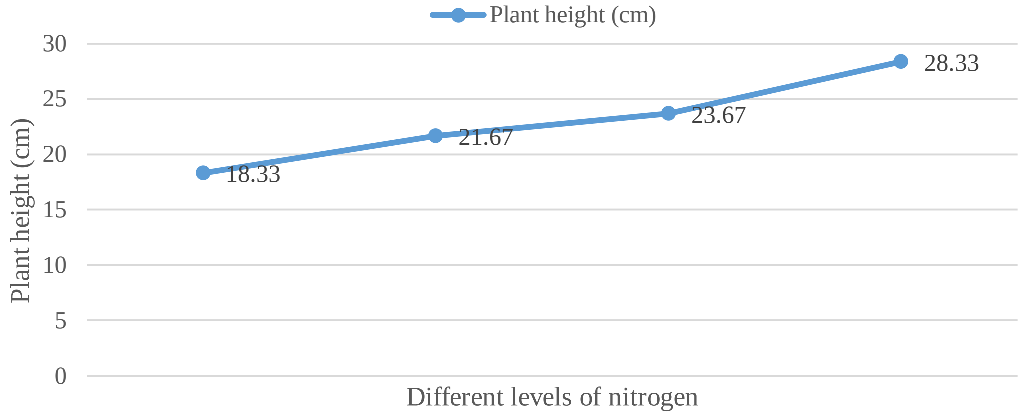


Figure 2: Effect of different levels of nitrogen on plant height of carrot

Statistically significant variation was recorded among different sulphur level on the plant height of carrot (App. III). Data revealed that, the maximum plant height (26.67 cm) was showed at the applying nitrogen fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum plant height (16.67 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al.* (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

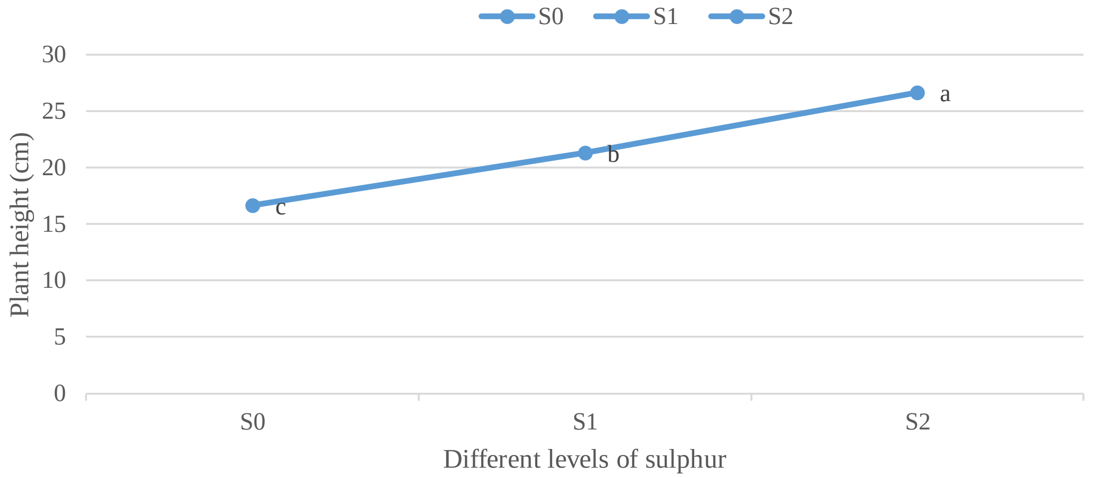


Figure 3: Effect of different levels of sulphur on plant height of carrot

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on plant height of carrot (App. III). The maximum plant height (30.33 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the others and followed by N_3S_1 (27.67 cm), N_2S_2 (26.67), N_2S_1 (26.33), N_1S_2 (25.33), N_1S_1 (24.67) and N_0S_2 (24.33 cm). The minimum plant height (15.33 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (16.33), N_2S_0 (18.67), N_1S_0 (20.33) and N_3S_0 (22.33 cm).

4.2. Number of leaves

Statistically significant variation was recorded among different nitrogen level on the number of leaves of carrot (App. III). Data revealed that, the maximum number of leaves (20.36 leaves) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum number of leaves (12.37 leaves) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Statistically significant variation was recorded among different sulphur level on the number of leaves of carrot (App. III). Data revealed that, the maximum number of leaves (17.77 leaves) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum number of leaves (10.67 leaves) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on the number of leaves of carrot (App. III). The maximum number of leaves (22.37 leaves) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically similar with N_3S_1 (21.77 leaves) and N_2S_2 (21.33) and followed by N_2S_1 (20.67), N_1S_2 (18.78), N_1S_1 (16.67) and N_0S_2 (16.37 leaves). The minimum number of leaves (10.67 leaves) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (12.33), N_2S_0 (12.67), N_1S_0 (13.36) and N_3S_0 (15.36 leaves).

4.3. Length of leaves

Statistically significant variation was recorded among different nitrogen level on the length of leaves of carrot (App. III). Data revealed that, the maximum length of leaves (18.87 cm) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum length of leaves (8.87 cm) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al.* (2013) and Stefanelli *et al.* (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Statistically significant variation was recorded among different sulphur level on the length of leaves of carrot (App. III). Data revealed that, the maximum length of leaves (18.67 cm) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum length of leaves (8.33 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al.* (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on length of leaves of carrot (App. III). The maximum length of leaves (19.67 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the others and followed by N_3S_1 (17.36 cm), N_2S_2 (16.67), N_2S_1 (15.33), N_1S_2 (14.67), N_1S_1 (13.33) and N_0S_2 (12.76 cm). The minimum length of leaves (7.67 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically similar with N_0S_1 (8.67 cm) and followed by N_2S_0 (9.87), N_1S_0 (10.33) and N_3S_0 (10.67 cm).

4.4. Fresh weight of plant

Statistically significant variation was recorded among different nitrogen level on the fresh weight of plant of carrot (App. IV). Data revealed that, the maximum weight of plant (67.33 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum weight of plant (42.67 g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Statistically significant variation was recorded among different sulphur level on the fresh weight of plant of carrot (App. IV). Data revealed that, the maximum weight of plant (65.67 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum weight of plant (40.67 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*.

(2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on fresh weight of plant of carrot (App. IV). The maximum fresh weight of plant (72.47 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the others and followed by N_3S_1 (68.87 g), N_2S_2 (67.63), N_2S_1 (64.67), N_1S_2 (63.36), N_1S_1 (61.36) and N_0S_2 (60.67 g). The minimum fresh weight of plant (38.87 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically similar with N_0S_1 (40.36) and followed by N_2S_0 (53.33), N_1S_0 (56.78) and N_3S_0 (58.33 g).

4.5. Dry weight of plant

Statistically significant variation was recorded among different nitrogen level on the dry weight of plant of carrot (App. IV). Data revealed that, the maximum dry weight of plant (8.31 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum dry weight of plant (5.33 g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Table 1: Effect of different levels of nitrogen on plant height, number of leaves, length of leaves, fresh weight of plant and dry weight of plant (g) of carrot

Nitrogen level	Number of leaves	Length of leaves	Fresh weight of plant (g)	Dry weight of plant (g)
N_0	12.37 d	8.87	42.67 d	5.33 d
N_1	15.33 c	12.67	48.67 c	6.36 c
N_2	18.27 b	16.33	56.36 b	7.67 b
N_3	20.36 a	18.87	67.33 a	8.31 a
LSD $_{(0.05)}$	1.16	1.23	1.21	0.55
CV (%)	0.56	0.56	0.39	0.36

Here, N_0 = 0 kg N/ha, N_1= 40 kg N/ha, N_2= 80 kg N/ha, $N_{3=}$ 120 kg N/ha

Statistically significant variation was recorded among different sulphur level on the dry weight of plant of carrot (App. IV). Data revealed that, the maximum dry weight of plant (8.21 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum dry weight of plant (4.77 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Table 2: Effect of different levels of sulphur on plant height, number of leaves, length of leaves, fresh weight of plant and dry weight (g) of plant of carrot

Sulphur level	Number of leaves	Length of leaves	Fresh weight of plant (g)	Dry weight of plant (g)
S_0	10.67 c	8.33 c	40.67 c	4.77 c
S_1	14.36 b	13.36 b	53.33 b	6.33 b
S_2	17.77 a	18.67 a	65.67 a	8.21 a
LSD $_{(0.05)}$	1.33	1.31	1.23	1.19
CV (%)	0.46	0.41	0.56	0.43

Here, S_0= 0 kg S/ha, S_1= 5 kg S/ha and S_2= 10 kg S/ha

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on dry weight of plant of carrot (App. IV). The maximum dry weight of plant (8.86 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically similar with N_3S_1 (8.21 g), N_2S_2 (7.86), N_2S_1 (7.19), N_1S_2 (6.67), N_1S_1 (6.43) and N_0S_2 (6.21 g). The minimum dry weight of plant (4.77 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (5.21), N_2S_0 (5.36), N_1S_0 (5.76) and N_3S_0 (6.19 g).

Table 3: Combined effect of nitrogen level and sulphur level on plant height, number of leaves, length of leaves, fresh weight of plant and dry weight (g) of plant of carrot

Combinations	Plant height (cm)	Number of leaves	Length of leaves (cm)	Fresh weight of plant (g)	Dry weight of plant (g)
N_0S_0	15.33 i	10.67 h	7.67 h	38.87 i	4.77 f
N_0S_1	16.33 h	12.33 g	8.67 h	40.36 i	5.21 e
N_0S_2	24.33 d	16.37 de	12.76 e	60.67 e	6.21 d
N_1S_0	20.33 f	13.36 f	10.33 g	56.78 g	5.76 d
N_1S_1	24.67 d	16.67 d	13.33 e	61.36 e	6.43 d
N_1S_2	25.33 c	18.78 c	14.67 d	63.36 d	6.67 c
N_2S_0	18.67 g	12.67 fg	9.87 g	53.33 gh	5.36 e
N_2S_1	26.33 bc	20.67 b	15.33 cd	64.67 cd	7.19 c
N_2S_2	26.67 bc	21.33 ab	16.67 c	67.63 bc	7.86 b
N_3S_0	22.33 e	15.36 e	10.67 f	58.33 f	6.19 d
N_3S_1	27.67 b	21.77 ab	17.36 b	68.87 b	8.21 ab
N_3S_2	30.33 a	22.37 a	19.67 a	72.47 a	8.86 a
CV (%)	6.79	4.47	8.32	8.69	5.57
LSD $_{(0.05)}$	2.601	0.285	2.223	2.358	1.795

Here, N_0= 0 kg N/ha, N_1= 40 kg N/ha, N_2= 80 kg N/ha, $N_{3=}$ 120 kg N/ha, S_0= 0 kg S/ha, S_1= 5 kg S/ha and S_2= 10 kg S/ha

4.6. Length of root

Statistically no significant variation was recorded among different nitrogen level on the length of root of carrot (App. IV). Data revealed that, the maximum length of root (8.33 inch) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically similar with other nitrogen level which were applied as treatment. Whereas, the minimum length of root (5.33 inch) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot. This confirms the report of Moniruzzaman *et al*. (2013)

and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Statistically significant variation was recorded among different sulphur level on the length of root (inch) of carrot (App. IV). Data revealed that, the maximum length of root (7.67 inch) was showed at the applying nitrogen fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum length of root (5.67 inch) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on length of root of carrot (App. IV). The maximum length of root (10.33 inch) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically similar with N_3S_1 (9.67 inch) and N_2S_2 (9.67) and followed by N_2S_1 (9.33), N_1S_2 (9.33), N_1S_1 (8.67) and N_0S_2 (8.33 inch). The minimum length of root (5.33 inch) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically similar with N_0S_1 (5.67), N_2S_0 (6.67), N_1S_0 (7.33) and N_3S_0 (7.67 inch).

4.7. Diameter of root

Statistically significant variation was recorded among different nitrogen level on the diameter of root of carrot (App. V). Data revealed that, the maximum diameter of root (5.67 cm) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum diameter of root (3.87 cm) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Statistically significant variation was recorded among different sulphur level on the diameter of root (cm) of carrot (App. V). Data revealed that, the maximum diameter of root (6.67 cm) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum diameter of root (4.67 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on the diameter of root of carrot (App. V). The maximum diameter of root (8.33 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from other treatments and followed by N_3S_1 (7.77 cm), N_2S_2 (7.33), N_2S_1 (7.33), N_1S_2 (6.67), N_1S_1 (6.33) and N_0S_2 (6.33 cm). The minimum diameter of root (2.67 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (3.33), N_2S_0 (4.33), N_1S_0 (4.67) and N_3S_0 (5.67 cm).

4.8. Dry weight of root

Statistically significant variation was recorded among different nitrogen level on the dry weight of root of carrot (App. V). Data revealed that, the maximum dry weight of root (71.33 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum dry weight of root (43.87g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

Table 4: Effect of different levels of nitrogen on length of root, diameter of root and dry weight of root (g) of carrot

Nitrogen level	Length of root (inch)	Diameter of root (cm)	Dry weight of root (g)
N_0	5.33 a	3.87 b	43.87 d
N_1	6.67 a	4.67 ab	56.97 c
N_2	7.67 a	5.33 a	63.58 b
N_3	8.33 a	5.67 a	71.33 a
LSD $_{(0.05)}$	4.23	5.56	5.56
CV (%)	0.33	0.43	0.76

Here, N_0 = 0 kg N/ha, N_1= 40 kg N/ha, N_2= 80 kg N/ha, $N_{3=}$ 120 kg N/ha

Statistically significant variation was recorded among different sulphur level on the dry weight of root (g) of carrot (App. V). Data revealed that, the maximum dry weight of root (77.36 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum dry weight of root (46.67 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

Table 5: Effect of different levels of sulphur on length of root, diameter of root and dry weight of root (g) of carrot

Sulphur level	Length of root (inch)	Diameter of root (cm)	Dry weight of root (g)
S_0	5.67 b	4.67 b	46.67 c
S_1	6.33 ab	5.33 ab	55.17 b
S_2	7.67 a	6.67 a	77.36 a
LSD $_{(0.05)}$	3.56	4.46	4.89
CV (%)	0.52	0.31	0.52

Here, S_0= 0 kg S/ha, S_1= 5 kg S/ha and S_2= 10 kg S/ha

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on dry weight of roots of carrot (App. V). The maximum dry weight of roots (78.87 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the others and followed by N_3S_1 (75.23 g), N_2S_2 (73.49), N_2S_1 (71.77), N_1S_2 (67.41), N_1S_1 (63.33) and N_0S_2 (62.29 g). The minimum dry weight of roots (41.87 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (46.67 g), N_2S_0 (52.89), N_1S_0 (55.56) and N_3S_0 (57.87 g).

Table 6: Combined effect of nitrogen level and sulphur level on length of root, diameter of root and dry weight of root (g) of carrot

Combinations	Length of root (cm)	Diameter of root (cm)	Dry weight of root (g)
N_0S_0	5.33 d	2.67 g	41.87 h
N_0S_1	5.67 d	3.33 f	46.67 g
N_0S_2	8.33 b	6.33 c	62.29 d
N_1S_0	7.33 cd	4.67 e	55.56 e
N_1S_1	8.67 b	6.33 c	63.33 d
N_1S_2	9.33 b	6.67 c	67.41 d
N_2S_0	6.67 d	4.33 e	52.89 f
N_2S_1	9.33 b	7.33 b	71.77 c
N_2S_2	9.67 ab	7.33 b	73.49 b
N_3S_0	7.67 bc	5.67 d	57.87 e
N_3S_1	9.67 ab	7.67 b	75.23 b
N_3S_2	10.33 a	8.33 a	78.87 a
CV (%)	5.89	8.92	7.67
LSD $_{(0.05)}$	0.255	0.389	0.195

Here, N_0= 0 kg N/ha, N_1= 40 kg N/ha, N_2= 80 kg N/ha, $N_{3=}$ 120 kg N/ha, S_0= 0 kg S/ha, S_1= 5 kg S/ha and S_2= 10 kg S/ha

4.9. Percent cracked roots

Statistically significant variation was recorded among different nitrogen level on the percent cracked roots of carrot per plot (App. V). Data revealed that, the minimum percent of cracked roots (0.89 %) per plot was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the maximum percent cracked roots (2.23 %) per plot was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

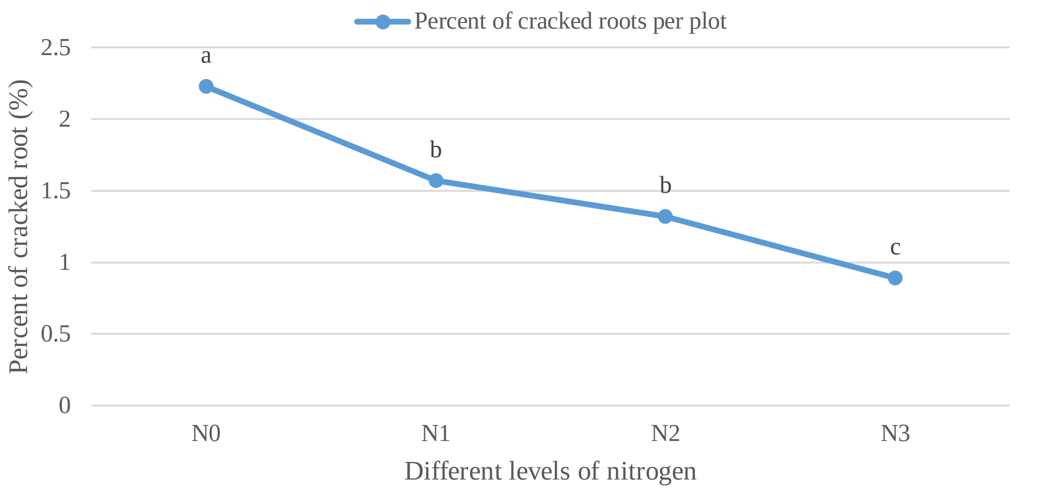


Figure 4: Effect of different levels of nitrogen on the percent of cracked roots per plot of carrot

Statistically significant variation was recorded among different sulphur level on the percent of cracked roots (%) of carrot (App. V). Data revealed that, the minimum percent of cracked roots (0.93 %) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the maximum percent of cracked roots (2.19 %) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

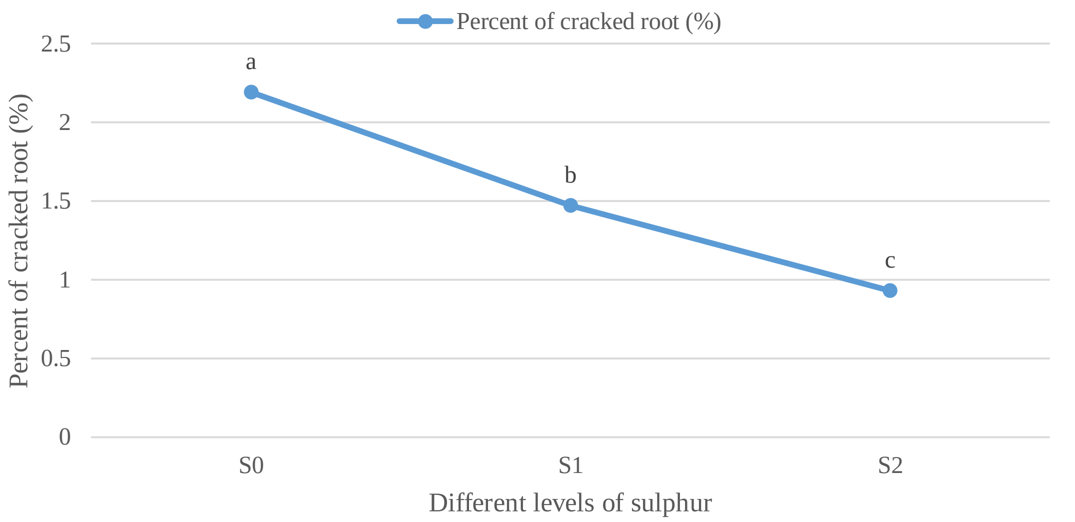


Figure 5: Effect of different levels of sulphur on the percentage of cracked roots per plot of carrot

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on percent of cracked root of carrot (App. V). The minimum percent of cracked root (0.73 %) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the others and followed by N_3S_1 (0.86 %), N_2S_2 (0.98 %), $N7_2S_1$ (1.13), N_1S_2 (1.29), N_1S_1 (1.37) and N_0S_2 (1.56 %). The maximum percent of cracked root (2.78 %) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically similar with N_0S_1 (2.57) and followed by N_2S_0 (2.19), N_1S_0 (1.78) and N_3S_0 (1.67 %).

4.10. Percent rotten roots

Statistically significant variation was recorded among different nitrogen level on the percent rotten roots of carrot per plot (App. VI). Data revealed that, the minimum percent rotten roots (0.53 %) per plot was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the maximum percent rotten roots (1.87 %) per plot was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

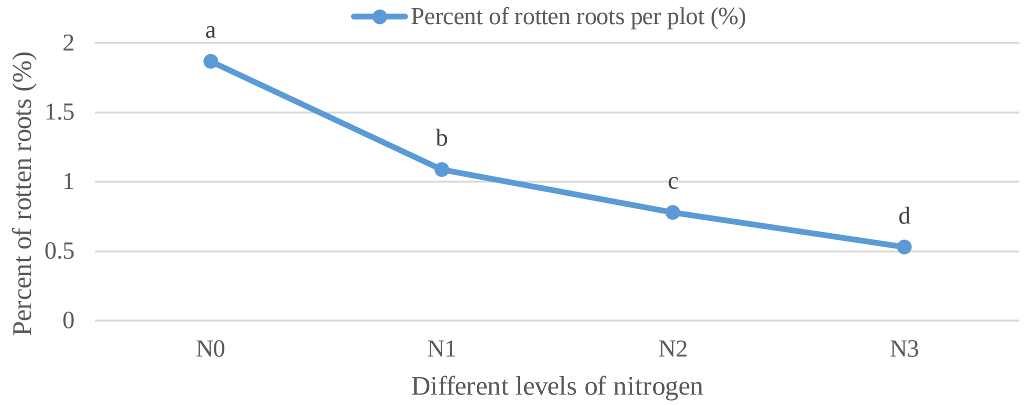


Figure 6: Effect of different levels of nitrogen on the percent of rotten roots per plot of carrot

Statistically significant variation was recorded among different sulphur level on the percent of rotten roots (%) of carrot (App. VI). Data revealed that, the minimum percent of rotten roots (0.49 %) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the maximum percent of rotten roots (1.11 %) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al*. (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

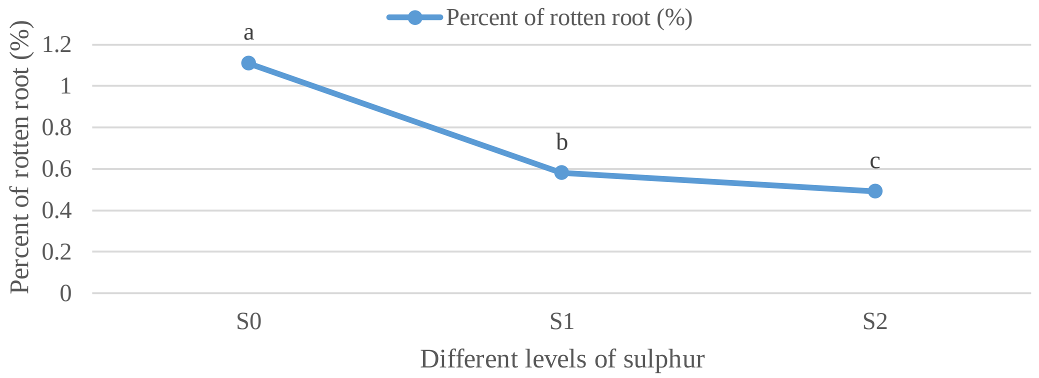


Figure 7: Effect of different levels of sulphur on the percentage of rotten roots per plot of carrot

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on percent of rotten roots of carrot (App. VI). The minimum percent of rotten roots (0.36 %) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically different from the other treatments and followed by N_3S_1 (0.43 %), N_2S_2 (0.49), N_2S_1 (0.56), N_1S_2 (0.59), N_1S_1 (0.67) and N_0S_2 (0.76 %). The maximum percent of rotten root (1.38 %) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically different from the other treatments and followed by N_0S_1 (1.27), N_2S_0 (1.11), N_1S_0 (0.93) and N_3S_0 (0.88 %).

4.11. Yield

Statistically significant variation was recorded among different nitrogen level on the yield of carrot (App. VI). Data revealed that, the maximum yield (ton/ha) of carrot (21.17 ton/ha) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. Whereas, the minimum yield (ton/ha) of carrot (16.23 ton/ha) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot, which was statistically different from other nitrogen level which were applied as treatment. This confirms the report of Moniruzzaman *et al*. (2013) and Stefanelli *et al*. (2010) that, the nitrogen level increased vegetative growth and larger fruits of carrot.

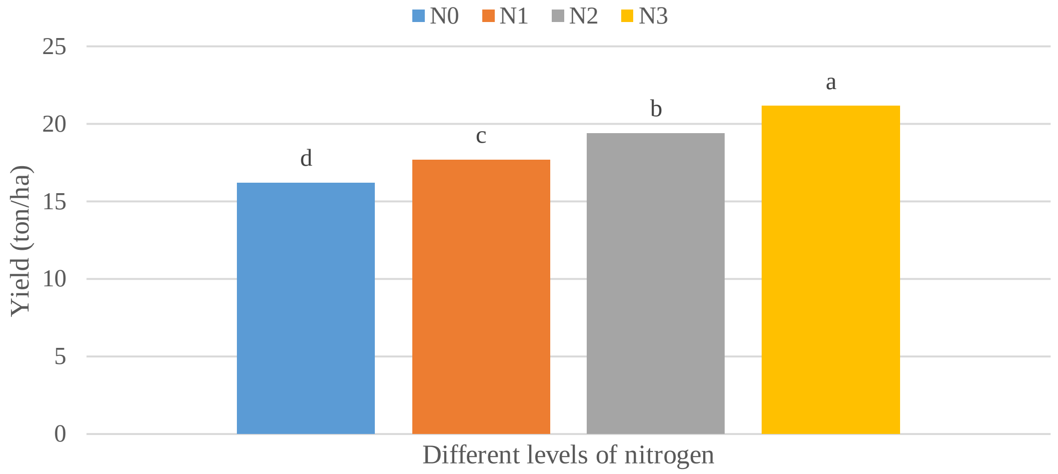


Figure 8: Effect of different levels of nitrogen on the yield of carrot

Statistically significant variation was recorded among different sulphur level on the yield (ton/ha) of carrot (App. VI). Data revealed that, the maximum yield (20.53 ton/ha) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. Whereas, the minimum yield (16.11 ton/ha) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot, which was statistically different from other sulphur level which were applied as treatment. This confirms the report of Singh *et al.* (2016) and Wafaa (2013) that, the sulphur level increased vegetative growth and fruit quality of carrot.

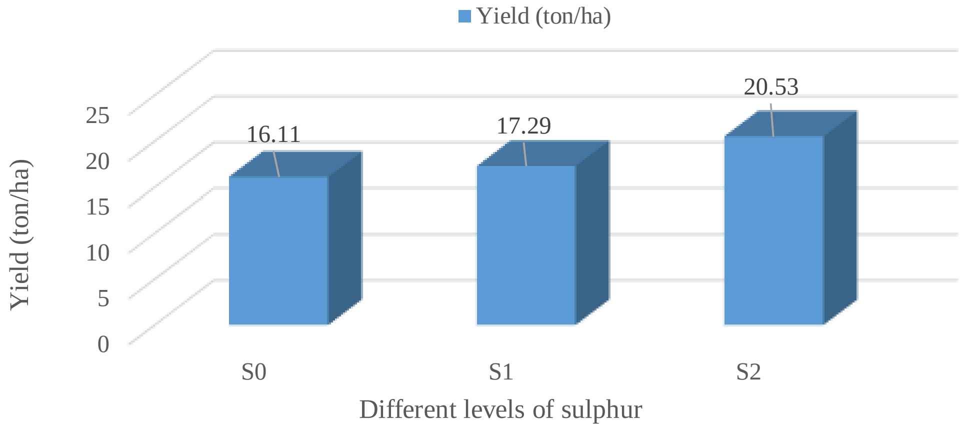


Figure 9: Effect of different levels of sulphur on the yield of carrot

Combined effect of different level of nitrogen and sulphur expressed significant differences due to their interaction effect on yield of carrot (App. VI). The maximum yield (22.21 ton/ha) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2) which was statistically similar with N_3S_1 (21.87 ton/ha) and followed by N_2S_2 (20.88), N_2S_1 (20.19), N_1S_2 (19.73), N_1S_1 (19.47) and N_0S_2 (18.72 ton/ha). The minimum yield (15.78 ton/ha) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0) which was statistically similar with N_0S_1 (16.27) and followed by N_2S_0 (16.92), N_1S_0 (17.89) and N_3S_0 (18.33 ton/ha).

Table 7: Combined effect of nitrogen and sulphur on yield attributing characters and yield of carrot

Combinations	Percent cracked roots per plot (%)	Percent rotten roots per plot (%)	Yield (ton/ha)
N_0S_0	2.78 a	1.38 a	15.78 g
N_0S_1	2.57 a	1.27 b	16.27 fg
N_0S_2	1.56 d	0.76 c	18.72 c
N_1S_0	1.78 c	0.93 c	17.89 d
N_1S_1	1.37 de	0.67 d	19.47 c
N_1S_2	1.29 e	0.59 d	19.73 c
N_2S_0	2.19 b	1.11 bc	16.92 e
N_2S_1	1.13 f	0.56 d	20.19 b
N_2S_2	0.98 f	0.49 de	20.88 b
N_3S_0	1.67 cd	0.88 c	18.33 d
N_3S_1	0.86 f	0.43 de	21.87 a
N_3S_2	0.73 g	0.36 e	22.21 a
CV (%)	5.97	5.36	2.12
LSD $_{(0.05)}$	0.244	0.227	2.45

Here, N_0= 0 kg N/ha, N_1= 40 kg N/ha, N_2= 80 kg N/ha, $N_{3=}$ 120 kg N/ha, S_0= 0 kg S/ha, S_1= 5 kg S/ha and S_2= 10 kg S/ha

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Horticulture farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from January 2019 to February 2020. From the results and discussion of this study some summary and conclusion were figured out and they were:

The maximum plant height (28.33 cm) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum plant height (18.33 cm) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum number of leaves (20.36 leaves) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum number of leaves (12.37 leaves) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum length of leaves (18.87 cm) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum length of leaves (8.87 cm) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum fresh weight of plant (67.33 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum fresh weight of plant (42.67 g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum dry weight of plant (8.31 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum dry weight of plant (5.33 g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum length of root (8.33 inch) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum length of root (5.33 inch) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum diameter of root (5.67 cm) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum diameter of root (3.87 cm) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum dry weight of root (71.33 g) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum dry weight of root (43.87 g) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The minimum percent of cracked roots (0.89 %) per plot was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the maximum percent cracked roots (2.23 %) per plot was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The minimum percent rotten roots (0.53 %) per plot was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the maximum percent rotten roots (1.87 %) per plot was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum yield (ton/ha) of carrot (21.17 ton/ha) was showed at the applying nitrogen fertilizer @ 120kg N/ha for carrot. Whereas, the minimum yield (ton/ha) of carrot (16.23 ton/ha) was showed at not applying nitrogen fertilizer @ 0kg N/ha for carrot.

The maximum plant height (26.67 cm) was showed at the applying nitrogen fertilizer @ 10kg S/ha for carrot. Whereas, the minimum plant height (16.67 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum number of leaves (17.77 leaves) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum number of leaves (10.67 leaves) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum length of leaves (18.67 cm) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum length of leaves (8.33 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum fresh weight of plant (65.67 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum fresh weight of plant (40.67 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum dry weight of plant (8.21 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum dry weight of plant (4.77 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum length of root (7.67 inch) was showed at the applying nitrogen fertilizer @ 10kg S/ha for carrot. Whereas, the minimum length of root (5.67 inch) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum diameter of root (6.67 cm) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum diameter of root (4.67 cm) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum dry weight of root (77.36 g) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum dry weight of root (46.67 g) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The minimum percent of cracked roots (0.93 %) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the maximum percent of cracked roots (2.19 %) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The minimum percent of rotten roots (0.49 %) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the maximum percent of rotten roots (1.11 %) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum yield (20.53 ton/ha) was showed at the applying sulphur fertilizer @ 10kg S/ha for carrot. Whereas, the minimum yield (16.11 ton/ha) was showed at not applying sulphur fertilizer @ 0kg S/ha for carrot.

The maximum plant height (30.33 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum plant height (15.33 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum number of leaves (22.37 leaves) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum number of leaves (10.67 leaves) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum length of leaves (19.67 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum length of leaves (7.67 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum fresh weight of plant (72.47 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum fresh weight of plant (38.87 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum dry weight of plant (8.86 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum dry weight of plant (4.77 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum length of root (10.33 inch) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum length of root (5.33 inch) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum diameter of root (8.33 cm) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum diameter of root (2.67 cm) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum dry weight of roots (78.87 g) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum dry weight of roots (41.87 g) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The minimum percent of cracked root (0.73 %) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The maximum percent of cracked root (2.78 %) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The minimum percent of rotten roots (0.36 %) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The maximum percent of rotten root (1.38 %) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

The maximum yield (22.21 ton/ha) was recorded from the application of nitrogen @ 120 kg N/ha and sulphur @ 10 kg S/ha (N_3S_2). The minimum yield (15.78 ton/ha) was recorded from the application of nitrogen @ 0 kg N/ha and sulphur 0 kg S/ha (N_0S_0).

From this study it can be concluded that, the level of nitrogen increases the vegetative growth of carrot. Nitrogen increases the plant height, number of leaves, length of leaves, length of roots, diameter of roots as well as yield of carrot. The level of sulphur increases the quality of carrot. Sulphur increases fresh weight of plant, dry weight of plant, dry weight of root as well as yield. As a result, the combination of nitrogen and sulphur increases the vegetative growth and quality of carrot as well as the yield of carrot. The optimum dose of nitrogen and sulphur are 120 kg N/ha and 10 kg S/ha respectively for the highest production of carrot.

CHAPTER VI

REFERENCES

Abdallah, M., Dubousset, L., Meuriot, F., Etienne, P., Avice, J.C. and Ourry, A. (2010). Effect of mineral sulphur availability on nitrogen and sulphur uptake and remobilization during the vegetative growth of *Brassica napus* L. *J. Expt. Bot*., **61**(10): 2335 2346.

Abdou, A.S., Al Darwish, F.H. Saleh, M.E., El-Tarabily, K.A., Sofian-Azirun, M. and Monitor, R.M. (2011). Effects of elemental sulfur, phosphorus, micronutrients and Paracoccus versutus on nutrient availability of calcareous soils. *Australian J. Crop Sci*., **5**: 554–561.

Ahmadi, H., Akbarpour, V., Dashti, F. and Shojaeian, A. (2010). Effect of different levels of nitrogen fertilizer on yield, nitrate accumulation and several quantitative attributes of five Iranian spinach accessions. *Amer-Eurasian J. Agric. Environ. Sci*., **8**(4): 468-473.

Alasalvar, C., Grigor, J.M. and Quantick, P.C. (1998). Method for the rapid static headspace analysis of carrot flavour: sugar and antioxidant. Paper presented at the Institute of Food Technologists Annual Meeting and Food Expo., Atlanta.

Alasalvar, C., Grigor, J.M., Zhang, D., Quantick, P.C. and Shahidi, F. (2001). Comparison of volatiles, phenolics, sugars, antioxidant vitamins, and sensory quality of different colored carrot varieties. *J. Agric. Food Chem*., **49**(3): 1410–1416.

Allaire-Leung, S.E., Wu, L., Mitchell, J.P. and Sanden, B.L. (2001). Nitrate leaching and soil nitrate content as affected by irrigation uniformity in a carrot field. *Agr. Water Manage.*, **48**(1): 37-50.

Amr, A. and Nadidi, N. (2001). Effect of cultivar and harvest date on nitrate (NO_3) and nitrite (NO_2) content of selected vegetables grown under open field and greenhouse conditions in Jordan. *J. Food Comp. Anal.*, **14**: 59-67.

Anikeenko, A. and Vintsunas, T.S. (1986). Chemical composition of some carrot varieties. Nauchno Tekhnicheskii Byullten Vsesoyuznogo Ordena Lenina i Ordena Družhby Narodov. *Nauchno Issledova Telskogo Instituta Rastenievodstva imeni NI Vavilova*., **161**: 36-38.

Anjaiah, T. and Padmaja, G. (2006). Effect of Nitrogen and farmyard manure on yield and quality of carrot. *J. Res. ANGRAU.*, **34**(2): 91-93.

Anjana, S.U., Muhammed, I. and Abrol, Y.P. (2007). Are nitrate concentrations in leafy vegetables within safe limits? *Curr. Sci.*, **92**(3): 355-360.

Anonymous. (1989). Annual Report, 1987-88.Bangladesh Agricultural Research Institute, Joydebpur, Gazipur., p.: 133.

Arscott, S.A. and Tanumihardjo, S.A. (2010). Carrots of many colors provide basic nutrition and bioavailable phytochemicals acting as a funct. *Food. Comp. Rev. Food Sci. Food Saf.*, **9**: 223-239.

Atkins, L. (1999). "Calcium content of raw vegetables", United States Department of Agriculture. *Agric.Res. Serv.*, U.S.A.

Augustin, J., MacDoel, R.E. and Paiter, G.C. (1977). Influence of fertilizer, irrigation and storage treatments on nitrate-N content of potato tubers. *Am. Potato J.*, **54**: 125-136.

Balvoll, G. (1995). Gransakdyrkning pa friland Landbruksforlaget, Oslo, Norway.

Batra, B.R. and Kallo. (1990). Effect of different levels of irrigation and fertilization on growth and yield of carrot for root production. *Vegetables Sci*., **17**(2): 127-139.

BBS. (2017). Bangladesh Bureau of Statistics. Ministry of Planning. Govt. of the People’s Republic of Bangladesh, pp.: 313-315.

Beyers, T. and Peery, G. (1992). Dietary carotenes vitamin C and vitamin E as protective antioxidants in human cancers. *Ann. Rev. Nutr*., **12**: 139-159.

Bose, T.K. and Som, M.G. (1990). Vegetable crops in India. NayaProkash, 206 Bidhan Sarani, Calcutta-6, India, pp.: 408-442.

Boskovic-Rakocevic, L., Pavlovic, R., Zdravkovic, J., Zdravkovic, M., Pavlovic, N. and Djuric, M. (2012). Effect of nitrogen fertilization on carrot quality. *African J. Agril. Res.*, **7**(18): 2884-2900.

Calatayud, Á., Gorbe, E., Roca, D. and Martinez, P.F. (2008). Effect of two nutrient solution temperatures on nitrate uptake, nitrate reductase activity, NH_4^+ concentration and chlorophyll a fluorescence in rose plants. *Environ. Exp. Bot.*, **64**(1): 65-74.

Cantliffe, D.J. (1973). Nitrate accumulation in table beets and spinach as affected by N, P and K nutrition and light intensity. *Agron. J*., **65**: 563-565.

Chen, B.M., Wang, Z.H., Li, S.X., Wang, G.X., Song, H.X. and Wang, X.N. (2004). Effects of nitrate supply on plant, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetables. *Plant Sci*., **167**: 635-643.

Chenard, C.H., Kopsell, D.A. and Kopsell, D.E. (2005). Nitrogen Concentration Affects Nutrient and Carotenoid Accumulation in Parsley. *J. Plant Nutr*., **28**(2): 285-297.

Cieślik, E. (1994). The effect of naturally occurring vitamin C in potato tubers on levels nitrates and nitrites. *Food Chem.*, **49**(3): 233-235.

Cox, L. and Koenig, T.R. (2010). "Solutions to Soil Problems: II High pH (Alkaline Soil)", United States University, Cooperative Extension, USA.

Cserni, I. and Prohaszka, K. (1988). The effect of N supply on nitrate, sugar and carotene content of carrot. *Acta Hort*., **220**: 303-307.

Cserni, I., Prohaszka, K. and Videni, L. (1983). Studies on the nutrient regime of carrots in container trials. *Zoldsegtermesztesi Kutato Intezet Bull*., **16**: 95-107.

Cui, Y., Dong, Y., Kaifeng, L. and Wang, Q. (2004). Effect of elemental sulfur on solubility of soil heavy metals and their uptake by maize. *Environ. Intern*., **30**: 323–328.

Du, T., Kang, S., Zhang, J., Li, F. and Yan, B. (2008). Water use efficiency and fruit quality of table grape under alternate partial root-zone drip irrigation. *Agric. Water Manag*., **95**: 659–668.

Ekbic, H.B., Ozdemir, G., Sabir, A. and Tangolar, S. (2010). The effects of different nitrogen doses on yield, quality and leaf nitrogen content of some early grape cultivars (*V. vinifera* L.) grown in greenhouse. *Afr. J. Biotechnol*., **9**(32): 5108-5112.

Evers, A.M. (1989). Effects of different fertilization practices on the carotene content of carrot. *J. Agr. Sci. Finland*., **61**: 7-14.

Gajewski, M., Węglarz, Z., Sereda, A., Bajer, M., Kuczkowska, A. and Majewski, M. (2009). Quality of carrots grown for processing as affected by nitrogen fertilization and harvest date. *Veg. Crops Res. Bull*., **70**: 135-144.

Gallichio, L., Boyd, K., Matanoski, G., Tao, X.G., Chen, L., Lam, T.K., Shiels, M., Hammond, E., Robinson, K.A., Caulfield, L.E., Herman, J.G., Guallar, E. and Alberg, A.J. (2008). Carotenoids and risk of developing lung cancer: a systematic review. *Am. J. Clin. Nutr*., **88**: 372-383.

Gomez, K.A. and Gomez A.A. (1984). Statistical Producers for Agricultural Research (2nd ed.). A Wiley Interscience Publication, John Wiley and Sons, New York, p.: 680.

Gutezeit, B. (1999). Yield and nitrate content of carrots as affected by nitrogen supply. *Acta Hort*., **506**: 87-91.

Gutezeit, B. (2000). Effect of N fertilizer on yield and nitrate level of carrot cultivars. *Gemuse (Munchen)*., **36**: 28-30.

Gutezeit, B. and Fink, M. (1999). Effect of cultivar and harvest date on nitrate content of carrot roots *J. Hort. Sci. Biotechnol*., **74**(3): 297-300.

Haider, Hassan, M., Ahmad, F. and Mustaq, F. (1991). Role of physiomorphic characters imparting resistance in cotton against some insect pests. *Pak. Entomol*., **21**(6): 1-6.

Hart, D.J. and Scott, K.J. (1995). Development and evaluation of an HPLC method for the analysis of carotenoids in foods, and the measurement of the carotenoid content of vegetables and fruits commonly consumed in the UK. *Food Chem*., **54**: 101−111.

Hartmann, P.E. (1983). Putative mutagens carcinogens in food. I. Nitrate/Nitrite ingestion and gastro cancer mortality. *Envior. Mutagen*., **5**: 111-121.

Heinonen, M. (1990). Carotenoids and provitamin A activity of carrot (*Daucus carota* L.) cultivars. *J. Agric. Food Chem*., **38**(3): 609-612.

Hochmuth, G.J., Brecht, J.K. and Basset, M.J. (1999). Nitrogen fertilization to maximize carrot yield and quality on a sandy soil. *Hort. Sci*., **34**(4): 641-645.

Jaggi, R.C., Aulakh, M.S. and Sharma, R. (2005). Impacts of elemental S applied under various temperature and moisture regimes on pH and available P in acidic, neutral and alkaline soils. *Biol. Fertil. Soils*., **41**: 52–58.

John, A., Ibrahim, M. and Ishaq, M. (2003). Nitrate accumulation in okra and carrot as influenced by fertilizer application. *Pak. J. Bot*., **35**(4): 637-640.

Kabata-Pendias, A. (2004). Soil-plant transfer of trace elements-an environmental issue. *Geoderma*., **122**(2–4): 143–149.

Kabir, J., Sen, H., Bhattacharya, N., Panda, P.K. and Bose, T.K. (2000). Production technology of vegetable crops. **In:** Tropical Horticulture (vol.2,ed.). Bose, T.K., Kabir, J., Das, P. and Joy, P.P. (Eds.). Naya Prokash, Calcutta, India, pp.: 72-240.

Kalt, W. (2005). Effects of production and processing factors on major fruit and vegetable antioxidants. *J. Food Sci.*, **70**: 11–19.

Kaya, M., Küçükyumuk, Z. and Erdal, I. (2009). Effects of elemental sulfur and sulfur-containing waste on nutrient concentrations and growth of bean and corn plants grown on calcareous soil. *African J. Biotech*., **8**: 448–449.

Kayser, A., Schroder, T.J., Grunwald, A. and Schulin, R. (2001). Solubilization and plant uptake of zinc and cadmium from soils treated with elemental sulfur. *Inter. J. Phytoremediation*., **3**: 381–400.

Kòňa, J. (2006). Nitrate accumulation in different parts of carrot root during vegetation period. *Acta Hort. et Regiotecturae*., **9**: 22-24.

Lee, R.B., Purves, J.V., Ratcliff, R.G. and Saker, L.R. (1992). Nitrogen assimilation and the control of ammonium and nitrate absorption by maize roots. *J. Exp. Bot*., **43**: 1385-1396.

Lee, S.K. and Kader, A. (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biol. Tec*., **20**: 207–220.

Lisiewska, Z. and Kmiecik, W. (1996). Effects of level of nitrogen fertilizer, processing conditions and period of storage of frozen broccoli and cauliflower on vitamin C retention. *Food Chem*., **57**(2): 267-270.

Markovic, V., Ilin, Z., Djurovka, M. and Lazic, B. (2002). Effect of preceding crop on growth dynamics, yield and quality of carrot. *Acta Hort*., **579**: 363-366.

Martinez, C.E. and Motto, H.L. (2000). Solubility of lead, zinc of copper added to mineral soils. *Environ. Pollu*., **107**: 153–158.

Mateljan, G. (2007). The world’s healthiest food. Nutrient in cabbage, shredded,boiled. George Mateljan Foundation, Chicago.

Matsuzoe, N., Zushi, K. and Johjima, T. (1998). Effect of soil water deficit on coloring and carotene formation in fruits of red, pink, and yellow type cherry tomatoes. *J. Japan. Soc. Hort. Sci*., **67**(4): 600–606.

Maurya, K.R. and Goswami, R.K. (1985). Effects of NPK fertilizers on growth, yield and qualxity of carrot. *Prog. Hort*., **17**(3): 212-217.

Mazur, Z. (1992). Effect of nitrogen fertilization on the level of nitrate and nitrite contents in vegetables. *Biul. Warzywn*., **38**: 123-139.

McKnight, M.G., Duncan, W.C., Leifert, C. and Golden, H.M. (1999). Dietary nitrate in man: friend or foe? *Br. J. Nutr*., **81**: 349-358.

Moniruzzaman, M., Akand, M.H., Hossain, M.I., Sarkar, M.D. and Ullah, A. (2013). Effect of Nitrogen on the Growth and Yield of Carrot (*Daucus carota* L.). *The Agriculturists*., **11**(1): 76-81.

Mozafar, A. (1993). Nitrogen fertlizers and the amount of vitamins in plants: A review. *J. Plant Nutr*., **16**(12): 2479-2506.

Mubashir, M., Malik, S.A., Khan, A.A., Ansari, T.M., Wright, S., Brown, M.V. and Islam, K.R. (2010). Growth, yield and nitrate accumulation of irrigated carrot and okra in response to nitrogen fertilization. *Pak. J. Bot.,* **42**(4): 2513-2521.

Musa, A., Ezenwa, I.S., Oladiran, J.A., Akanya, H.O. and Ogbadoyi, E.O. (2010). Effect of soil nitrogen levels on some micronutrients, anti-nutrients and toxic substances in *Corchorus olitorius* grown in Minna, Nigeria. *Afr. J. Agric. Res*., **5**(22): 3075-3081.

Nube, M. and Voortman, R.L. (2006). Simultaneously addressing micronutrient deficiencies in soils, crops, animal and human nutrition: opportunities for higher yields and better health. Staff Working Paper WP-06-02. Stichting Onderzoek Wereldvoedselvoorziening van de Vrije Universiteit. Centre for World Food Studies, pp.: 1– 41.

Orman, Ş. and Kaplan, M. (2011). Effects of elemental sulphur and farmyard manure on pH and salinity of calcareous sandy loam soil and some nutrient elements in tomato plant. *J. Agric. Sci. Technol.*, **5**(1): 20-26.

Pokluda, R. (2006). An assessment of the nutritional value of vegetables using an ascorbate-nitrate index. *Veg. Crops Res. Bull.*, **64**: 28-37.

Raynal-Lacroix, C. (1994). Nitrogen Nutrition of Carrots. *Proc. Third Congress of the European Soc. Agronomy*, Padova, Italy, pp.: 616-617.

Rashid, M.M. (1999). Shabje Bigjan (in Bengali), (2nd edn.) Rashid Publishing House, 94 old D. O. II. S., Dhaka-1206, pp.: 498-508.

Rikabdar, F.H. (2000). Adhunik Upaya Shabje Chush (in Bengali). Agriculture Information Service, Khamarbari, Dhaka, pp.: 29-30.

Rudich, J., Kalmar, D., Geizenberg, C. and Harel, S. (1977). Low water tensions in defined growth stages of processed tomato plants and their effects on yield and quality. J. Hort. *Sci.*, **52**: 391–399.

Sadhu, M.K. (1993). Root Crops. **In:** Vegetable Crops (2nd edn.). Bose, T.K., Som, M.G. and Kabir, J. (Eds.). Naya Prokash, Calcutta, India. pp.: 470-578.

Salunkhe, D.K. and Kadam, D.D. (1998). Handbook of Vegetable Science and Technology. Marcel Dekker, Inc. New York.

Santamaria, P. (2006). Nitrate in vegetables: toxicity, content, intake and EC regulation. *J. Sci. Food Agric.*, **86**: 10-17.

Sarker, M.N. (1999). Effect of nitrogen, phosphorus and potash on the yield of carrot. M.Sc. thesis, Dept. of Hort. BAU, Mymensingh, Bangladesh.

Scherer, H.W., Pacyna, S., Spoth, K.R. and Schulz, M. (2008). Low levels of ferredoxin, ATP, and leghemo globin contribute to limited N_2 fixation of peas (*Pisum sativum* L.) and alfalfa (*Medicago sativa* L.) under S deficiency conditions. *Biol. Fertil. Soil.,* **44**: 909-916.

Singh, D.P., Singh, H., Ali, J. and Singh, S.P. (2016). Productivity, profitability and nutrient uptake in carrot (*Daucus carota*) and radish (*Raphanus sativus*) crops under sulphur nutrient. *JOUR*., **86**: 1577-1580.

Steer, B.T. (1982). Nitrogen and nitrate accumulation in species having different relationships between nitrate uptake and reduction. *Ann. Bot*., **49**(5): 191-198.

Stefanelli, D., Goodwin, I. and Jones, R. (2010). Minimal nitrogen and water use in horticulture: Effects on quality and content of selected nutrients. *Food Res. Int.*, **43**: 1833-1843.

Takáč, P., Zabová, S.T., Kozáková, Ľ. and Benková, M. (2009). Heavy metals and their bioavailability from soils in the long-term polluted Central Spiš region of SR. *Plant Soil Environ.,* **55**: 167–172.

Van Der Boon, J., Steenhuizen, J.W. and Steingröver, E.G. (1988). Effect of EC and Cl and NH_4 concentration of nutrient solutions on nitrate accumulation in lettuce. *Acta Hort*., **222**: 35-42.

Vicente, A.R., Manganaris, G.A., Sozzi, G.O. and Crisisto, C.H. (2009). Postharvest Handing: A Systems Approach. **In:** "Nutritional Quality of Fruits and

Vegetables”. Florkowski, W.J., Shewfelt, R.L., Brueckner, R. and Prussia, S.E. (Ed.), Elsevier INC., pp.: 81–86.

Wafaa, H.M. (2013). Yield, quality and micronutrients uptake of carrot (*Daucus carota* L.) and some soil properties as affected by organic fertilizers and elemental sulphur application. *Egypt J. Soil Sci.*, **53**(4): 537-554.

Wiebe, H.J. (1987). Effect of plant densities and nitrogen supply on yield harvest date and quality of carrots. *Acta Hort*., **198**: 191-198.

Xia, L., Zhiwei, S., Lei, J., Lei, H., Chenggang, R., Man, W. and Chuangen, L. (2011). High/low nitrogen adapted hybrid of rice cultivars and their physiological responses. *Afr. J. Biotechnol*., **10**(19): 3731-3738.

Yawalker, K.S. (1992). Vegetable Crops of India (4th ed.). Agri-Horticultural Publishing House, Nagpur, India, p.: 68.

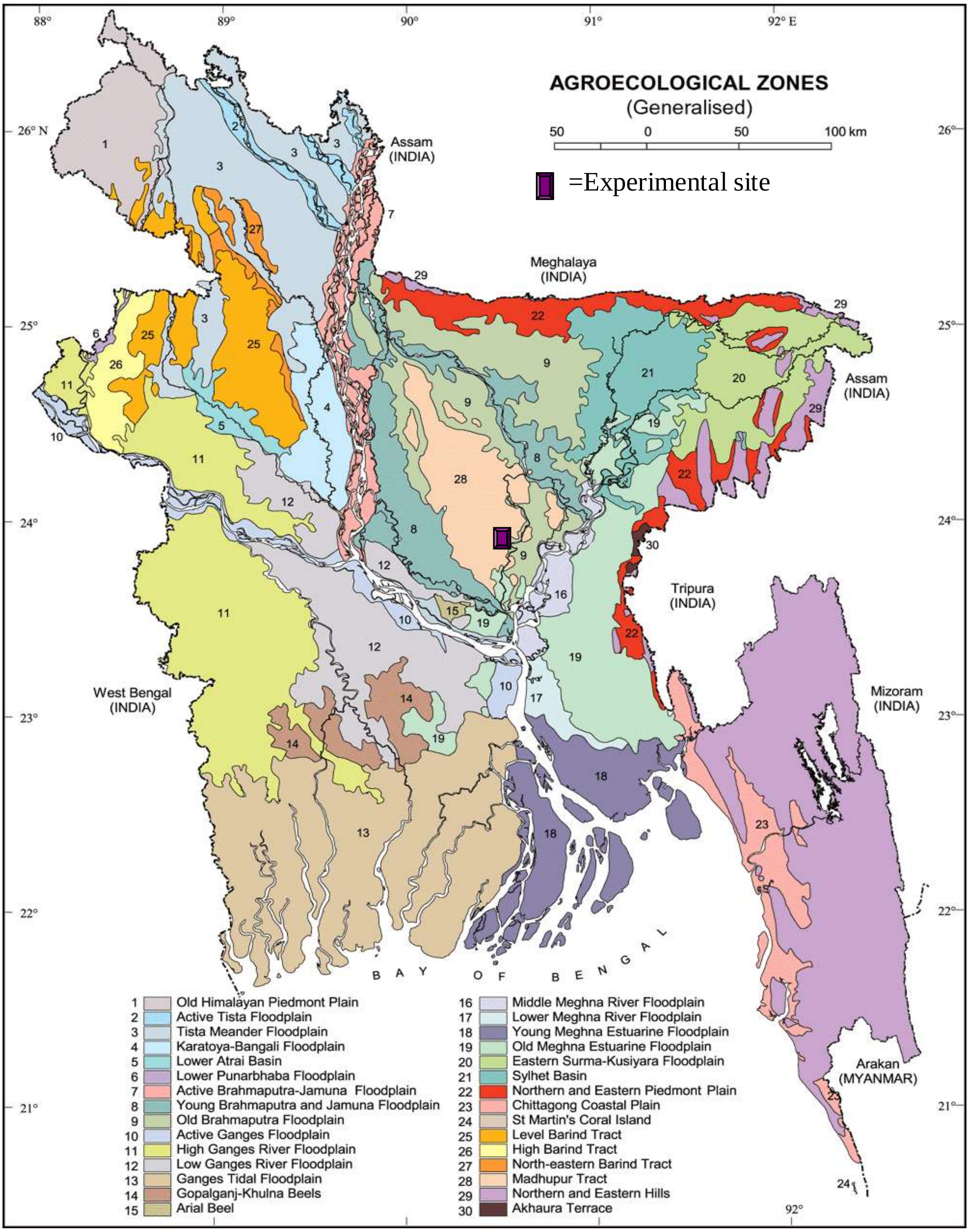
Zhang, C.X., Ho, S.C., Chen, Y.M., Fu, J.H., Cheng, S.Z. and Lin, F.Y. (2009). Greater vegetable and fruit intake is associated with a lower risk of breast cancer among Chinese women. *Int. J. Cancer*., **125**: 181-188.

Zushi, K. and Matsuzoe, N. (1998). Effect of soil water deficit on vitamin C, sugar, organic acid, amino acid and carotene contents of large-fruited tomatoes. *J. Japan. Soc. Hort. Sci*., **67**(6): 927–933.

CHAPTER VII

APPENDIXES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix III: Analysis of variance of the data on the effect of nitrogen and sulphur on plant height, number of leaves and length of leaves (cm) of carrot

Source of variance	Degrees of freedom	Mean square		
		Plant height	Number of leaves	Length of leaves
Replication	2	0.197 NS	0.011 NS	0.114 NS
Factor A	3	47.647 **	47.427 **	61.54 **
Factor B	2	30.194 **	5.235 **	36.789 **
A×B	6	15.255 **	0.716 *	12.09 **
Error	22	0.089	0.001	0.065

**= Significant at 1% level; *= Significant at 5% level, NS= Non-significant

Appendix IV: Analysis of variance of the data on the effect of nitrogen and sulphur on fresh weight of plant (g), dry weight of plant (g) and length of root (inch) of carrot

Source of variance	Degrees of freedom	Mean square		
		Fresh weight of plant	Dry weight of plant	Length of root
Replication	2	0.105 NS	0.002 NS	0.19 NS
Factor A	3	62.754 **	0.321 *	61.669 **
Factor B	2	24.268 **	0.069 *	22.464 **
A×B	6	21.561 **	0.124 *	31.255 **
Error	22	0.073	0.001	0.042

**= Significant at 1% level; *= Significant at 5% level, NS= Non-significant

Appendix V: Analysis of variance of the data on the effect of nitrogen and sulphur on diameter of root, dry weight of root and percent cracked roots of carrot

Source of variance	Degrees of freedom	Mean square		
		Diameter of root	Dry weight of root	percent cracked roots per plot
Replication	2	0.003 NS	0.003 NS	0.001 NS
Factor A	3	13.312 **	12.011 **	15.136 **
Factor B	2	1.61 *	3.149 *	2.24 *
A×B	6	0.158 *	0.14 *	0.057 *
Error	22	0.002	0.001	0.001

**= Significant at 1% level; *= Significant at 5% level, NS= Non-significant

Appendix VI: Analysis of variance of the data on the effect of nitrogen and sulphur on percent rotten roots per plot of carrot

Source of variance	Degrees of freedom	Mean square	
		Percent rotten roots	Yield
Replication	2	0.000 NS	0.047 NS
Factor A	3	12.28 **	27.876 **
Factor B	2	1.019 *	38.052 **
A×B	6	0.026 *	5.814 **
Error	22	0.001	0.079

**= Significant at 1% level; *= Significant at 5% level, NS= Non-significant