# RESPONSE OF DIFFERENT MICRONUTRIENTS AND SPACING ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum* L.)

**SUMAIYA AFRIN JHUMA**


**DEPARTMENT OF HORTICULTURE**
**SHER-E-BANGLA AGRICULTURAL UNIVERSITY**
**DHAKA -1207**

**JUNE, 2015**

# RESPONSE OF DIFFERENT MICRONUTRIENTS AND SPACING ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum* L.)

**BY**

**SUMAIYA AFRIN JHUMA**

**REG. NO. 09-03703**

*A Thesis*
*Submitted to the Department of Horticulture*
*Sher-e-Bangla Agricultural University, Dhaka-1207,*
*In partial fulfillment of the requirements*
*for the degree*
*of*
**MASTER OF SCIENCE (MS)**
**IN**
**HORTICULTURE**
**SEMESTER: JANUARY-JUNE, 2015**

**Approved By:**

| | |
|---|---|
| **Dr.Tahmina Mostarin**<br>Associate Professor<br>Department of Horticulture<br>SAU, Dhaka<br>**Supervisor** | **Dr. Khaleda Khatun**<br>Associate Professor<br>Department of Horticulture<br>SAU, Dhaka<br>**Co-Supervisor** |

**Dr.Tahmina Mostarin**
**Chairman**
**Examination Committee**

# DEPARTMENT OF HORTICULTURE
## Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

## *CERTIFICATE*

This is to certify that thesis entitled, **"RESPONSE OF DIFFERENT MICRONUTRIENTS AND SPACING ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum* L.)"** submitted to the, **Department of Horticulture**, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in HORTICULTURE**, embodies the result of a piece of bona fide research work carried out by **SUMAIYA AFRIN JHUMA**, Registration No.: 09-03703 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

**Dated: June, 2015**
**Dhaka, Bangladesh**

**Dr. Tahmina Mostarin**
Associate Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Dhaka-1207
**Supervisor**

Dedicated to
My
Beloved Parents

## *ACKNOWLEDGEMENT*

*At first the author expresses all praises to the '**Almighty Allah**' who enables her to complete a piece of research work and prepare this thesis for the degree of Master of Science (M.S.) in Horticulture.*

*The author like to express her deepest sense of gratitude, sincere appreciation to her respected supervisor and chairman **Dr. Tahmina Mostarin,** Department of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for her scholastic guidance, support, encouragement and valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript.*

*The author also expresses her gratefulness and best regards to respected co- supervisor, **Dr. Khaleda Khatun,** Department of Horticulture, Sher-e Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimable help, valuable suggestions throughout the research work and preparation of the thesis.*

*The author expresses sincere appreciation to her brother, sister, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.*

*June, 2015*

*SAU, Dhaka* **The Author**

# RESPONSE OF DIFFERENT MICRONUTRIENTS AND SPACING ON THE GROWTH AND YIELD OF GARLIC (*Allium sativum* L.)

**BY**

**SUMAIYA AFRIN JHUMA**

## ABSTRACT

The experiment was conducted at Horticultural Farm, Sher-e-Bangla Agricultural University, during the period from November 2013 to April 2014 to find out the response of different micronutrients and spacing on the growth and yield of garlic. The experiment consists of two factors. Factor A: four levels of plant nutrients $T_0$: $S_0B_0Zn_0$ (control), $T_1$: $S_{15}B_2Zn_5$, $T_2$: $S_{20}B_4Zn_{10}$ and $T_3$: $S_{25}B_6Zn_{15}$ (kg/ha) respectively. Factor B: three levels of spacing $S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm and $S_3$ = 15 cm × 15 cm were used for the present study. The experiment was laid out in RCBD with three replications. Results showed that highest yield of garlic (5.66 t) was found from $T_3$ treatment and lowest yield (3.42 t) was found from $T_0$ treatment. For spacing, $S_1$ gave highest yield (5.25 t) and $S_3$ gave lowest yield (4.43 t) yield of garlic. The $T_3S_1$ treatment combination was found highest yield (6.57 t) and lowest yield (3.36 t) was found from$T_0S_3$ treatment combination. Calculating the benefit cost ratio $T_3S_1$ gave the highest economic return (2.52) compared with rest of the treatment combinations. So $S_{25}B_6Zn_{15}$ with 10 cm × 10 cm spacing gave highest yield of garlic.

# LIST OF CONTENTS

# LIST OF CONTENTS (Contd.)

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF APPENDICES

# LIST OF PLATES

# LIST OF ABBRIVIATIONS

| | | |
|---|---|---|
| BARI | = | Bangladesh Agricultural Research Institute |
| BCR | = | Benefit Cost Ratio |
| cm | = | Centimeter |
| $^0$C | = | Degree Centigrade |
| DAS | = | Days after sowing |
| *et al.* | = | and others *(at elli)* |
| Kg | = | Kilogram |
| Kg/ha | = | Kilogram/hectare |
| g | = | gram (s) |
| LER | = | Land Equivalent Ratio |
| LSD | = | Least Significant Difference |
| MP | = | Muriate of Potash |
| m | = | Meter |
| $P^H$ | = | Hydrogen ion conc. |
| RCBD | = | Randomized Complete Block Design |
| TSP | = | Triple Super Phosphate |
| t/ha | = | ton/hectare |
| % | = | Percent |

# CHAPTER I

## INTRODUCTION

Garlic *(Allium sativum* L.) is well known as a spice crop in Bangladesh as well as in the world. It is an aromatic herbaceous annual spice and one of the most important bulb crops belonging to the family Alliaceae (Kurian, 1995). It is the second most widely used Alliums after onion (Bose and Som, 1990) with the characteristics of pungent smell. The major garlic producing countries of the world are China, South Korea, Spain, India, USA, Egypt, Thailand and Turkey (FAO, 2000).

Garlic has been considered as a rich source of carbohydrates, proteins and phosphorus. It is popular all over the world as a valuable spice for different dishes. Aqueous extracts of garlic cloves (allicin and related disulphides) significantly reduce cholesterol level in men (Augusti, 1977). It is also used as a popular remedy for various diseases. According to the Unani and Ayurvedic medicines in the treatments of diseases like chronic infection of stomach and intestine, dysentery, typhoid, cholera and diseases of lungs garlic is successfully used (Chopra *et al,* 1958). In recent, oil, powder are prepared from it for adding flavor to the curries (Pruthi, 1976). Besides, it is also used in preparing chutneys, pickles, tomato ketchup etc.

The average yield of garlic in Bangladesh is only 4.40 t/ha (BBS, 2010), which is very low as compared to that of other countries. In Bangladesh about 164,000 metric tons of garlic was produced from approximately 92000 hectares of land in 2009-2010 (BBS, 2010). The requirement of garlic in Bangladesh is about 85,000 metric tons (Rahim, 1992). The crop is extensively cultivated during the winter season of Bangladesh. Garlic ranks second in world production among the Alliums after onion (Purseglove, 1975).

Use of appropriate nutrient management plays a specific role in the growth and yield of garlic. For proper nutrient supply, both organic and inorganic fertilizers can be used and resulted better crop yield. Inorganic fertilizer supplies sufficient nutrients for growth and development of plant. Among the major macro nutrients, NPK are used largely by the plants for better physio-morphological and biological development. Application of nitrogenous fertilizer causes vigorous vegetative growth and linear increase in yield. But increased use of inorganic fertilizer in crop production causes health hazards, create problem to the environment including the pollution of air, water, soil etc. Use of organic manures is essential for proper growth and development of garlic. In addition to being a good source of plant nutrients, organic manure improves texture, structure, humus, aeration, water holding capacity and microbial activity of soil and thus helps to increase and conserve the soil productivity.

Judicious application of fertilizer may enhance bulb yield significantly. Nitrogen is required for cell division and vital for plant growth. It directly involved in photosynthesis. Potassium helps in the root development and increase the efficiency of leaf in the manufacture of sugar and starch. Phosphorus promotes early root formation and growth. It also involved cell division, cell enlargement and increase water use efficiency. The sulphur compounds in garlic have received a lot of attention because of it potential antibiotics and flavor properties. Boron is essential for promotes maturity. Zinc is necessary for chlorophyll production and necessary for starch formation. So different plant nutrients are physiologically important element and it has a miscellaneous effect on vegetative and reproductive stages in plant body.

Plant spacing influences the growth and yield of garlic. Yield of garlic is dependent on the number of plants accommodated per unit area of land. Planting of garlic at proper spacing also increases the yield and improves the grade of bulbs. Wider spacing increased number of leaves and greater plant height of garlic

has been reported by several authors (Om and Srivastava, 1977). Increased bulb size in garlic with wider spacing has been noted by a number of authors (Menezes *et al*. 1974). Accommodation of reduced number of plants per unit area involves wider spacing is directly reduces the yield (Rahim *et al*., 1984). Thus the increased number of plant per unit area in closer spacing compensates the loss of reduced bulb sizes and ultimately increases the yield. Reports generally agree that higher plant spacing gave higher yield, but lower bulb weight of garlic (Duranti and Cuocolo, 1984).

Therefore, nutrient management with plant spacing and in combination with each other may lead to better performance of the crops. The present study was undertaken to observe the following objectives:

1. To observe the effect of different micronutrients on the growth and yield of garlic
2. To find out the best spacing for growth and yield of garlic
3. To observe out the combined effects of different micronutrients and spacing on the growth and yield of garlic

# CHAPTER II

## REVIEW OF LITERATURE

Garlic is an important spice crop in Bangladesh for its culinary and medicinal uses. The production of garlic bulb is greatly influenced by different micronutrients and spacing. They play an important role on growth and yield of garlic. To ensure better yield, proper nutrient management need to be assured. The present study has been under taken to investigate the response of different nutrients and spacing on the growth and yield of garlic. Research findings related to the present study have been reviewed here.

### 2.1 Effect of different nutrients

Organic matter influences the physical, chemical and biological properties of soil through its quantity in soil is very small. Organic matter content of a particular soil is an indicator of its productivity.

Farooqui *et al*. (2009) conducted a study to enhance the productivity of garlic through assessing the effect of different levels of nitrogen and sulphur. The experiment consisting of 4 levels of nitrogen (50, 100, 150 and 200 kg/ha) and 4 levels of sulphur (0, 20, 40 and 60 kg/ha) were applied as basal dose and top dressing. Application of 200 kg nitrogen/ha significantly increased the plant height (cm), number of leaves per plant, neck thickness (cm), bulb diameter(cm), number of cloves per bulb, fresh weight of 20 cloves (g), dry weight of 20 cloves (g), fresh weight of bulb (g), dry eight of bulb (g) and bulb yield (q $ha^{-1}$). Among various levels of sulphur tried (60 kg/ha) exhibited the best growth and yield attributes. Significantly higher yield of garlic was obtained with the treatment combination (200 kg n ha-1 + 60 kg S/ha).

Naik and Hosamani (2003) conducted an experiment at Dharwad, Karnataka, India to study the effect of different levels of N, P and K on growth and yield of garlic

under rainfed condition. There were twenty-four treatment combinations of fertilizers comprising four levels of N (0, 50, 100 and 150 kg/ha), three levels of P (0, 40 and 80 kg/ha) and two levels of K (0 and 60 kg/ha). They reported that among the fertilizer combinations 100:40:60 kg NPK/ha was found to be the optimum for increasing plant height, number of leaves per plant, number of bulbs per plot, number of cloves per bulb and bulb yield per hectare.

Naik and Hosamani (2003) conducted an experiment to study the effect of different levels of N, P and K on growth and yield of garlic under rain-fed condition of Dharwad, Karnataka, India. There were twenty-four treatment combinations of fertilizer comprising four levels of N (0, 50, 100 and 150 kg/ha), three levels of P (0, 40 and 80 kg/ha) and two levels of K (0 and 60 kg/ha). They reported that among the fertilizer combinations, 100:40:60 kg NPK/ha was found to be the optimum for increasing plant height, number of leaves per plant, number of bulbs per plot, number of cloves per bulb and bulb yield per hectare.

Khalil *et al*. (2002) conducted an experiment to study the effects of farm yard (FYM: 40, 50 and 60$m^3$/feddan) manures on onion cv. Shandaweel 1. N (100 kg/feddan as urea) was also applied at 45 and 60 days after transplanting, whereas P (30 kg/feddan as calcium superphosphate) was applied as a basal dressing. K (24 kg/feddan as potassium sulfate) was incorporated before transplanting. The tallest plants were obtained with 25 and 30$m^3$ chicken manure/feddan (1 feddan = 0.42 ha). Chicken manure and inorganic fertilizers were more effective than FYM in increasing leaf number per plant. The highest average bulb weight, marketable bulb yield were recorded for 25 $m^3$ chicken manure/feddan. Chicken manures resulted in the highest total bulb yield.

Yadav and Yadav (2001) conducted an experiment to determine the effect of NICAST (OM) in comparison to the recommended dose of manure and fertilizers in onion cv. Ro-1. The experiment consisted of 10 treatments of

manure and fertilizers. The rates of manure and fertilizers were, FYM (30 t/ha), NPK (100:50:100 kg/ha), NICAST (250 kg/ha), NICAST (500 kg/ha), NICAST (750 kg/ha), Vermicompost (15 t/ha) respectively. They reported that out of 10 treatments FYM + NPK gave the highest significant bulb yield (370.37 q/ha).

An experiment was conducted by Abbey (2000) using the treatments: 3 t/ha poultry' manure, 340 kg NPK (15-15-15)/ha and 1.5 t/ha poultry manure plus 100 kg NPK (15-15-15)/ha. A combination of poultry manure and NPK fertilizer gave the highest yield of 12.4 t/ha.

Sardar *et al.* (1999) conducted an experiment to study the effects of applying N (0, 50, 100 or 150 kg/ha), P (0, 40 or 80 kg/ha) and K (0 or 60 kg/ha) on garlic cv. Kanpur Local. They reported that bulb yields were increased as the rate of each element applied increased. A fertilizer rate of 100 kg N + 80 kg P + 60 kg K/ha was recommended for garlic production.

Gupta *et al.* (1999) conducted a field experiment to study the effect of organic manure and inorganic fertilizers on growth, yield and quality of kharif onion cv. Agrifound Dark Red. The organic manures evaluated were sunflower cake @ 19q/ha, poultry manure @ 57q/ha and FYM @ 143 q/ha and 72 q/ha. The inorganic fertilizers evaluated were urea @ 252 kg/ha, CAN 444 kg/ha and ammonium sulphate @ 565 kg/ha. The control plot was maintained without any organic/inorganic fertilizer. The bed size was 3.6xl.8m. They reported that FYM @ 72.0 q/ha along with ammonium sulphate @ 565 kg/ha were effective in increasing the growth, yield and quality contributing characters such as bulb colour.

Wani *et al.* (1998) conducted an experiment on garlic in sterile soil and revealed that *Glomus mosseae* used the insoluble P. sources (Pressmud, rock phosphate and bone meal) for enhancing growth and yield. Inoculation

with *G. mosseae* significantly increased plants height, number of leaves per plant and weight, size and yield of bulbs.

Another experiment was conducted by Bull *et al.* (1998) in Brazil on garlic. They reported that organic fertilizer can substitute for phosphate fertilization in the recommended dosage for spring garlic.

Harun-or Rashid (1998) conducted an experiment at the Bangladesh Agricultural University, Mymensingh on the effects of NPKS on the growth and yield of onion at different plant spacing. He reported that the maximum bulb weight (40-50g) and bulb yield (20-75 t/ha) were found from the combination of 125-150-150-30 kg N, $P_2O_5$, $K_2O$, S/ha and the minimum bulb yield (16.75 t/ha) was recorded from the control treatment (no NPKS). He reported that application of *NPKS* increased the plant height, leaf number, and length of bulb, bulb diameter, bulb weight as well as the bulb yield. He recommended 100-150-200-30 kg N, $P_2O_5$, $K_2O$ t/ha for the cultivation of BARI peaj-1 at BAU farm conditions. But Islam (1998) found that nitrogen at 120 kg/ha produced the maximum bulb weight and bulb yield (25.5 t/ha).

Jalil (1998) carried out an experiment to study the effect of planting time and the paclobutrazol and sulphur fertilizer on the growth, yield and sulphur content of garlic. He used 0, 20, 40 and 80 kg S/ha. He concluded that, the bulb yield was increased with increasing the level of S. The highest bulb yield (4.33 t/ha) was obtained from 80 kg S/ha.

Zhang *et al.* (1998) conducted an experiment in China on NPK absorption in garlic. The ratio of NPK absorbed by garlic was 1:0.3:0.71. The peak of N and K absorption was at the inflation stage of squamose bulbs and the peak of P absorption was during sprout elongation. The recommended optimum application of NPK was 160-350 kg, 120-155 kg and 133.4 kg/ha in Henan Province. They reported that combination of organic fertilizers

with NPK fertilizers increased the yield by 78.4-118.4%.

An investigation was done by Aly *et al*. (1997) to observe the effect of some organic amendments on the density of nematodes associated with garlic. For this purpose, they used pigeon manure, poultry manure and sawdust (all at 900 kg/ha 2 weeks before sowing of garlic bulbs). The population density of nematodes were determined in Field plots. They found that pigeon and poultry manures were markedly more effective in controlling the nematodes than sawdust. Garlic yield was most significantly increased by pigeon manure, followed by poultry manure and sawdust.

Fertilizers are indispensable for the production system of modern agriculture. Among the factors that affect crop production, fertilizer is the single most important one that plays a crucial role in yield increase. Inorganic fertilizer today holds the key to the success of the crop production system in Bangladesh Agriculture, being responsible for about 50 percent of the total production (BARC, 1997).

Rizk (1997) conducted an experiment to investigate the effects of plant density and NPK fertilizers on the productivity of onion. He noted that increasing the NPK rate increased all the vegetative growth parameters measured and increased the yield of bulbs.

Hossain (1997) conducted an experiment to study the effect of different levels of nitrogen and potash on the growth and yield of garlic at the Horticultural Farm of Bangladesh Agricultural University, Mymensingh. All parameters namely, plant height, number of levels per plant, leaf length, weight of foliage, pseudo stem and bulb diameter, weight of roots, dry matter contents of foliage, bulb and roots, weight of bulb and yield of bulb varied significantly with the application of nitrogen. A few of these characters namely, leaf length, weight of foliage, bulb diameter, weight of bulb and bulb yield were significantly influenced by potassium levels. The

highest bulb yield (8.45 t/ha) was obtained when the plants were raised with the highest nitrogen level (200 kg/ha) and the lowest yield (5.61 t/ha) was recorded in the control. Application of potassium at 120 kg $K_2O$/ha produced the highest bulb yield (7.64/ha).

An investigation was done by Varu *et al.* (1997) with organic and inorganic fertilizers to observe the effects on the growth and yield of onion. Onion was given the following fertilizer treatments: NPK (100 kg N, 50 kg P2O5, 50 kg K20/ha), farmyard manure (FYM at 50 t/ha), a concentrated organic manure (Dharatidhara at 4 t/ha); FYM (25 t/ha) + Dharatidhara (2 t/ha): FYM (25 t/ha) + NPK (full rate), FYM (95 t/ha) + NPK (half rate) + Dharatidhara (2 t/ha); and no fertilizer. The highest bulb yield (32.70 t/ha) was obtained from the FYM + NPK + Dharatidhara treatment. This treatment also gave the highest bulb diameter, weight and volume.

Bhattarai *et al.* (1996) conducted experiments in 3 places of Nepal (Mallajh, Lower Salija and Flemja). They obtained that at Hemja the marketable bulb yield with FYM alone was significantly higher than the FYM + NPK fertilizers whereas at lower Salija and Mallajh it was higher with FYM + NPK application. Though the results were not consistent across the sites, it seems likely that onion production can be successfully done purely under organic manuring practices.

Verma *et al.* (1996) investigated the effects of N (0, 50, 100 or 1 50 kg/ha), P (0, 40 or 80 kg $P_2O_5$ /ha) and K. (0 or 50 kg $K_2O$/ha) on growth and yield of garlic. They reported that specific gravity and dry weight were significantly influenced due to increasing rates of N.

Ashok *et al.* (1996) carried out an experiment with garlic in sandy loam soil supplied with 0, 50, 100 or 150 kg N; 0, 40 or 80 kg P and 0 or 60 kg K/ha and reported that the highest yield was obtained with 100 kg N + 80 kg P + 60 kg K/ha.

Bertoni *et al.* (1996) carried out an experiment in France on the study of sulphur nutrition in garlic cv. Messidrome in a green house pot experiment. Leaf and root sulphur concentration decreased during senescence due to remobilization of organic sulphur from leaves to bulbs during bulbs growth.

Singh *et al.* (1996) conducted an experiment in India on the response of onion to nitrogen and sulphur. Four doses of nitrogen 0, 60, 120 and 180 kg/ha and four doses of sulphur 0, 20, 40 and 80 kg/ha were applied on onion cv. Pusa Red in the Field at Agra during 1991-93. Yield as well as plant N and S content were significantly increased with increasing rate of N and S. Increasing rate of S upto 40 kg/ha increased yield.

Warade *et al.* (1996) worked with different sources of nutrients on yield of onion bulbs at Rahuri, India. The highest bulb yield (27.7 t/ha) was obtained from 40 t FYM/ha + NPK (100, 50 and 50 kg/ha, respectively) followed by 40 t FYM/ha + NPK (75, 50 and 50 kg/ha, respectively) + bio-fertilizer inoculation. These 2 treatments increased yields by 64.4 and 64.0%, respectively, compared with controls which received no fertilizers.

Seno *et al.* (1996) studied the effect of four doses of $P_2O_5$ (control, 150, 300 and 450 kg/ha) and four doses of chicken manure (control, 4, 8 and 12 t/ha) on the culture of garlic. The phosphorus, compost and additional nutrients (20 kg N, 90 kg $K_2O$, 2.2 kg B and 4 kg Zn per ha) were applied. Two foliar applications of nutrients were made with 1% urea at 40 and 60 days after planting. The phosphorus induced linear decrease for the plant length at 30 days and for the production of medium sized bulbs therefore increased the average weight of bulbs. The chicken manure induced a linear increase in the average weight of bulbs.

Verma *et al.* (1996) investigated the effects of N (0, 50, 100 or 1 50 kg/ha), P (0, 40 or 80 kg $P_2O_5$ /ha) and K. (0 or 50 kg $K_2O$/ha) on growth and yield of garlic. They reported that specific gravity and dry weight were significantly influenced due to increasing rates of N.

Ashok *et al.* (1996) carried out an experiment with garlic in sandy loam soil supplied with 0, 50, 100 or 150 kg N; 0, 40 or 80 kg P and 0 or 60 kg K/ha and reported that the highest yield was obtained with 100 kg N + 80 kg P + 60 kg K/ha.

Mallanagouda *et al.* (1995) conducted an experiment to investigate the effects of NPK and farmyard manure on the growth and yield of onions. The recommended rate of NPK was applied alone or in combination with FYM. FYM was applied alone or in combination with half the recommended dose of NPK. The highest yield of onion (4698.38 kg/ha) was obtained from plots treated with the recommended rate of NPK + FYM.

Alam (1995) conducted an experiment to study the effect of paclobutrazol and sulphur fertilizer on growth, yield and sulphur content of garlic at the Horticulture Farm of BAU, Mymensingh during 1994-95. Four levels of sulphur viz., 0, 10, 20 and 40 kg/ha were applied. He found that sulphur played an appreciable role in yield increase by increasing the number of leaves/plant, plant height, number of cloves/bulb, bulb fresh and dry weight and yield. Sulphur @40 kg/ha was found to be more effective.

Vinay and Singh *et al.* (1995) conducted a two year field experiment in India on the effect of sulphur sources and levels on yield and uptake of nutrients by garlic cv. white skined. Sulphur (s) was applied as gypsum, elemental sulphur, sodium sulphate or potassium sulphate at 0, 25, 50 or 100 kg S/ha during sowing with basal doses of N, P and K. Increased rate of applied S increase the bulb yield and uptake rates and also bulb concentration of NP increased significantly.

Chermsini *et al.* (1995) conducted a field experiment on the effect of boron source on the productivities of garlic in the northern part of Thailand following rice cultivation for major soils (Typic Tropaquals). Boron was applied as borax ($Na_2B_40_710H_2O$), coalfly ash or fritted trace elements. 24-40% yield was increased

with boron application in compared with untreated plants. Coalfly ash at 825 g B/ha produced the highest yield (6.13 t/ha) and also produced the largest and heaviest garlic cloves.

Bhonde *et al.* (1995) conducted a field experiment on the effect of micro-nutrients on growth, yield and quality of kharif onion. In three years studies on onion cv. Agrifound dark red grown during the kharif season under Nasik condition, it is found that the zinc, copper and boron had a significant effect on bulb development and yield as well as bulb quality when applied in combination of 3 ppm Zn + 1 ppm Cu + 0.5 ppm B at 30 and 45 days after transplanting as foliar application gave the highest returns.

Vinay *et al.* (1995) conducted an experiment to find out the response of onion to N, P, Zn and FYM. They reported that the highest bulb yield (50.6 g plot) was obtained from plants fertilized with FYM (10 t/ha) + 40 kg N /ha + 60 kg P/ha.

Bevacqua *et al.* (1994) observed that onion seedlings transplanted to compost treated plots established more vigorously than those in the control plots. They also found that compost treatments increased yields (FW) of onions compared with controls.

Cho *et al.* (1994) conducted an experiment to assess the effect of organic matters and lime materials on quality improvement of tissue cultured garlic. For this purpose, they used organic matter (rice straw, compost or fermented poultry manure) and/or lime and the growth, yield were investigated. They found that organic manure improved yield but the lime application had no effect on yield.

Abbas *et al.* (1994) conducted an experiment in Indonesia with a local garlic cultivar where N was applied at 0, 50, 100 or 150 kg/ha as urea and

0, 30, 60 or 90 kg $K_2O$/ha as muriate of potash. Garlic yield was found to be highest with 100 kg N/ha and 90 kg $K_2O$/ha. However, there was no significant interaction between N and K in this respect.

Katwale and Saraf (1994) stated that the largest bulb yield was obtained from the application of NPK at the rate of 125:60:100 kg/ha, respectively in onion. They also reported that the rate gave the highest economic return.

Singh *et al.* (1994) carried out an experiment in Uttar Pradesh, India to investigate the effects of N (as urea at 0, 100 or 200 kg N/ha) on the growth of garlic cv. Amaranle. Plants also received 50 kg $P_2O_5$/ha and 50 kg $K_2O$/ha. They observed that vegetative growth and yield (62.07 q/ha) were maximum for plants receiving N at the rate of 100 kg/ha.

Sarvananan and Nambisan (1994) conducted an experiment at Kodiakanal, Madras, India on garlic. Garlic crop was given 0, 50, 100 or 150 kg N; 0, 25, 50 or 75 kg P and 0, 25, 50 or 75 kg K/ha in various combinations. Mean bulb yield was the highest (9750 kg/ha) with 100 kg N + 75 kg P + 50 kg K/ha.

Vachhani and Patel (1993) conducted an experiment on the effects of nitrogen (50, 100 or 150 kg N/ha), phosphorus (25, 50 or 75 kg $P_2O_5$/ha) and potash (50, 100 or 150 $K_2O$/ha) levels on the growth and yield of onion. They reported that plant height, number of leaves/plant, bulb weight and yield were highest with 150 kg N/ha. Increasing phosphorus application increased the number of leaves per plant and weight, size and yield of bulbs. Application of K increased only the number of leaves per plant.

Nasiruddin *et al.* (1993) conducted an experiment on the effect of potassium and sulphur on the growth and yield of onion at Mymensingh of Bangladesh. It revealed that the increased plant height, leaf production ability of the plant, decreases bulb weight as well as the bulb yield were

obtained from 10 kg potash and 30 kg sulphur/ha, respectively.

In a field trial in Indian on a local garlic cultivar planted at a spacing of 15x7.5cm. Selvaraj *et al.* (1993) found that the mean uptake of N, P, K and Mg at harvest (calculated from plant nutrient content) was 251.2, 19.03, 298.0 and 2.64 kg/ha, respectively. They obtained the highest yield (22.0 t/ha) with the application of N, K ($K_2O$) and MgS04 at 75, 75 and 50 kg/ha, respectively (in addition to 25 t FYM and 90 kg $P_2O_5$/ha.

Wang *et al.* (1992) worked in China with garlic and found that the optimum N, P and K requirements for higher yield of garlic were 260.27, 60.86 and 369.67 ppm, respectively. They also observed that garlic yield was increased significantly as N, P and K supply was increased.

Kropisz (1992) carried out an experiment using composted pine bark (CPB) + vegetable matter, compost sawdust (CS) + vegetable matter (added to CPB and CS at 10, 20 or 30% by volume) and FYM were applied at 25 t/ha in 3-year field trials with cabbage, onion and carrot. All the organic fertilizers were applied in the first year only. NPK fertilizers were applied annually and there were plots where NPK alone was applied. Organic fertilizers in all cases improved cropping, with the highest average yields being obtained 110 plots receiving FYM + NPK.

An investigation was done by Goto and Kimoto (1992) to observe the effect of different organic fertilizers on onion cultivar Pira Ouro. Onion was given the following fertilizer treatments: (1) castor bean cake, (2) poultry manure (3) sewage sludge or (4) FYM, and in each case P + KorN + P + K was added. There was also an N + P + K variant and P + K as the control. N was used at 80 kg/ha. $P_2O_5$ at 180 kg/ha and $K_20$ at 120 kg/ha. The quantities for (1), (2), (3) and (4) were 1600, 4000, 4000 and 16000 kg/ha, respectively. N was applied in 3 split doses. The highest commercial yields were obtained with treatments (1) + P + K and (4) + N + P + K (12.1

t/ha in each case).

Eid *et al.* (1991) in Egypt found that growth parameters and its components were generally increased with increased K application rate up to 100 kg $K_2O$/feddan and with micronutrient mixture (Cu, Zn and Fe).

Pandey *et al.* (1991) studied with four levels of nitrogen (0, 50, 100 and 150 kg/ha), three levels of phosphorus (0, 40 or 80 kg/ha) and two levels of potash (0 and 50 kg/ha) to determine the yield and quality of karif onion. They found that the maximum yield and net return were achieved with N: P: K at 150:40:50 kg/ha.

Amado and Teixeira (1991) studied in a fallow area with or without N and all the treatments received 120 kg $P_2O_5$/ha and 66 kg $K_2O$/ha. Combined application of NPK gave the highest dry matter and bulb yield of onion. They also reported to the amount of dry matter of the cover crop residues.

An experiment was carried out by Francois (1991) to evaluate the yield and quality of garlic and onion under excess boron condition. Garlic cv. California Early and onion cv. South Port white Globe were grown in out door sand culture condition. Boron was applied with irrigation water as cutlure solutions concentration of 0.5, 1.0, 5.0, 10.0, 15.0 or 20.0 mg B/litre. With each unit increase in B in soil solution above 4.3 and 8.9 mg B/litre the relative yields of garlic and onion were reduced by 2.7% and 1.9% respectively. Garlic bulb weight and diameter were reduced with the increasing B solution concentration while the onion bulb weight and diameter did not affect significantly.

A field experiment was carried out by Jana and Kabir (1990) to study the effect of S on the growth and yield of onion cv. Nasik Red. Sulphur powder at 0, 30, 40 and 50 kg $ha^{-1}$ were applied along with FYM, N, P and K as usual dose. The highest plant height (48.62 cm), number of leaves (9.14),

bulb diameter (6.13 cm), root length (13.78 cm), weight of 10 bulbs (1.02 kg) and yield 30.69 t $ha^1$ were recorded with sulphur at a dose of 30 kg per hectare.

Setty *et al.* (1989) studied the effects of nitrogen, phosphorus and potash on the growth and yield of garlic at Dharwad, India. Application at three levels each of N (0, 100 and 200 kg/ha), $P_2O_5$ (0, 50 and 100 kg/ha) and $K_2O$ (0, 50 and 100 kg/ha) were made. Application of N at 200 kg/ha produced significant increases in plant height, number of leaves, neck thickness, bulb size, number of cloves/bulb and yield. Application of P at 100 kg/ha increased the number of leaves, bulb size and number of cloves/bulb. Application of K at 100 kg/ha produced significantly larger bulbs. The largest bulb diameter (3.67 cm) and the highest yield (7.91 t/ha) were observed with the 100 kg N + 50 kg $P_2O_5$ + 50 kg $K_2O$/ha treatment.

In Indonesia, low land and highland garlic crops are traditionally fertilized with $N:P_2O_5:K_2O$ at the rate of 250:90:150 kg/ha. Since the garlic crop is grown after 2 preceding rice crops, which are heavily fertilized, Asandhi (1989) conducted an experiment to determine whether omitting P and K and reducing the N rate to 120 kg/ha was possible. The results showed that P and K fertilization was needed and that decreasing the N rates reduced plant growth and garlic yield. The best method of N fertilization was the application of 80 kg N/ha at 15, 30 and 45 days after planting.

Khalaf and Taha (1988) carried out two field experiments in Egypt to evaluate the effect of organic manure 0 and 20 $cm^3$/feddan [1 feddan = 0.24 ha] and sulphur (0, 250 and 500 kg/feddan) on the growth, plant mineral contents, yield, bulb quality and volatile oil content of garlic. The treatments were applied during land preparation. They reported that both organic matter and S were beneficial for plant growth, total yield and quality.

In a trial conducted in Indonesia, Gudi *et al.* (1988) observed that application of manure increased fresh yield of garlic. They applied stable manure to garlic at 0 to 10 t/ha and found that 10 t/ha stable manure gave the highest yield (12.2 kg/4.5 $m^2$) compared to control (5.2 kg/4.5$m^2$).

Hedge (1988) conducted an experiment with cv. Pusa Red and found that application of N fertilizer increased the bulb yield, but not quality. It was also showed that the dry matter production of bulb was increased due to uptake of more N, P, K, Ca and Mg nutrients.

Hilman and Noordiyata (1988) conducted an experiment in a rice field at Ciwidey, Indonesia to study equilibrium N, P and K fertilization on garlic yield. The results showed that the equilibrium N, P and K fertilization at several levels did not significantly affect bulb diameter, bulb length, number of cloves per bulb, or fresh bulb weight. However, the treatments indicated a significant effect on bulb dry weight.

Soto (1988) carried out an experiment with critical levels for P, K and S and response to N. The rates were 100 kg/ha each of N, $P_2O_5$ and $K_2O_5$ and 50 kg S/ha. Nitrogen was applied at 0, 50, 100 and 150 kg/ha. He mentioned that 50 kg N/ha gave the best yield response.

Khalaf and Taha (1988) conducted an experiment in Egypt to study the response of garlic plants grown on calcareous soil to organic manuring and sulphur application. Two experiments were conducted to evaluate the effects of organic manure (0 and 20 m/freedan) and sulphur (0, 250 and 500 kg/freedan) on the growth, plant mineral contents, yield, bulb qualities and bulb volatile oil content of garlic. The treatments were applied during land preparation. Both organic manure and S were very effective for plant growth, total yield and quality as well as N, P and K contents in the plant tissues. The high S rates was more beneficial then the low one.

Pereira *et al.* (1987) carried out an experiment on fertilization in Brazil with garlic. Plants were grown without any fertilization, with NPK or with compost at 10, 20, 30, 40 or 50 t/ha. The highest yield (7067 kg/ha) was obtained with 20 t compost /ha.

Borabash and Kochina (1987) worked in Ukrain on mineral fertilization with garlic productivity. They reported that mineral fertilization increased the assimilating leaf area, photosynthetic productivity and yield of garlic. The yields of underground bulbs and of underground bulbs + aerial bulbils at 90:90:90 kg/ha N: $P_2O_5$; $K_2O$ treatments were 6.48 and 7.50 t/ha, respectively and returns were highest in this treatments although the 90:90:150 kg/ha treatment gave the highest yield.

Singh (1987) in his trial with onion cv. Pusha Red at different levels and combination of NPK fertilizers observed a significant response from N but not from K. The highest yield (26.04 t/ha) was obtained with N and $P_2O_5$ at 112.5 and 196.9 kg/ha respectively.

Results over 2 years trial conducted by Saimbhi *et al.* (1987) indicated that applying of NPK at the highest rate gave the greatest bulb size, maximum yield (33.89 t/ha) and best quality of dehydrated onions. The highest NPK combination was 100 kg N, $P_2O_5$ and 60 kg $K_2O$ per hectare.

Guandi and Asandhi (1986) studied the effect of fertilization on garlic cv. Lumba Hijau planted at 20 × 40$m^2$ plots and fertilized with 0, 80, 160 or 240 kg N/ha as urea or $(NH_4)_2SO_4$ + 120 $K_2O$/ha as KC1 or $K_2SO_4$ + 120 kg $P_2O_5$/ha as triple super phosphate. They observed that higher rates of N produced greater plant heights and greater stem diameter.

Pal and Pandey (1986) conducted an experiment in India to investigate the effect of different levels of fertilizers. Plant growth was significantly increased by the application of 150 kg N, 250 kg P and 75 kg K/ha. Bulb

yield of garlic was significantly increased by 150 kg N, 250 kg P and 75 kg K/ha (9.49 t/ha compared with 3.39 t/ha in control receiving no NPK).

Sulphur is a macro-nutrient occuring in soil both in organic and inorganic forms. It performs a vital role for plants growth and synthesis of amino acids (Cysteine, Cystine and Methonine), coenzyme A, biotin, thiamine (Vit. B), chlorophyll and is an important part of ferodoxin. Characteristic taste and smell of garlic is due to sulphur content. In most soils, organic sulphur provides the major source. The average sulphur content of the each soil crust is 0.06-0.10%. The major sulphur bearing minerals are Gypsum ($CaSO_4.2H_2O$), Epsomite ($MgSO_4.7H_2O$), Mirabilite ($Na_2SO_4.10H_2O$), Pyrite ($FeS_2$) and Sphalarite (ZnS). Plant uptakes sulphur in the forms of $SO_4$ from the soil solution or soil colloids. Sulphur becomes in reduced forms like FeS, $FeS_2$ and $H_2S$ under water logged condition Guandi and Asandhi (1986).

Beresniewiez and Novvosiecski (1986) reported that application of 200 kg N, 200 kg $P_2O_5$, 200 kg $K_2O$, 20 kg Mg, 5 kg Mn, 5 kg Zn, 10 kg Cu and 1.5 kg Mo/ha gave the highest yields. Yields were further increased when organic fertilizer (lignite or peat) at 100 MT/ha and Ca at 2 t/ha were applied at the same time.

Madan and Sandhu (1985) noticed that good plant growth and maximum bulb yield and dry matter contents were obtained with $N:P_2O_2:K_2O$ at 12:60:60 kg/ha in onion.

Das *et al.* (1985) conducted an experiment at the Bidhan Chandra Krishi Viswavidyalaya, Cooch Behar, India on the effect of fertilization of $N:P_2O_5$ and/or $K_2O$ at 0-120:0-60:0-120 kg/ha. The average yield of garlic was highest (6.32 t/ha) with NPK at 60:60:120 kg/ha.

Asiegbu *et al.* (1984) carried out an experiment in Nigeria on onion with farmyard manure and reported that bulb diameter and the percentage of grade 1 bulbs were increased with increasing FYM application. They also found that onion yields were maximum with 20 t FYM/ha.

In 2-years trial conducted by Limat *et al.* (1984) with the cv. Amaranle of garlic, the plants were grown on soil into which the following were incorporated: green manure (*Crotalaria spectabilis*), FYM (30 t/ha), processed industrial waste (30 t/ha) or venniculite (6 t/ha). Profitability was the greatest with bulbs grown using processed industrial waste followed by FYM.

Nelson (1983) conducted an experiment on garlic fertilization trial. May planted garlic on silt loam soil was supplied with combination of (1) N at 100, 150 or 200 kg/ha as a basal dressing 100 days after planting (2) 25 or 325 kg/ha and (3) 25 or 175 + 150 kg K/ha. Both yield and bulb size were improved by increasing the basal N rate, increased N side dressing improved bulb size and when combined with the higher P rate it also raised the yield. The different K rates had no effect on yield or bulb size.

Rashid (1983) recommended 10 tons of cowdung, 175 kg of Urea, 125 kg of TSP and 150 kg of MP per hectare for successful onion cultivation in Bangladesh.

Agrawal *et al.* (1981) conducted an experiment at the Vegetable Research Farm, Kanpur, India during 3 consecutive seasons of 1968-69 to 1970-71 with three trials on onion cv. Kalianpur Red Round. The plant received N, $P_2O_5$ and/or $K_2O$ at 80-160; 40-80 kg/ha. The highest yield was obtained from plots receiving 160:40:40 or 80:40:80 kg/ha. The application of nitrogen alone at 80 kg/ha gave satisfactory yield (2.02 t/ha) and was the most economic dose.

Gupta and Gaffar (1980) conducted an experiment to study the effect of different row' spacing under different combinations of nitrogen, phosphorus and potassium

on the growth and yield of onion. Application of NPK exerted a significant effect on the yield and yield contributing characters of onion. Economic yield was obtained from NPK application @ 46:36:36 kg/ha Paterson (1979) conducted an experiment in America to study the sulphur fertilization effects on yield and pungency of onion. He found that yield of onion was increased by 22.48% with application of sulphur at 17 kg/ha.

Minard (1978) conducted an experiment in New Zealand with garlic cloves of 2 sizes (1.0-1.9 and 2.0-2.9g) fertilized with N at 0 or 210 kg/ha, P at 263-1250 kg/ha, K at 0 or 750 kg/ha and lime (as ground lime stone) at 5 or 15 t/ha. The highest yield was obtained from larger bulb size, receiving N and K at high and low rates, respectively.

Lazzari *et al*. (1978) found that the application of higher nitrogen fertilizer improved the yield and quality of garlic grown in a loam soil in Argentina.

Islam and Haque (1977) in Bangladesh studied the effect of NPK on an indigenous cultivar of onion, and observed that the combined dose of nitrogen at 60 kg, phosphorus at 35 kg and potash at 35 kg per hectare produced the highest yield.

Rahman *et al.* (1976) studied the effect of NPK on the local onion cv. Faridpur Bhatti in Bangladesh. They found that a combined dose of nitrogen at 56 kg/ha, phosphorus at 67 kg/ha and potash at 67 kg/ha produced the best results in order to get the highest yield. Higher level of nitrogen application (112 kg/ha) resulted in decreased yield but increased levels of potassium (135 kg/ha) increased the size and yield of bulbs.

Rahman and Faruque (1975) studied the effect of NPK on onion cv. White Creole and found that an application of N: P: K @ 90:45:45 kg/ha resulted in the highest yield.

Maurya and Lai (1975) conducted an experiment to study the effect of boron in relation to the growth and development of onion. Pusa red onion was grown in

sand culture treated with 0, 1, 2 or 3 ppm of boron. Best response in terms of leaf and root numbers and fresh and dry weights of plants and bulbs were recorded from 1 ppm boron. Different growth characters were found to depress with the increasing concentration of boron. Organic fertilizer improves the physical, chemical and biological condition of soil. Fertilizers play a very important role in utilizing the soils for an efficient crop production. A number of works investigated the combined effect of organic and inorganic fertilizers.

Bari (1974) stated that a dose of 66:88:88 kg N, $P_2O_5$ and $K_2O$ per hectare gave the highest yield of onion.

Pande and Mundra (1971) conducted an experiment on response of garlic to varying levels of N, P and K. in Madhya Pradesh, India and reported that the height of plant, number of leaves, length of bulbs, diameter of the bulbs, fresh and dry weight of top growth and yield of garlic bulbs per hectare were significantly increased by the application of N.

Pimpin (1970) reported the results of a study conducted with garlic cv. *Blanca piacintin* where 0, 80 and 160 kg/ha each of N, $P_2O_5$ and $K_20$ were applied in factorial combinations. N and K improved the number and weight of bulbs, but P had negative effects on these parameters.

Lazo *et al*. (1969) in their trial on the use of NPK fertilizers in onion at the rate of 50, 100, 150 kg per hectare observed that nitrogen used alone or in combination with phosphorus and potash responded well.

Purewal and Daragan (1961) conducted an experiment on fertilization with garlic in India. The application of nitrogen increased the weight of individual bulb significantly over control. Highest response was obtained on the weight of individual bulb with 112.27 kg/ha nitrogen. Phosphorus and potash did not give any response.

## 2.2 Effect of spacing on growth and yield of garlic

Optimum number of plants per hill is one of the most important and uncontroversial factors for maximizing the yield of a crop. The results of many researchers relating to number of plants per hill of underground crops including garlic are reviewed.

Hussena *et al*. (2014) conducted a field experiment to determine the effect of intra-row spacing on the growth performance of garlic. The experiment was conducted on a randomized complete block design with three replications. Only one local variety was used on the experiment. The result of the experiment revealed significant difference among treatments with regard to plant height at 56 days after emergence. Plant height was influenced by intra row spacing such that plant height increases when the intra row spacing of the plant decreases. A significance difference was also recorded in leaf width, leaf length and leaf number per plant as influenced by intra row spacing ($P<0.05$). The highest leaf width (1.99cm) was recorded in treatment five (planted with 20cm plant spacing). The wider the plant spacing the higher was the leaf number. However the results of the experiment did not include yield components. Thus, a similar research should be conducted so as to assure the results of this experiment and to include yield components.

Rajas *et al.* (1993) in a trial in India as the effect of varying levels of sulphur and spacing compared with frequencies of irrigation on the yield of onion grown in ridarhha. The onion cv. Pusa Red was grown during the rabi season of 1990-91. Four rates of sulphur 0, 40, 60 and 80 kg/ha. 3 plant spacings 10 × 15 cm, 15 ×15 cm and 20 x15 cm and 5, 10. 15 days irrigation intervals were used. The highest yield 28.11 t/ha was obtained from 80 kg S/ha with a plant spacing of 10 × 15 cm and an irrigation intervals of 5 days.

Herison *et al*. (1993) conducted an experiment on three onion cultivars viz., sweet sandwich, vega and Yula in the green house in 200 cell plastic trays and thinned to one, two or three seedlings/cell. Seedlings were transplanted into the field 12 weeks after sowing, without separating individual plants from multi plant cells. Two and three plants/cell yielded a higher percentage of bulbs of 76 mm in diameter, however one plant/cell yielded more bulbs of 102 mm in diameter.

Mandal *et al*. (1973) conducted an experiment at Trivandrum in India using non branched (H-165) and branched (H-97) types of tapioca (Manihot csculenta) to study the effect of plant density, fertility level and shoot number on tuber yield and quality of tapioca hybrids and found that two plants per hill gave better yield than did one plant per hill. They recommended spacing of 75 cm × 75 cm, with two plants per hill and of 90 cm×90 cm with one plant per lull for types H-165 and H-97, respectively.

### 2.3 Interaction of different nutrients and spacing

Sing *et al*. (2004) conducted an experiment in Uttar Pradesh, India to get the highest production of garlic. Treatments comprised: 3 N rates (0, 80 and 160 kg/ha; $N_0$, $N_1$ and $N_2$, respectively), 3 planting dates (10 September, 10 October and 10 November, $T_1$, $T_2$ and $T_3$ respectively) and 3 row spacing (10×10, 15×15 and 20×20 $cm^2$; $S_1$, $S_2$ and $S_3$, respectively). The interactions of different levels of nitrogen, planting time and spacing significantly influenced the plant height and yield of garlic. Combined effects of early planting time with the highest nitrogen rate ($T_1N_2$) produced a high growth and yield. Early planting with lower spacing resulted in a high yield, while a large number of cloves and fresh weight per bulb were recorded with early planting and the widest spacing ($T_1S_3$). The largest bulb diameter was recorded with the widest spacing and highest nitrogen rate ($S_3N_2$). The highest level of nitrogen and widest spacing *(*$S_3N_2$) proved less effective the growth and yield of garlic.

An experiment was conducted by Das and Mohanty (2001) to evaluate the effect of plant density (8×8, 10×8, 10×10 and 15×10 $cm^2$) and N:P:K rates (50:50:50, 75:75:75, 100:100:100 and 125:125:125 kg/ha) on the yield of garlic cv. Madrasi. Among the spacing treatments, *8'8* cm (at 900 plants/plot) produced the highest yield (165.28 q/ha), followed by 8×8 cm among the fertilizer treatments. N:P:K at 100:100:100 kg/ha produced the highest bulb yield (153.78 q/ha), followed by 125:125:125 kg/ha. Combination of 10×8 cm spacing and 100:100:100 kg N:P:K/ha resulted in the maximum yield of 170.27 q/ha.

# CHAPTER III

## MATERIALS AND METHODS

The present study was carried out to study the response of different micronutrients and spacing on the growth and yield of garlic (*Allium sativum L.*) during the period from November 2013 to April 2014. Materials and methods of the present study have been discussed by the following headings –

### 3.1 Experimental site

The experiment was conducted at Horticultural Farm in Sher-e-Bangla Agricultural University, Dhaka-1207. The experiment was carried out during November 2013 to April 2014. It was located in the south western corner of the university and corner of the farm.

### 3.2 Climate

The climate of the experimental field was sub-tropical and was characterized by high temperature, heavy rainfall during Kharif-1 season (March-June) and scanty rainfall during Rabi season (October-March) associated with moderately low temperature. The monthly average temperature, humidity, rainfall and sunshine hours prevailed at the experimental area during the cropping season are presented in Appendix I.

### 3.3 Soil

The land belongs to the Agro-ecological zone "Madhupur tract" (AEZ-28) and selected land was medium high land with adequate irrigation facilities. The soil of the experimental site were well drained and medium high. The physical and chemical properties of soil of the experimental site sandy loam in texture and having soil $p^H$ varied from 5.45-5.61. Organic matter content ware very low (0.83). The physical composition such as sand, silt, clay content were 40%, 40% and 20% respectively. The soil property of the experimental field was presented in Appendix II.

### 3.4 Materials used for the experiment

Cloves of BARI Rasun-1 variety was collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

### 3.5 Land preparation

The selected experimental plot was first opened by a power tiller in the month of October, 2013, one month before planting. Several ploughing and cross ploughing with power tiller followed by laddering were done until the desired tilth was

achieved for planting the cloves. The corners of the plots were trimmed by spade. The clodes were broken into friable soil and the surface of the soil was leveled. During land preparation weeds and stubbles of the previous crops were collected and removed from the field. Irrigation and drainage channels were prepared around the plots.

### 3.6 Manuring and fertilization

Urea, Triple Super Phosphate (TSP) and Murate of Potash (MP) were used as the fertilizer source of the nutrient elements N, P and K respectively. A standard dose of NPK @ 100, 55,160 kg /ha was used in all treatments. The following doses of manure and fertilizer were used for the present study:

| Fertilizer | | Doses/ha | Nutrients | Sources |
|---|---|---|---|---|
| Cow dung- | | 15 t | - | Nature |
| Mustard oil cake | | 2 t | - | Nature |
| Urea | | 218 kg | 100 kg N | $CO(NH_2)_2$ |
| TSP | | 275 kg | 55 kg P | $Ca(H_2PO4)_2$ |
| MP | | 320 kg | 160 kg k | KCl |
| Gypsum | $T_1$ | 84 kg | 15 kg S | $CaSO_4.H_2O$ |
| | $T_2$ | 112 kg | 20 kg S | |
| | $T_3$ | 139 kg | 25 kg S | |
| Boric acid | $T_1$ | 12 kg | 2 kg B | $H_3BO_3$ |
| | $T_2$ | 24 kg | 4 kg B | |
| | $T_3$ | 36 kg | 6 kg B | |
| Zinc Sulphate | $T_1$ | 15 kg | 5 kg Zn | $ZnSO_4.H_2O$ |
| | $T_2$ | 29 kg | 10 kg Zn | |
| | $T_3$ | 43 kg | 15 kg Zn | |

### 3.7 Design and Layout of the experiment

The two factors experiments having 12 different treatment combinations were laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole experimental area was divided into three blocks and each of which was then divided into 12 unit plots. The twelve treatment combinations were then distributed randomly among the unit plots of each block so as to all of treatments were placed once in each block. The size of each unit plot was 0.6 m × 0.9 m. The space between the blocks and plots were 50cm and 30cm respectively (Fig. 1).

### 3.8 Experimental treatments

Two factors were used in the experiment viz. four levels of nutrients (T) and three levels of spacing (S).

#### 3.8.1 Factor- A: Four levels of micronutrients

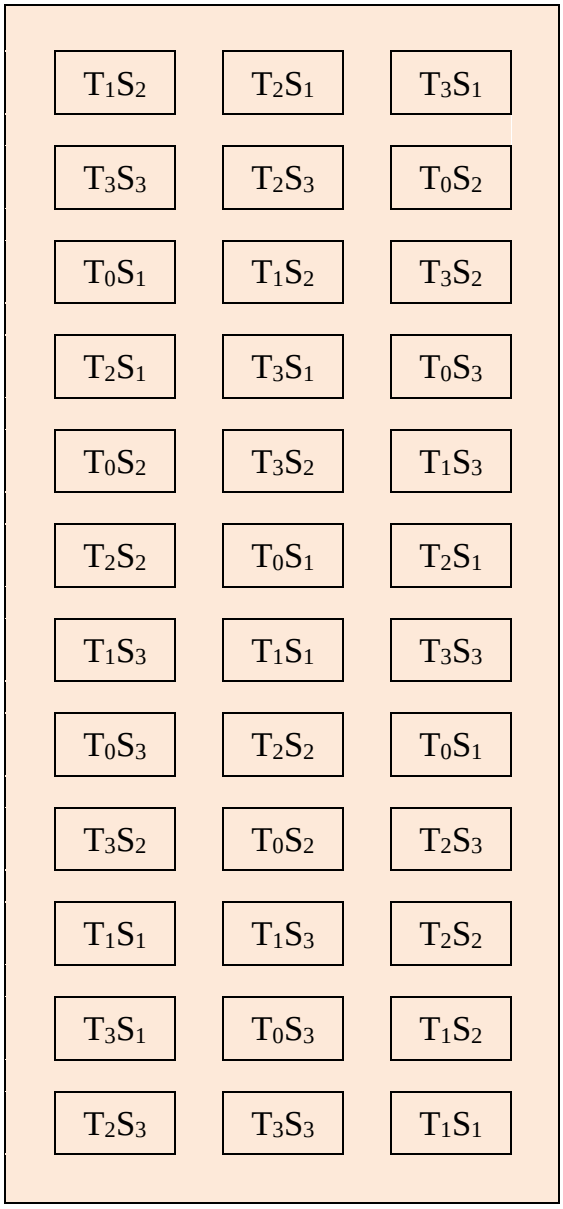
$T_0$ = $S_0B_0Zn_0$ (Kg/ha) (Control)
$T_1$ = $S_{15}B_2Zn_5$ (Kg/ha)
$T_2$ = $S_{20}B_4Zn_{10}$ (Kg/ha)
$T_3$ = $S_{25}B_6Zn_{15}$ (Kg/ha)

#### 3.8.2 Factor –B: Three levels of spacing

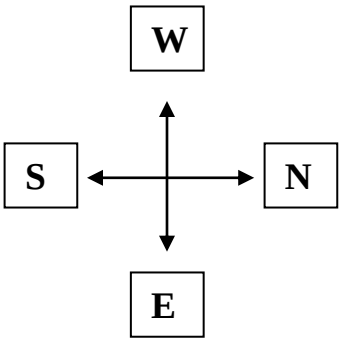
$S_1$ = 10 cm × 10 cm
$S_2$ =15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

#### 3.8.3 Treatment combinations (Micronutrients × spacing)

$T_0S_1$, $T_0S_2$, $T_0S_3$, $T_1S_1$, $T_1S_2$, $T_1S_3$, $T_2S_1$, $T_2S_2$, $T_2S_3$, $T_3S_1$, $T_3S_2$, $T_3S_3$
Altogether, there were 12 treatment combinations.




**Legend**




**Treatments:**

**Factor A: Micronutrients**

$T_0$ = $S_0B_0Zn_O$
$T_1$ = $S_{15}B_2Zn_5$
$T_2$ = $S_{20}B_4Zn_{10}$
$T_3$ = $S_{25}B_6Zn_{15}$

**Factor B: Spacing**

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

**Experiment layout:**

Plot to plot distance = 0.6 m
Block to block distance =0.9m
Plot size = 0.6×0.9 $m^2$
Replication = 3

Fig.1. Layout of the experimental field

### 3.9 Planting method of clove

The cloves for planting were selected from large bulbs of garlic. The cloves were separated from bulbs immediately before planting. Planting was done by placing cloves at a depth of 2.5 cm in the soil with the use of a pointed stick. The cloves were inserted vertically with the root plate down making sure that there was a root-soil contact. Selected cloves were planted in each unit plot maintaining spacing of different treatments required. Cloves were also planted around the experimental plot area to check border effect.

### 3.10 Intercultural operations

After planting the cloves, the experimental area was kept under careful observation and the following intercultural operations were done.

#### 3.10.1 Gap filling

The unsproutcd cloves were replaced by healthy seedling taken from border plants within two weeks after planting. The damaged plants were also replaced by healthy border plants.

#### 3.10.2 Weeding

Weeding was done regularly to keep the plots free from weeds and to pulverise the soil.

#### 3.10.3 Irrigation

Frequency of watering depended upon the moisture status of the soil. Irrigation was given by a watering can as and when needed. Irrigations were provided in each plot uniformly. Mulching was done after each irrigation at appropriate time by breaking the soil crust.

### 3.10.4 Plant protection

After complete emergence of the crop, rovral @ 25gm /10 liters of water was applied at an interval of 15 days upto one month before harvesting to control purple leaf blotch disease of garlic.

### 3.10.5 Harvesting

The crop was harvested on 03 April, 2014, after attaining maturity, showing the sign of drying out of most of the leaves and softening of the neck of the bulb.

### 3.11 Collection of data

Ten plants were selected randomly from each unit plot for the collection of data. Data were collected periodically at 30, 45, 60, 75 and 90 DAS (Days after sowing) and at harvest in respect of following characters:

### 3.11.1 Plant height (cm)

Plant height was measured from ten plants in centimeter (cm) from the ground level to the tip of the longest leaf of the sample plants at 30, 45, 60, 75 and 90 DAS and at harvest. The mean was also calculated.

### 3.11.2 Number of leaves per plant

The numbers of leaves of 10 sample plants were counted at 30, 45, 60, 75 and 90 DAS and at harvest and their average was calculated.

### 3.11.3Diameter of neck (cm)

Diameter of pseudostem was taken at the neck of 10 randomly selected bulbs at 30, 45, 60, 75 and 90 DAS and at harvest and their average was calculated.

### 3.11.4 Bulb length (cm)

Bulb length was measured from ten plants in centimeter (cm) from the ground level to the end of the clove formation at harvest and the mean was calculated.

### 3.11.5 Bulb diameter (cm)

The diameter at the middle part of the bulb was taken from ten randomly selected plants after harvest with a slide calipers and their mean was recorded in cm.

### 3.11.6Bulb weight per plant (g)

After harvest, the root and top portion were removed keeping only 2.5cm pseudostem with the bulb, the bulb weight of 10 selected plants were taken and their mean was calculated.

### 3.11.7 Number of cloves per bulb

After harvesting the numbers of cloves of 10 selected bulbs were counted thoroughly. The mean number of cloves per bulb was calculated by dividing the total number of cloves counted from ten bulbs by ten.

### 3.11.8 Yield of bulb per plot (g)

Bulb yield per plot was recorded by harvesting all the bulbs in each plot and taking their weight after removing roots and pseudostem keeping only 2.5 cm with the bulb. Yield per plot was expressed in gram (g).

### 3.11.9 Yield of bulb per hectare (t)

Yield of bulb per plot was converted into yield per hectare and was expressed in tons.

## 3.12 Statistical analysis

The collected data from the experiment on yield and yield components were statistically analyzed following experiment in RCBD wherever necessary. The mean for all treatments were calculated and analyses of variance of the parameters under study were performed by F variance test. The significance of the difference among the means of treatment combinations was estimated by Dunean's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez,1984).The means of the parameters were separated by least significant difference (LSD).

### 3.13 Economic analysis

The cost of production was analyzed in order to find out the most economic combination different level of population density and phosphorus application. All input cost included the cost for lease of land and interests on running capital in computing the cost of production. The interests were calculated @ 14% in simple rate. The market price of goldenrod spike was considered for estimating the cost and return. Analyses were done according to the procedure of Alam *et al*. (1989). The benefit cost ratio (BCR) was calculated as follows:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return per hectare (Tk.)}}{\text{Total cost of production per hectare (Tk.)}}$$

# CHAPTER IV

## RESULTS AND DISCUSSION

The experiment was conducted at the Horticultural farm in Sher-e-Bangla Agricultural University during the period from November 2013 to April 2014 to find out the response of different micronutrients and spacing on the growth and yield of garlic. The analysis of variance (ANOVA) of the data on different growth and yield parameters are presented in Appendices III-VII. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following sub-headings:

### 4.1 Plant height (cm)

Plant height was significantly influenced by micronutrient at different days after sowing of garlic (Table 1 and Appendix III.).It was observed that at 30 DAS, there was no significant effect on plant height among the treatments but in case of 45, 60, and 75 DAS plant height was significantly influenced by different levels of plant nutrient. Plant height was increased within 30 DAS to 75DAS. At 75 DAS, the highest plant height (44.66cm) was achieved from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the lowest plant height (38.38cm) was observed from control $T_0$ ($S_0B_0Zn_O$) treatment. Similar results were found from the findings of Farooqui *et al*. (2009). Hence it may be inferred that the increase in plant height may be due to the favorable influence and balanced absorption of nutrients, increased role of photosynthesis, reduced transpiration and stimulation of root system. Harun-or Rashid (1998) and they observed that plant height was significantly influence by different plant nutrient application to garlic crop field.

Table1. Effect of different micronutrients on plant height at different days after sowing of garlic

| Treatments | Plant height(cm) | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0$ | 24.58 | 28.88 b | 33.52 c | 38.38 c |
| $T_1$ | 24.90 | 31.51 a | 36.45 b | 43.68 b |
| $T_2$ | 25.08 | 31.89 a | 37.17 a | 43.83 b |
| $T_3$ | 25.54 | 32.00 a | 37.22 a | 44.66 a |
| **$LSD_{0.05}$** | **NS** | **0.6766** | **0.5247** | **0.3344** |

Here,

$T_0$ = $S_0B_0Zn_O$ (kg/ha), $T_1$ = $S_{15}B_2Zn_5$ (kg/ha),
$T_2$ = $S_{20}B_4Zn_{10}$ (kg/ha), $T_3$ = $S_{25}B_6Zn_{15}$ (kg/ha)

Different spacing had significant variation on plant height of garlic at different days after sowing (DAS) (Table 2 and Appendix III). Plant height increased with decreased plant spacing up to a certain limited time (30DAS to 75DAS) . At 75 DAS, the highest plant height ( 43.90 cm) was achieved from $S_1$ (10 cm × 10 cm) treatment. Again, the lowest plant height (40.16cm) was observed from $S_3$ (15 cm × 15 cm) treatment which was statistically similar $S_2$ (15 cm × 10 cm) treatment. The variation in plant height as influenced by spacing was perhaps due to proper utilization of nutrient, moisture and light. Similar result also revealed by Hussena *et al*. (2014). They found that plant height was influenced by intra row spacing such that plant height increases when the intra row spacing of the plant decreases.

Table. 2. Effect of different spacing on plant height at different days after sowing of garlic

| **Treatments** | **Plant height (cm)** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $S_1$ | 26.32 a | 32.39 a | 37.21 a | 43.90 a |
| $S_1$ | 25.11 b | 30.77 b | 36.03 b | 41.85 b |
| $S_1$ | 23.65 c | 30.04 b | 35.03 c | 40.16 b |
| **$LSD_{0.05}$** | **1.039** | **1.030** | **0.9609** | **1.009** |

Here,

$S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm, $S_3$ = 15 cm × 15 cm

Combined effect of different nutrient and spacing on plant height of garlic was statistically significant at different days after sowing (DAS) (Table 3 and Appendix III). At 75DAS, the highest plant height (47.93cm) was found in $T_3S_1$ ($S_{25}B_6Zn_{15}$ with 10cm×10cm) treatment combination. On the contrary the lowest plant height (36.37cm) at 75 DAS was recorded from $T_0S_3$ ($S_0B_0Zn_0$ with 15cm×15cm) treatment combination. Similar result was also found by Sing *et al*. (2004) and they observed that different plant nutrients with different spacing and planting dates had significant influence on plant height.

Table 3.Combined effect of different micronutrients and spacing on plant height at different days after sowing of garlic

| Treatments | Plant height (cm) | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0S_1$ | 25.43 c | 32.03 cd | 37.03 c | 44.63 c |
| $T_0S_2$ | 24.10 d | 30.57 f | 35.48 d | 41.40 e |
| $T_0S_3$ | 22.80 f | 28.57 h | 33.10 e | 36.37 h |
| $T_1S_1$ | 26.10 b | 32.40 bc | 38.00 b | 44.07 c |
| $T_1S_2$ | 24.27 d | 30.73 f | 35.37 d | 42.70 d |
| $T_1S_3$ | 23.43 e | 28.93 gh | 33.42 e | 38.57 g |
| $T_2S_1$ | 27.87 a | 32.87 b | 38.43 b | 46.73 b |
| $T_2S_2$ | 24.87 c | 30.93 ef | 35.53 d | 42.80 d |
| $T_2S_3$ | 24.03 d | 29.13 gh | 34.03 e | 40.20 f |
| $T_3S_1$ | 28.33 a | 35.53 a | 40.60 a | 47.93 a |
| $T_3S_2$ | 25.03 c | 31.57 de | 36.83 c | 44.53 c |
| $T_3S_3$ | 24.03 d | 29.57 g | 35.23 d | 41.70 e |
| **$LSD_{0.05}$** | **0.5487** | **0.7164** | **0.9087** | **0.5792** |
| **CV(%)** | **9.38** | **8.80** | **7.98** | **7.82** |

Means in a column followed by the same letter do not differ significantly at 5% level

Here,

$T_0$ = $S_0B_0Zn_O$ (kg/ha)
$T_1$ = $S_{15}B_2Zn_5$ (kg/ha)
$T_2$ = $S_{20}B_4Zn_{10}$ (kg/ha)
$T_3$ = $S_{25}B_6Zn_{15}$ (kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

## 4.2 Number of leaves per plant

There was significant difference in the number of leaves per plant of garlic due to different plant nutrient at different days after sowing (DAS) (Table 4 and Appendix IV). It was observed that at 30 DAS, there was no significant effect on number of leaves per plant among the treatments but in case of 45, 60 and 75 DAS number of leaves per plant was significantly influenced by different levels plant nutrients. At 75 DAS, the highest number of leaves per plant (6.52) was achieved from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the lowest number of leaves per plant (6.0) was

observed from $T_0$ ($S_0B_0Zn_O$) treatment which, was statistically similar $T_1$ ($S_{15}B_2Zn_5$) treatment. From the results of the present study indicated that optimum levels of macro and micro fertilizers combination might have induced better growing condition, perhaps due to supply of adequate plant nutrients which ultimately led to the production of more leaves per plant. The result obtained from the present was supported by Farooqui *et al*. (2009), Setty *et al.* (1989), Vachhani and Patel (1993), Alam (1995) and Jana and Kabir (1990) in respect of number of leaves per plant.

Table 4. Effect of different micronutrients on number of leaves per plant at different days after sowing of garlic

| **Treatments** | **Number of leaves plant$^{-1}$** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0$ | 3.74 | 4.52 c | 5.10 c | 6.00 c |
| $T_1$ | 3.78 | 4.78 b | 5.29 b | 6.02 c |
| $T_2$ | 3.79 | 4.88 b | 5.37 b | 6.28 b |
| $T_3$ | 3.80 | 5.03 a | 5.54 a | 6.52 a |
| **$LSD_{0.05}$** | **NS** | **0.1197** | **0.1157** | **0.1312** |

Here

$T_0 = S_0B_0Zn_O$ (kg/ha), $T_1 = S_{15}B_2Zn_5$ (kg/ha),

$T_2 = S_{20}B_4Zn_{10}$ (kg/ha), $T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

Number of leaves per plant of garlic was significantly influenced by different spacing at different days after sowing (DAS) (Table 5 and Appendix IV). It was

observed that at 30, 45, 60 and 75 number of leaves per plant was significantly influenced by different levels of spacing. At 75 DAS, the highest number of leaves per plant (6.28) was achieved from $S_3$ (15 cm × 15 cm) treatment which was statistically similar with $S_2$ (15 cm × 10 cm) treatment and the lowest number of leaves per plant (6.10) was observed from $S_1$ (10 cm × 10 cm) treatment. Such results obtained from the present study might be due to cause of nutritional factors in soil. Generally lower number of plants was provided more nutrients compared to higher population with same nutrient status in the soil that was provided and caused more number of leaves plant from higher plant spacing.

Table 5. Effect of different spacing on number of leaves per plant at different days after sowing of garlic

| **Treatments** | **Number of leaves plant$^{-1}$** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $S_1$ | 3.66 b | 4.70 b | 5.37 b | 6.10 b |
| $S_1$ | 3.83 a | 4.79 b | 5.28 a | 6.23 a |
| $S_1$ | 3.85 a | 4.92 a | 5.32 a | 6.28 a |
| **$LSD_{0.05}$** | **0.1002** | **0.1037** | **0.1021** | **0.1037** |

Here,

$S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm, $S_3$ = 15 cm × 15cm

Combined effect of different micronutrient and spacing was statistically significant in respect of number of leaves per plant at different days after sowing (DAS) (Table 6and Appendix IV). Gradually increased number of leaves per plant was observed till 75 DAS. At 75 DAS, the maximum (6.77) number of leaves per plant was found in $T_3S_3$ ($S_{25}B_6Zn_{15}$ with 15cm×15cm) treatment combination which was statistically identical with $T_2S_3$ treatment combination and the

minimum (5.87) number of leaves per plant was found in $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×0cm) treatment combination which was statistically similar to $T_1S_1$, $T_2S_1$ and $T_3S_1$ treatment combinations. Such results obtained from the present study might be due to cause of nutritional factors in soil and different spacing. Generally more nutrients and higher spacing plant get more food and space for vigorous growth and produce more leaves compared to lower nutrients and spacing.

Table 6. Combined effect of different micro nutrients and spacing on leaves per plant at different days after sowing of garlic

| **Treatments** | **Number of leaves per plant** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0S_1$ | 3.60 f | 4.47 e | 4.80 e | 5.87 f |
| $T_0S_2$ | 3.73 de | 4.77 cd | 5.23 d | 6.10 de |
| $T_0S_3$ | 3.87 bc | 4.93 bc | 5.37 cd | 6.33 bc |
| $T_1S_1$ | 3.60 f | 4.50 e | 5.17 d | 5.93 ef |
| $T_1S_2$ | 3.73 de | 4.77 cd | 5.27 cd | 6.17 cd |
| $T_1S_3$ | 3.90 ab | 4.93 bc | 5.50 bc | 6.40 b |
| $T_2S_1$ | 3.63 ef | 4.60 de | 5.20 d | 5.93 ef |
| $T_2S_2$ | 3.80 b-d | 4.77 cd | 5.27 cd | 6.20 b-d |
| $T_2S_3$ | 3.90 ab | 5.13 ab | 5.63 ab | 6.60 a |
| $T_3S_1$ | 3.77 cd | 4.63 de | 5.33 cd | 5.97 ef |
| $T_3S_2$ | 3.80 b-d | 4.93 bc | 5.40 cd | 6.20 b-d |
| $T_3S_3$ | 4.00 a | 5.20 a | 5.73 a | 6.77 a |
| **$LSD_{0.05}$** | **0.1071** | **0.2074** | **0.2208** | **0.1855** |
| **CV(%)** | **6.72** | **7.06** | **6.87** | **5.93** |

Means in a column followed by the same letter do not differ significantly at 5% level
Here,

$T_0 = S_0B_0Zn_O$ (Kg/ha)
$T_1 = S_{15}B_2Zn_5$ (Kg/ha)
$T_2 = S_{20}B_4Zn_{10}$ (Kg/ha)
$T_3 = S_{25}B_6Zn_{15}$ (Kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

### 4.3 Neck diameter (cm)

Application of different micronutrients had significant effect of neck diameter per plant of garlic at different days after sowing (DAS) ( Table 7 and Appendix v). Neck diameter was increased within 30 DAS to 75DAS. At 75 DAS the maximum neck diameter per plant (0.58cm) was achieved from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the minimum neck diameter per plant (0.51cm) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. These result indicated that the different levels of S, Zn, B nutrients with NPK fertilizers combinedly supplied plant nutrients and provided better growing conditions which helped for getting proper vegetative growth as well as maximum neck diameter. Farooqui *et al*. (2009) and Setty *et al.* (1989) also observed that different plant nutrients significantly affect neck diameter of garlic during cropping season.

Table 7. Effect of different micronutrient on neck diameter per plant at different days after sowing of garlic

| **Treatments** | **Neck diameter plant$^{-1}$ (cm)** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0$ | 0.30 c | 0.33 c | 0.48 c | 0.51 d |
| $T_1$ | 0.31 b | 0.37 b | 0.50 b | 0.53 c |
| $T_2$ | 0.31 b | 0.38 ab | 0.52 a | 0.56 b |
| $T_3$ | 0.32 a | 0.39 a | 0.52 a | 0.58 a |
| **$LSD_{0.05}$** | **0.0098** | **0.0142** | **0.01693** | **0.0203** |

Here,

$T_0 = S_0B_0Zn_O$ (kg/ha), $T_1 = S_{15}B_2Zn_5$ (kg/ha),

$T_2 = S_{20}B_4Zn_{10}$ (kg/ha), $T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

Significant variation was found for different spacing on neck diameter per plant (cm) of garlic at different days after sowing (DAS) (Table 8 and Appendix V). Neck diameter increased with increased plant spacing up to a certain limited time (30DAS to 75DAS). At 75 DAS the highest neck diameter per plant (0.55cm) was recorded from $S_3$ (15 cm × 15 cm) treatment and the lowest neck diameter per plant (.52cm) was observed from $S_1$ (10 cm × 10 cm) treatment. Optimum number of plants per unit area probably influenced to produce maximum neck diameter of garlic. Higher density of population show higher competition for nutrient uptake that resulted minimum neck diameter with closer spacing.

Table 8. Effect of different spacing on neck diameter per plant at different days after sowing of garlic

| **Treatments** | **Neck diameter plant$^{-1}$ (cm)** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $S_1$ | 0.30 b | 0.36 b | 0.50 b | 0.52 c |
| $S_1$ | 0.31 a | 0.37 b | 0.50 b | 0.53 b |
| $S_1$ | 0.32 a | 0.38 a | 0.52 a | 0.55 a |
| **$LSD_{0.05}$** | **0.0085** | **0.0121** | **0.0145** | **0.0113** |

Here,
$S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm, $S_3$ = 15 cm × 15 cm

Combined effect of different plant nutrients and spacing on neck diameter per plant of garlic at different days after sowing (DAS) had considerable variation among the treatments (Table 9 and Appendix V). At 75 DAS, the maximum neck diameter per plant (0.65cm) was found in $T_3S_3$ ($S_{25}B_6Zn_{15}$ with 15cm ×15cm) treatment combination and the minimum neck diameter per plant (0.46cm) was found in $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×10cm) treatment combination which was statistically similar $T_0S_2$ ($S_0B_0Zn_0$ with 15 cm × 10 cm ) treatment combination.

Table 9.Combined effect of different micronutrients and spacing on neck diameter per plant at different days after sowing of garlic

| **Treatments** | **Neck diameter per plant (cm)** | | | |
|---|---|---|---|---|
| | **30 DAS** | **45 DAS** | **60 DAS** | **75 DAS** |
| $T_0S_1$ | 0.27 e | 0.32 e | 0.44 e | 0.46 f |
| $T_0S_2$ | 0.30 d | 0.34 de | 0.46 de | 0.48 ef |
| $T_0S_3$ | 0.30 d | 0.34 de | 0.48 cd | 0.51 de |
| $T_1S_1$ | 0.30 d | 0.36 cd | 0.49 cd | 0.52 d |
| $T_1S_2$ | 0.30 d | 0.36 cd | 0.52 bc | 0.56 bc |
| $T_1S_3$ | 0.33 b | 0.40 b | 0.51 c | 0.58 b |
| $T_2S_1$ | 0.30 d | 0.36 cd | 0.49 cd | 0.53 cd |
| $T_2S_2$ | 0.31 cd | 0.36 cd | 0.51 c | 0.58 b |
| $T_2S_3$ | 0.33 b | 0.39 b | 0.54 b | 0.59 d |
| $T_3S_1$ | 0.30 d | 0.36 cd | 0.50 c | 0.53 cd |
| $T_3S_2$ | 0.32 bc | 0.37 c | 0.51 c | 0.60 b |
| $T_3S_3$ | 0.37 a | 0.45 a | 0.61 a | 0.65 a |
| **$LSD_{0.05}$** | **0.017** | **0.024** | **0.030** | **0.034** |
| **CV(%)** | **12.05** | **9.70** | **9.46** | **13.97** |

Means in a column followed by the same letter do not differ significantly at 5% level

Here,

$T_0 = S_0B_0Zn_O$ (kg/ha)
$T_1 = S_{15}B_2Zn_5$ (kg/ha)
$T_2 = S_{20}B_4Zn_{10}$ (kg/ha)
$T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

### 4.4 Bulb length (cm)

Effect of different micronutrient showed significant variation on bulb length of garlic (Fig. 2 and Appendix VI). Increased trend was found with increased nutrient levels. The highest bulb length of garlic (3.41 cm) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment which was statistically similar with $T_2$ ($S_{20}B_4Zn_{10}$) treatment where the lowest bulb length of garlic (2.95 cm) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. Setty *et al.* (1989) and Pande and Mundra (1971) observed that different nutrients had significant effect on bulb size.

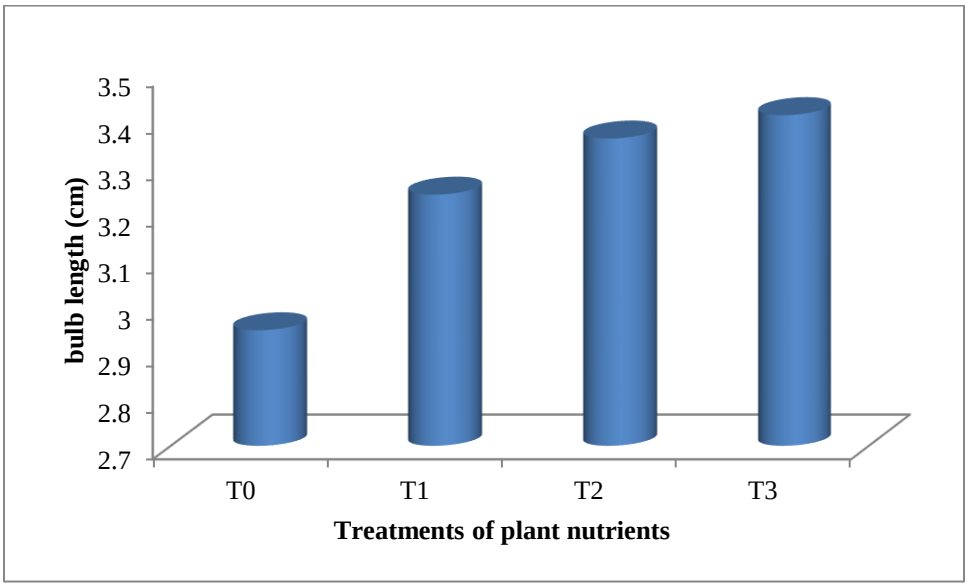



Fig.2. Effect of different micronutrients on bulb length of garlic

Here,

$T_0 = S_0B_0Zn_O$ (kg/ha), $T_1 = S_{15}B_2Zn_5$ (kg/ha),

$T_2 = S_{20}B_4Zn_{10}$ (kg/ha), $T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

Under the present study, different levels of spacing proved significant variation for bulb length of garlic (Fig. 3 and Appendix VI). Comparatively higher spacing showed higher bulb length. The maximum bulb length of garlic (3.34 cm) was recorded from $S_3$ (15 cm × 15 cm) treatment. Where the minimum bulb length of garlic (3.15 cm) was recorded from $S_1$ (10 cm × 10 cm) treatment. It can also be signified that maximum bulb length from higher spacing was achieved due to available nutrient, sunlight and easy intercultural operation.

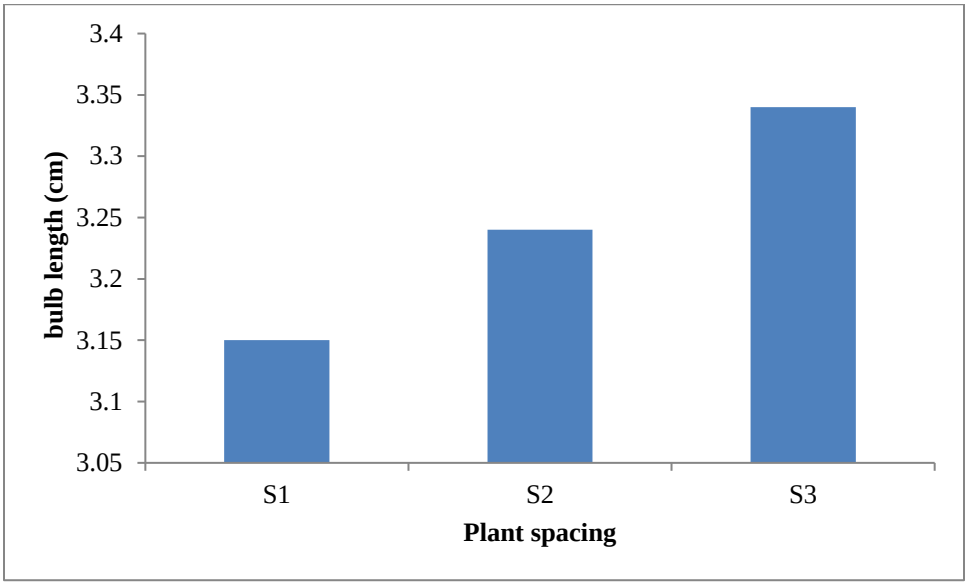



Fig .3. Effect of different plant spacing on bulb length of garlic

Here,

$S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm, $S_3$ = 15 cm × 15 cm

Bulb length of garlic varied significantly by combined effect of different levels of micronutrient and spacing (Table 10 and Appendix VI). The highest bulb length (3.62 cm) was obtained from $T_3S_3$ ($S_{25}B_6Zn_{15}$ with 15cm×15cm) Treatment combination, which was statistically similar with $T_2S_3$ treatment combination. The lowest bulb height (2.81 cm) was recorded from $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×10cm) treatment combination, which was statistically similar with $T_0S_2$ treatment combination. Intermediate results were found from the rest of the treatment combinations.

### 4.5 Bulb diameter (cm)

Different micronutrient levels showed significant variation for bulb diameter of garlic (Table 11 and Appendix VI). It was found that the highest bulb diameter of garlic (3.20 cm) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment where the lowest bulb diameter of garlic (2.92 cm) treatment was recorded from $T_0$ ($S_0B_0Zn_O$) treatment, which was statistically identical with $T_1$ ($S_{15}B_2Zn_5$) treatment. Different levels of plant nutrient showed significant influence on bulb diameter and it was supported by the findings of Farooqui *et al*. (2009), Setty *et al.* (1989), Francois (1991) and Varu *et al.* (1997).

Significant levels of spacing showed significant variation for bulb diameter (cm) of garlic (Table 12 and Appendix VI). Result indicated that higher spacing gave higher bulb diameter and the maximum bulb diameter of garlic (3.22 cm) was recorded from $S_3$ (15 cm × 15 cm) treatment where the minimum height bulb diameter of garlic (2.94 cm) was recorded from $S_1$ (10 cm × 10 cm) treatment. Sing *et al*. (2004) observed that wider spacing provide higher bulb diameter.

Bulb diameter was significantly varied by combined effect of different micronutrient and spacing (Table 10 and Appendix VI). The result obtained from the present study pointed out that the highest bulb diameter of garlic (3.34 cm) was obtain from $T_3S_3$ ($S_{25}B_6Zn_{15}$ with 15m×15cm) treatment combination which, was statistically similar with $T_2S_3$ and $T_3S_2$ treatment combination. The lowest bulb diameter of garlic (2.72 cm) was recorded from $T_0S_1$($S_0B_0Zn_0$ with 10cm×10cm) treatment combination which was statistically similar with $T_0S_2$ treatment combination. Comparison with highest and lowest bulb diameter, the treatment combination of $T_1S_3$ and $T_2S_1$ gave medium result. Actually when more nutrients present in soil with sufficient quantity plant uptake more nutrient and in higher spacing plants get more nutrient, sunlight, water and minerals due to lower population. That is why bulb diameter was increased.

Table 10.Combined effect of different micro nutrients and spacing on bulb length (cm), bulb diameter (cm) of garlic

| Treatments | Bulb length (cm) | Bulb diameter (cm) |
|---|---|---|
| $T_0S_1$ | 2.81 g | 2.72 f |
| $T_0S_2$ | 2.87 g | 2.79 f |
| $T_0S_3$ | 3.08 f | 3.00 de |
| $T_1S_1$ | 3.16 ef | 2.92 e |
| $T_1S_2$ | 3.18 ef | 3.02 de |
| $T_1S_3$ | 3.35 cd | 3.16 bc |
| $T_2S_1$ | 3.20 ef | 3.07 cd |
| $T_2S_2$ | 3.39 cd | 3.22 b |
| $T_2S_3$ | 3.55 ab | 3.26 ab |
| $T_3S_1$ | 3.27 de | 3.23 b |
| $T_3S_2$ | 3.45 bc | 3.25 ab |
| $T_3S_3$ | 3.62 a | 3.34 a |
| **$LSD_{0.05}$** | **0.1417** | **0.0928** |
| **CV(%)** | **9.97** | **5.65** |

Means in a column followed by the same letter do not differ significantly at 5% level

Here,

$T_0 = S_0B_0Zn_O$ (kg/ha)
$T_1 = S_{15}B_2Zn_5$ (kg/ha)
$T_2 = S_{20}B_4Zn_{10}$ (kg/ha)
$T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

### 4.6 Bulb weight per plant (g)

Bulb weight per plant was significantly influenced due to different levels of micronutrient (Fig. 4 and Appendix VII). Bulb weight was increased with increasing plant nutrients. Results showed that the maximum bulb weight per plant (16.31 g) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the lowest bulb weight of per plant (12.02 g) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. From the above results, it was noted that S, B, Zn micro nutrients and NPK when combinedly used the nutrients become available to plants and much bulb formation was occurred.

The available soil nutrients supported proper vegetative growth by producing succulent bulb with more protoplasm in the cells in comparison to less available nutrient in garlic. The results found from the findings of Farooqui *et al*. (2009), Gudi *et al.* (1988), Pande and Mundra (1971), Hilman and Noordiyata (1988), Alam (1995) and Maurya and Lai (1975) were similar with the present study.

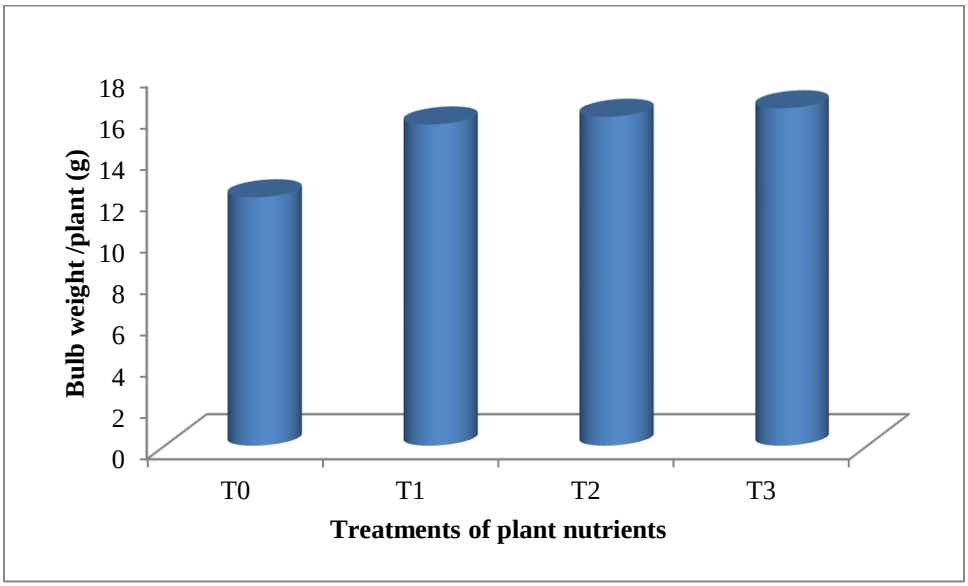



Fig.4. Effect of different micro nutrient on bulb weight per plant of garlic

Here,

$T_0 = S_0B_0Zn_O$ (kg/ha), $T_1 = S_{15}B_2Zn_5$ (kg/ha),

$T_2 = S_{20}B_4Zn_{10}$ (kg/ha), $T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

Bulb weight per plant was significantly influenced by different level of spacing (Fig. 5 and Appendix VII). It was observed that higher spacing gave maximum bulb weight. The maximum bulb weight per plant (16.12 g) was recorded from $S_3$ (15 cm × 15 cm) treatment where the lowest bulb weight per plant (13.69 g) was recorded from $S_1$ (10 cm × 10 cm) treatment. It might be due to the fact that in treatment $S_3$ (15 cm × 15 cm) treatment received adequate plant nutrients, no inter competition among plants, favorable growing atmosphere which contributed to

maximum bulb weight of garlic. The result achieved from the present study was conformity with the findings of Sing *et al*. (2004) who observed higher bulb weight from wider spacing.

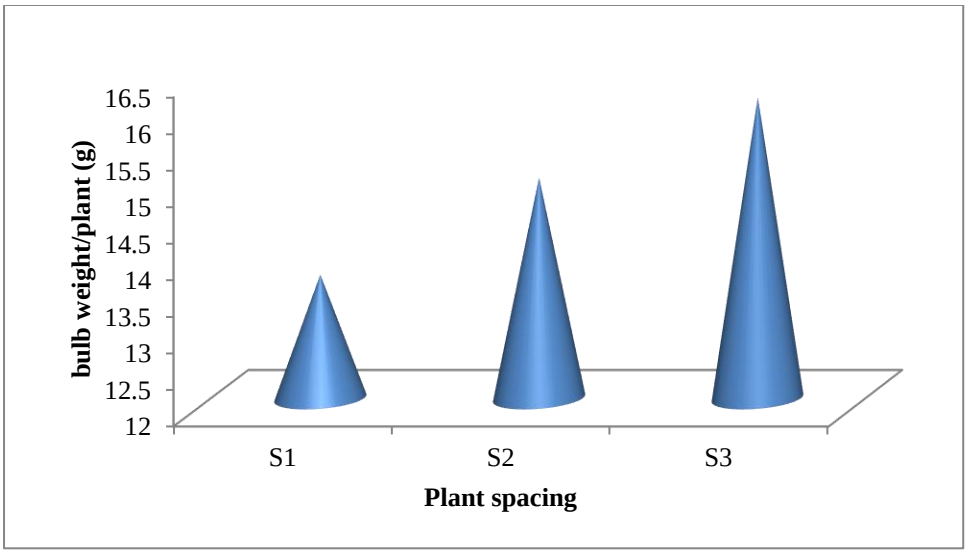



Fig.5. Effect of different plant spacing on bulb weight per plant of garlic

Here,

$S_1$ = 10 cm × 10 cm, $S_2$ = 15 cm × 10 cm, $S_3$ = 15 cm × 15 cm

Combined effect of different levels of micronutrient and spacing proved significant differences on bulb weight per plant of garlic (Table 13 and Appendix VII). Results revealed that the highest bulb weight per plant (18.20 g) was obtained from $T_3S_3$ ($S_{25}B_6Zn_{15}$ with 15cm×15cm) treatment combination, which was statistically similar with $T_2S_3$ treatment combination. The lowest bulb weight per plant (10.50 g) was recorded from $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×10cm) treatment combination. Rest of the treatment combination performed intermediate results in terms of fresh bulb weight per plant compared to all other treatments.

### 4.7 Number of cloves per bulb

Different levels of micronutrient showed significant variation for number of cloves per bulb of garlic (Table 11 and Appendix VII). Observed result showed that the

maximum number of cloves per bulb of garlic (22.25) was recorded from $T_2$ ( $S_{20}B_4Zn_{10}$) treatment which was statistically similar with $T_3$ ($S_{25}B_6Zn_{15}$) treatment where the minimum number of cloves per bulb of garlic (18.11) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. Similar result was found from the findings of Farooqui *et al*. (2009), Naik and Hosamani (2003), Setty *et al.* (1989) and Hilman and Noordiyata (1988).

The variation in terms of number of cloves per bulb of garlic was observed by different level of spacing (Table 12 and Appendix VII). It was found that lower spacing gave lower number of cloves per bulb and the highest number of cloves per bulb (22.16) was recorded from $S_3$ (15 cm × 15 cm) treatment where the lowest number of cloves per bulb (19.89) was recorded from $S_1$ (10 cm × 10 cm) treatment which was statistically similar to $S_2$ (15 cm × 10 cm) treatment. Similar result was found from the findings of Sing *et al*. (2004).

Table 11: Effect of different micronutrients on bulb diameter (cm), number of cloves per bulb, yield per plot (g) and yield per hectare (ton) of garlic

| Treatment | Bulb diameter (cm) | Number of cloves per bulb | Yield per plot (g) | Yield per hectare (ton) |
|---|---|---|---|---|
| $T_0$ | 2.92 c | 18.11 c | 184.50 d | 3.42 d |
| $T_1$ | 2.97 c | 21.39 b | 203.04 c | 3.76 c |
| $T_2$ | 3.11 b | 22.25 a | 280.62 b | 5.20 b |
| $T_3$ | 3.20 a | 21.94 a | 305.82 a | 5.66 a |
| $LSD_{0.05}$ | 0.0632 | 0.3761 | 3.894 | 0.267 |
| CV (%) | 3.162 | 7.114 | 5.179 | 4.443 |

Means in a column followed by the same letter do not differ significantly at 5% level
Here,

$T_0 = S_0B_0Zn_O$ (kg/ha)
$T_1 = S_{15}B_2Zn_5$ (kg/ha)
$T_2 = S_{20}B_4Zn_{10}$ (kg/ha)
$T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

Combined effect of different micronutrient and spacing had significant effect on number of cloves per bulb of garlic (Table 13 and Appendix VII). Results demonstrated that the highest number of cloves per bulb (23.99) was obtained from $T_3S_3$ treatment combination. The lowest number of cloves per bulb of garlic (16.80) was from $T_0S_1$ treatment combination which was statistically similar to $T_0S_2$ treatment combination. The results obtained from all other combined effect gave intermediate results.

### 4.8 Yield per plot (g)

Yield per plot of garlic was significantly affected by different levels of micronutrient (Table 11 and Appendix VII). Higher application of plant nutrients gave higher bulb yield per plot. Results specified that the highest yield per plot of garlic (305.82 g) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment where the lowest yield per plot of garlic (184.50 g) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment.

Different levels of spacing had significant effect on yield per plot of garlic (Table 12 and Appendix VII). It was found that the highest yield per plot of garlic (283.50 g) was recorded from $S_1$ (10 cm × 10 cm) treatment where the lowest yield per plot of garlic (238.95 g) was recorded from $S_3$ (15 cm × 15 cm) treatment. The obtained results represented that maximum yield contributing characters was best with higher spacing but in case of yield closer spacing gave maximum yield and this result might be due to cause of higher plant population from closer spacing.

Table 12: Effect of different spacing on bulb diameter (cm), number of cloves per bulb, yield per plot (g) and yield per hectare (ton) of garlic

| Treatment | Bulb diameter (cm) | Number of cloves per bulb | Yield per plot (g) | Yield per hectare (ton) |
|---|---|---|---|---|
| $S_1$ | 2.94 c | 19.89 b | 283.50 a | 5.25 a |
| $S_2$ | 3.05 b | 20.72 b | 258.80 b | 4.79 b |
| $S_3$ | 3.22 a | 22.16 a | 238.95 c | 4.43 c |
| $LSD_{0.05}$ | **0.1066** | **0.9111** | **3.365** | **0.273** |
| **CV (%)** | **2.713** | **5.382** | **3.794** | **3.719** |

Means in a column followed by the same letter do not differ significantly at 5% level

Here,
$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

Yield per plot of garlic was significantly affected by combined effect of different levels of micronutrient and spacing (Table 13 and Appendix VII). It was observed that the highest yield per plot (354.78 g) was obtained from $T_3S_1$ ($S_{25}B_6Zn_{15}$ with10cm×1ocm) treatment combination. Results also revealed that the lowest yield per plot of garlic (181.44 g) was recorded from $T_0S_3$ ($S_0B_0Zn_0$ with 15cm×15cm) treatment combination ,which was statistically similar to $T_0S_2$ treatment combination. The results obtained from all other treatment combination gave intermediate results compared to highest and lowest results. Higher number of plant population need higher amount of nutrients. Under the present study, closer spacing with higher nutrient doses gave the higher yield and this type of achievement might be due to higher plant population.

### 4.9 Yield per hectare

Different micronutrient showed significant variation on yield (t $ha^{-1}$) of garlic (Table11 and Appendix VII). Results represented that the highest yield of garlic (5.66 t $ha^{-1}$) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment. Again, the lowest yield of garlic (3.42 t $ha^{-1}$) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. The results obtained from the present study was similar with the findings of Farooqui *et al*. (2009), Limat *et al.* (1984), Setty *et al.* (1989) and Agrawal *et al.* (1981).

There was significant variation on yield (ton per hectare) of garlic due to the effect of different spacing (Table12 and Appendix VII). Results specified that the highest yield of garlic (5.25 t $ha^{-1}$) was recorded from $S_1$ (10 cm × 10 cm) treatment where the lowest yield of garlic (4.43 t $ha^{-1}$) was recorded from $S_3$ (15 cm × 15 cm) treatment. The results obtained from the present study was similar with the findings of Hussena *et al*. (2014), Haider (2001) and Dragland (1986).

Yield of garlic was significantly affected by combined effect of different micronutrient and spacing (Table 13 and Appendix VII). Results identified that the highest yield of garlic (6.57 t $ha^{-1}$) was obtained from $T_3S_1$ ($S_{25}B_6Zn_{15}$ with 10cm×10cm) treatment combination. The lowest yield of garlic (3.36 t $ha^{-1}$) was recorded from $T_0S_3$ ($S_0B_0Zn_0$ with 15cm×15cm) treatment combination. This result might be due to presence of favorable nutrient present in soil and higher population also contributed in the formation of the height yield of garlic. Similar results were observed by Sing *et al*. (2004).

Table 13: Combined effect of different micronutrient and spacing on bulb weight plant$^{-1}$, number of cloves bulb$^{-1}$, yield plot$^{-1}$(g) and yield ton per hectare of garlic

| **Treatments** | **Bulb weight per plant (g)** | **Number of cloves bulb$^{-1}$** | **Yield plot$^{-1}$ (g)** | **Yield (t ha$^{-1}$)** |
|---|---|---|---|---|
| $T_0S_1$ | 10.50 g | 16.80 f | 187.92h | 3.48 h |
| $T_0S_2$ | 11.90 f | 17.30 f | 184.14 i | 3.41 i |
| $T_0S_3$ | 13.10 e | 18.57 e | 181.44 *i* | 3.36 j |
| $T_1S_1$ | 13.67 de | 19.87 d | 292.68 c | 5.42 c |
| $T_1S_2$ | 13.93 d | 20.97 c | 272.70 e | 5.05 e |
| $T_1S_3$ | 16.60 b | 22.73 b | 246.78 g | 4.57 g |
| $T_2S_1$ | 14.23 d | 20.23 d | 298.62 b | 5.53 b |
| $T_2S_2$ | 16.87b | 22.83 b | 286.20 d | 5.30 d |
| $T_2S_3$ | 17.63 a | 23.27 b | 257.04 f | 4.76 f |
| $T_3S_1$ | 15.73 c | 21.57 c | 354.78 a | 6.57 a |
| $T_3S_2$ | 16.93 b | 22.94 b | 292.14 c | 5.41 c |
| $T_3S_3$ | 18.20 a | 23.99 a | 270.54 e | 5.01 e |
| **$LSD_{0.05}$** | **0.5987** | **0.6731** | **2.033** | **0.041** |
| **CV (%)** | **14.91** | **12.61** | **8.36** | **7.59** |

Means in a column followed by the same letter do not differ significantly at 5% level

Here,

$T_0$ = $S_0B_0Zn_O$ (Kg/ha)
$T_1$ = $S_{15}B_2Zn_5$ (Kg/ha)
$T_2$ = $S_{20}B_4Zn_{10}$ (Kg/ha)
$T_3$ = $S_{25}B_6Zn_{15}$ (Kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

## 4.10 Economic performances

Input costs for land preparation, cost of seed, fertilizer and manpower required for all the operations from sowing to harvesting of garlic were recorded for unit plot and converted into cost per hectare. Fixed cost for all the treatment was same. The total cost of production was the total cost of input and fixed cost. The economic analysis was done to find out the gross and net return and the benefit cost ratio in the present experiment and presented under the following headings:

### 4.10.1 Gross return

In the combination of different micronutrients spacing showed various gross return under different treatment combination (Table 14). The height gross return (TK. 262800/ha) was obtained from the $T_3S_1$ ($S_{25}B_6Zn_{15}$ with 10cm×10cm) treatment combination and the second height gross return (TK.221200/ha) was obtained in $T_2S_1$ treatment combination. The lowest gross return (TK.134400/ha) was obtained from the $T_0S_3$ ($S_0B_0Zn_0$ with 15cm×15cm) treatment combination.

### 4.10.2 Net return

In case of net return, different treatment combination showed different type of net return. The height net return (TK. 158392/ha) was obtained from the $T_3S_1$($S_{25}B_6Zn_{15}$ with 10cmx10cm) treatment combination and the second height net return (TK.1209211/ha) was obtained in $T_3S_2$ treatment combination. The lowest net return (TK.40551/ha) was obtained from the $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×10cm) treatment combination.(Table 14).

### 4.10.3 Benefit Cost Ratio

The combination of different nutrient and spacing for benefit cost ratio was different in all treatment combination (Table 14). The height benefit cost ratio (2.52) was obtained from the $T_3S_1$($S_{25}B_6Zn_{15}$ with 10cm×10cm) treatment combination and the second height benefit cost ratio (2.27) was obtained from $T_2S_2$ and $T_3S_2$ treatment combination. The lowest benefit cost ratio (1.41) was obtained from the $T_0S_1$ ($S_0B_0Zn_0$ with 10cm×10cm) treatment combination. From the economic point of view, it was apparent form the above results that the treatment combination of $T_3S_1$ was more profitable than rest of treatment combinations.

Table 14. Economic performances regarding gross return, net return and benefit cost ratio (BCR) of garlic

| Treatment | Cost of production (Tk. $ha^{-1}$) | Yield (t $ha^{-1}$) | Gross return (Tk. $ha^{-1}$)* | Net return (Tk. $ha^{-1}$) | BCR |
|---|---|---|---|---|---|
| $T_0S_1$ | 98649 | 3.48 | 139200 | 40551 | 1.41 |
| $T_0S_2$ | 89719 | 3.41 | 136400 | 46681 | 1.52 |
| $T_0S_3$ | 83022 | 3.36 | 134400 | 51378 | 1.62 |
| $T_1S_1$ | 100569 | 5.42 | 216800 | 116231 | 2.16 |
| $T_1S_2$ | 91639 | 5.05 | 202000 | 110361 | 2.20 |
| $T_1S_3$ | 84942 | 4.57 | 182800 | 97858 | 2.15 |
| $T_2S_1$ | 102488 | 5.53 | 221200 | 118712 | 2.16 |
| $T_2S_2$ | 93559 | 5.30 | 212000 | 118441 | 2.27 |
| $T_2S_3$ | 86862 | 4.76 | 190400 | 103538 | 2.19 |
| $T_3S_1$ | 104408 | 6.57 | 262800 | 158392 | 2.52 |
| $T_3S_2$ | 95479 | 5.41 | 216400 | 120921 | 2.27 |
| $T_3S_3$ | 88781 | 5.01 | 200400 | 111619 | 2.26 |

* Selling cost = 40.00 $Tk.kg^{-1}$

$T_0$ = $S_0B_0Zn_O$ (kg/ha)

$T_1$ = $S_{15}B_2Zn_5$ (kg/ha)

$T_2$ = $S_{20}B_4Zn_{10}$ (kg/ha)

$T_3$ = $S_{25}B_6Zn_{15}$ (kg/ha)

$S_1$ = 10 cm × 10 cm

$S_2$ = 15 cm × 10 cm

$S_3$ = 15 cm × 15 cm

Market price of garlic @ TK.40000 /ton ; Gross return = Total yield (t/ha) × TK.40000

Net return = Gross return- Total cost of production

Benefit Cost Ratio (BCR) = Gross return/ Total cost of production

# CHAPTER V

## SUMMARY AND CONCLUSION

An experiment was conducted at Horticultural Farm of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from November 2013 to April 2014. Cloves of BARI Rasun-1 variety was used for the present study and collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. The experiment was consisted of two factors: (1) Factor – A: Four levels of micro nutrients *viz*. (i) $T_0$ = $S_0B_0Zn_O$ (kg/ha), (ii) $T_1$ = $S_{15}B_2Zn_5$ (kg/ha), (iii) $T_2$ = $S_{20}B_4Zn_{10}$ (kg/ha) and (iv) $T_3$ = $S_{25}B_6Zn_{15}$ (kg/ha) and (2) Factor – B: Three levels of spacing *viz*. (i) $S_1$ = 10cm × 10 cm, (ii) $S_2$ = 15cm × 10 cm and (iii) $S_3$ = 15 cm× 15 cm. Altogether, there were twelve treatment combinations in this experiment. The size of unit plot was 0.6m × 0.9 m. The experiment was laid out in RCBD with three replications. The collected data from the experiment on growth, yield and yield components were statistically analyzed and mean were compared with LSD values.

Different parameters were selected for data collection and data were collected on Plant height (cm), Number of leaves per plant, Neck diameter (cm), Bulb height (cm), Bulb diameter (cm), Bulb weight per plant (g), Number of cloves per bulb, Yield per plot (g) and Yield per hectare (ton).

The result of the experiment revealed that all the parameters studied were significantly influenced by different nutrient levels. At 30 DAS, there was no significant effect on the plant height and number of leaves per plant. But in case of 45, 60 and 75 plant height, number of leaves per plant and neck diameter were significantly influenced by different levels of plant nutrient. At 75 DAS, the highest plant height (44.66cm), number of leaves per plant (6.52), neck diameter per plant (0.58cm) were achieved from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the lowest

plant height (38.38cm), number of leaves per plant (6.0) , neck diameter per plant (0.51cm ) were observed from control $T_0$ ($S_0B_0Zn_O$) treatment. The highest bulb height of garlic (3.41 cm), bulb diameter (3.20 cm) , bulb weight per plant (16.31 g) were recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment and the lowest bulb height (2.95 cm), bulb diameter (2.92 cm), bulb weight per plant (12.02g) were recorded from $T_0$ ($S_0B_0Zn_O$) treatment. The maximum number of cloves per bulb of garlic (22.25) was recorded from $T_2$ ($S_{20}B_4Zn_{10}$) treatment where the minimum number of cloves per bulb of garlic (18.11) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. The highest yield per plot of garlic (305.82 kg) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment where the lowest yield per plot of garlic (184.50 kg) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment. The highest yield of garlic (5.66 t $ha^{-1}$) was recorded from $T_3$ ($S_{25}B_6Zn_{15}$) treatment. Again, the lowest yield of garlic (3.42 t $ha^{-1}$) was recorded from $T_0$ ($S_0B_0Zn_O$) treatment.

Different plant spacing showed significant effect on growth parameters of garlic at different days after sowing (DAS). At 75 DAS, the highest plant height (43.90 cm) was achieved from $S_1$ (10 cm × 10 cm) but the highest number of leaves $plant^{-1}$ ( 6.28) and highest neck diameter $plant^{-1}$ (0.55) was achieved from $S_3$ (15 cm × 15 cm) treatment. Another way at 75 DAS the lowest plant height (40.16 cm) was achieved from $S_3$ (15 cm × 15 cm) treatment but the lowest number of leaves $plant^{-1}$ (6.10) and lowest neck diameter $plant^{-1}$ (0.52cm) was achieved from $S_1$ (10 cm × 10 cm) treatment. The highest height of bulb of garlic (3.34 cm), bulb diameter(16.12cm), bulb weight per plant (16.12g), number of cloves per (22.16) bulb was recorded from $S_3$ (15 cm × 15 cm) treatment. The lowest bulb height (3.15cm), bulb diameter (2.94 cm), dry matter content of bulb (43.12%), dry matter content of leaves (19.84%), bulb per plant (13.69g), number of cloves per bulb (19.89) were obtained from $S_1$ (10 cm × 10 cm) treatment. It was found that the highest yield per plot of garlic (283.50 g) was recorded from $S_1$ (10 cm × 10 cm) treatment where the lowest yield per plot of garlic (238.95 g) was recorded

from $S_3$ (15 cm × 15 cm). It was observed that the highest yield of garlic (5.25 t $ha^{-1}$) was recorded from $S_1$ (10 cm × 10 cm) treatment where the lowest yield of garlic (4.43 t $ha^{-1}$) was recorded from $S_3$ (15 cm × 15 cm) treatment.

Combined effect of micronutrients and spacing showed significant effect on growth parameters of garlic at different days after sowing (DAS). At 75 DAS, highest plant height (47.93cm) was found in $T_3S_1$ treatment combination but the highest number of leaves (6.77) and highest neck diameter $plant^{-1}$ (0.65cm) were found in $T_3S_3$ treatment combination. Similarly, the lowest plant height (36.37cm) was recorded from $T_0S_3$ but the lowest number of leaves $plant^{-1}$ (5.87) and lowest neck diameter $plant^{-1}$ (0.46cm) were found in $T_0S_1$ treatment combination .Combined effect of plant nutrients and spacing showed significant effect on yield and yield contributing parameters of garlic. Results showed that the highest bulb height (3.62 cm), fresh weight of bulb $plant^{-1}$ (18.20 g), highest bulb diameter (3.34 cm) and highest number of cloves $bulb^{-1}$ (23.99) were achieved from $T_3S_3$ treatment combination but the highest yield $plot^{-1}$ (354.78 g) and highest yield $ha^{-1}$ (6.57 ton) were obtained from $T_3S_1$ treatment combination. On the other hand the lowest height of bulb (2.81 cm), bulb weight $plant^{-1}$ (10.50 g), bulb diameter (2.72 cm) and number of cloves $bulb^{-1}$ of garlic (16.80) were recorded from $T_0S_1$ but the lowest yield $plot^{-1}$ (181.44 g) and yield $ha^{-1}$ (3.36 ton) were recorded from $T_0S_3$ treatment combination.

In terms of economic consideration, the highest and lowest cost of production were Tk. 1,04,408 $ha^{-1}$ and Tk. 83,022 $ha^{-1}$ involved in the treatment combination of $T_3S_1$ and $T_0S_3$ respectively. Again, the highest gross return Tk. 2,62,800 $ha^{-1}$ and highest net return (Tk. 1,58,392 $ha^{-1}$) was obtained from the treatment combination of $T_3S_1$ where the lowest gross return Tk. 1,34,400 $ha^{-1}$ and lowest net return (Tk. 4,0551 $ha^{-1}$) were found from the treatment combination of

$T_0S_3$ . The highest benefit cost ratio (BCR) (2.52) was found from the treatment combination of $T_3S_1$ where the lowest (1.41) was recorded from $T_0S_1$. Thus it was evident that the $S_{25}B_6Zn_{15}$ (kg/ha) with 10 cm × 10 cm plant spacing ($T_3S_1$) gave the highest garlic yield (6.57 t $ha^{-1}$) with highest net return (Tk. 1,58,392 $ha^{-1}$) and benefit cost ratio (BCR).

## Conclusion:

Considering the above result of this experiment; the following conclusion and recommendations can be drawn:

- In the experiment higher dose of nutrient $T_3(S_{25}B_6Zn_{15})$ was more effective than lower dose of nutrient $T_0(S_0B_0Zn_O)$.
- The spacing $S_3$ (15cm× 15cm) gave higher cloves per bulb but the spacing $S_1$ (10cm ×10cm) gave maximum yield per hectare.
- During the investigation, the best treatment combination was obtained from $T_3S_1$ ($S_{25}B_6Zn_{15}$ with 10 cm × 10 cm ) having yield potentiality of 6.57 t/$ha^{-1}$ and BCR 2.52 .

Considering the situation of the present experiment, further study might be conducted in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability and other performances.

# REFERENCES


Abbas, M., Rajat, S.S. Tomar, S. and Sharma K.K.(1994). Effect of nitrogen and potassium on the growth and yield of garlic. *J. Potassium Res*. **10**(4): 33-342. [Cited from Hort. Abstr., 66(6): 4950, 1996],

Abbey, L. (2000). Etfect of poultry manure and post-production application of fungicide on the shelf-life of onion cv. Bawku Red. *Crop Res*. Hisar, Ghana, **20**(1): 87-92.

Agrawal, M.L., Kinra, K.Z. and Singh, H.N. (1981). Manurial requirement of onion in gangetic alluvium of Uttar Prodesh. *Indian. J. Agril. Res.,* **15**(1): 5-10

Ahmed, Z.(2006). Effects of nitrogen and irrigation interval on the growth and yield of onion. M. S. Thesis, Dept, of Hort. BAU, Mymensingh. pp. 1-3.

Alam, M.S., Iqbal, M.T., Amin, M.S. and Gaffer, M.A.(1989). Krishitattik Foshaler Utpadan O Unnayan. (In Bengali). T.M. Jubair Bin Iqbal, Manik Potal. Meghai, Sirajgonj. pp. 231-239.

Alam, M.D. (1995). Effect of paclobutrozol and S fertilizer on the growth yield and sulphur content of garlic. MS Thesis, Bangladesh Agril. Univ., Mymensingh. pp. 92-95.

Aliudin, T.(1980). The effect of rate and time of nitrogen application on the growth and yield of garlic. *Buletin Penelitian Hortikultura*, (8): 12- 15. [Cited from Hort. Abst., **53** (12): 827, 1983.]

Aly, Khan., Shaukat, S.S. and A. Khan.(1997). Effect of some organic amendments on the density of nematodes associated with garlic (*Allium sativum* L.). Applied *Entom and Phytopath., Pakistan*, **66** (I&2): 13-18.

Amado. T.J. and Teixeira ,L.A.I.(1991). Cover crop effects on nitrogen supply and onion yield. *Onion Newsletter for the Tropics*, No. 3: 13-15.

Asandhi, A.A.(1989). Application of nitrogen, phosphours and potassium fertilizers in low land garlic farming. *Buletin Peneletian Horticulture*, 18(2): 1-7. [Cited from Soil and Fertilizers, **54**(8): 10723, 1991],

Asiegbu, J.E. and Uzo J.O.(1984). Studies on yield and yield component responses of vegetable crops to farmyard manure rates in the presence of inorganic fertilizer. *J. of Agric. Univ. of Puerto. Rico, Nigeria,* **68**(3): 243-252.

Asandhi, A. A. (1989). Application of nitrogen, phosphorus and potasium fertilizers in low land garlic farming. *Buletin Peneletian Horticulture*, 18(2): 1-7. [cited from Hort. Abst., 54(8): 1294, 1991],

Ashok, K., Singh G.N. and Kumar A.(1996). Effect of NPK on growth, yield and quality of garlic *(.Allium Sativum* L). *Recent Hort*., 3 (1): 118-121.

Augusti. K. T.(1977). Hypocholesterolaemic effect of garlic (*Allium sativum* L.). *Indian J. Expt. Biol.,* 15(6): 489-490

BARC.(1997). Fertilizer Recommendation Guide-1997. Bangladesh Agricultural Research Council, Farmgate, Dhaka. 95 p.

Bari, M. A.(1974). Effect of NPK and irrigation on the yield of onion (*Allium cepa* L.). M.Sc. (Ag.) Thesis, Department of Agronomy, BAU, Mymensingh.

BBS. (2004) Monthly Statistical Bulletin in Bangladesh. June. Statistics Division. Ministry' of Planning, Government of People's Republic of Bangladesh.

BBS. (2010) Monthly Statistical Bulletin in Bangladesh. June. Statistics Division. Ministry' of Planning, Government of People's Republic of Bangladesh.

BBS, (2005). Monthly Statistical Bulletin, October, (2006). Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh. Dhaka. P. 54.

Bertoni, G., Bemadae, A. M. and Morard, P.(1996). Study of sulphur nutrition in garlic. *Agrochimica*, 40: 2-3, 94-102.

Beresniewiez, A. and Nowosiecski, O. O.(1986). Effect of increasing rate of mineral lertilizers with simultaneous application of organic fertilizers and liming on vegetable yields and soil salinity. *Biuletyn Warzywniczy*, 26(2): 41-62. [*Cited from Hort. Abst*., 57(4): 262, 1987].

Bevacqua, R. F. and Mellano,V. J. (1994). Cumulative effects of studge compost on crop yield and soil properties. Communications in soil science and plant analysis, 25(3-4): 395-406. [*Cited from Hort. Abst*., 65(4): 2693, 1995],

Bhattarai, S. P., and Subedi, P. P. (1996). Studies on normal season onion variety nutrition and management trial at outreach research sites during 1993/94 season. *Lumle Reg. Agril. Res. Centre, Kaski, Nepal,* 96(10): 49. [Cited from Hort. Abst., 67(10): 8439, 1997].

Bhonde, S. R., Ram, L., Pandey ,U. B. and Tiwari,H. N. (1995). Effect ot micro-nutrients on growth, yield and quality of Kharif onion. *News Letter. National Horticultural Research and Development foundation,* 14-15:1, 16-20.

Bogatirenko, A.K. (1975). The effects of organic and mineral fertilizers on garlic yield and nutrient removal from the soil. *Referatimyi Zhwenal*, (1975). 12, 55, 630. [Cited from Hort. Abst., 46(9): 8378, 1976],

Borabash, O. Yu., and. Kochina, T. N.(1987). The effect of mineral fertilizers on garlic productivity. *Ref. Zhumal*, pp. 12-16. [Cited from Hort. Abstr., 60(5): 3284, 1990].

Bose, T. K., and Som, M. G.(1990). Vegetable Crops in India (1st edn.*), Naya Prakash, Calcutta, India,* pp. 583-601.

Bull, L. T., Forli, F., lecchio, M. A. and Correa, J. C. (1998). Relations between resin extractable soil phosphours and response of vernalized garlic to phosphate fertilization of Five soils, with and without organic fertilizer. *Revista Brasileira de ciencia do solo*, 22(3): 459-470. [Cited from Hort. Abst. 55(4): 350, 1992].

Chermsini, C., Watanabe, H., Attajarusit, S., Tuntiwarawit, J. and Kaewaroj, S. (1995). Elfect of boron sources on garlic *(Allium sativum* L.) productivity. *Biology and Fertility of Soils,* 20(2): 125-129.

Cho, K. R., Park, C. K, Kang, C. S.,Yang, J. S. and Kwun, K.C.(1994). Effects of organic matters and lime materials on quality improvement of tissue cultured garlic *{Allium satvum* L.). *RDA J. Agril. Sci., Korea, 36(2): 282-288.*

Chopra, K. N., Chopra, I. C., Handa, K.L.and Kapur, L.D. (1958). Chopra's indigenous drugs of India (2nd edn.), Un Dhua Sons Private Ltd. Calcutta, 271-274.

Chowdhury, M. H.(2006). Effect of plant density and number of plants per hill on the growth and yield of onion. M. S. Thesis, Dept, of C Bot. Bangladesh Agril. Univ., Mymensingh. pp. 1-3.

Das, A. K., Som, M. G., Sadhu, M. K. and Bose, T. K.(1985). Responces to varying levels of N, P and K on growth and yield of multiple clove garlic *(Allium sativum* L.). Indian Agric., 29(3): 183-189.

Das, J.N. and Mohanty, B.K. (2001). Effect of plant density and mineral nutrition on the yield of garlic *(Allium sativum* L.) cv. Madrasi. Vegetable Sci., India, 28(1): 92-93.

Devjatova, V.F. (1969). Response of garlic to mineral fertilizers. *Himija set. Hort*.. 7(4): 27-28. [Cited from Hort. Abst., 42(5): 531, 1972].

Dragland, S. (1986). Plant density and row spacing in Carrots. Forskning-Og Forsok i Landbruket, Statens Foreskingsstasjion kise, Norway. 37:3, 139-145. [Cited from Flort. Abstr. 59 (3): 359, 1989].

Duranti, A. and Cuocolo, L. (1984). The effect of clove weight and distance between the rows on the yield of *Allium sativum L.* cv. *Messidrome. Rivista della ortoflorofrutticaltura, Itaiana,* 68 (1):25-36. [Cited from Hort. Abst., 54 (9): 6141 (1984)].

Eid, S.M., Shafsakh N.S., and Abo-Sedera, F.A. (1991). Effect of potassium lertilizer and toliar application of certain micro-nutrient combinations on growth, yield and composition of garlic plants. Annals Agril. Sci., Moshtohor, Egypt, 29(2): 981-993. [Cited from soil and Fertilizers, 57(8): 12361, 1994].

FAO and UNDP. (1988). Agro-ecological Region of Bangladesh. Land Resources Appraisal of Bangladesh for Agricultural Development. BGD/81/035. Tech. Rep. 2. FAO and UNDP, Rome, pp. 106-107.

FAO. (1988). Production year book. Food and Agricultural Organizations of the United Nations, Rome, Italy, 52: 59-60.

FAO. (2000). Reports of Food and Agricultural Organization of the United Nations, Italy, Rome. 51: 155.

FAO. (2006). FAO Production Year Book of the United Nations food and Agriculture Organization, Rome, Italy, 51: 145-146.

Farooqui, M.A., Naruka, I.S., Rathore, S.S., Singh, P.P. and Shaktawat, R.P.S. (2009).Effect of nitrogen and sulphur levels on growth and yield of garlic (*Allium sativum* L.). As. J. Food Ag-Ind. Special Issue, S18-23.

Francois, L.E. (1991). Yield and quality responses of garlic and onion to excess boron. Hort. Science, 26(5): 547-549.

Fritsch, F. N., Christian, N. G. and Ferreya, E. R.(1990). Respone of garlic (*Allium sativum L.)* cv. Espan of INIA to nitrogen fertilization. Investgation Agricola. 10 (2):85-89. [cited from Hort. Abst., *66* (10):990,1992].

Frost, D. J. and Kretchman, D. W. (1988). Plant spatial arrangement and density effects on small and medium vine processing tomatoes. *J. Amer. Soc. Hort. Sci.*, 1 13 (1): 51-53.

Gomez, K. A. and Gomez, A. A.(1984). Statistical procedures for agricultural research, 2nd edition. John Willy and Sons, New York. p p.28-102.

Goto, R. and Kimoto,T.(1992). Effect of different organic fertilizers on productivity of summer onions. *Horticultura-Brasileira, Brazil*, 10(2): 114-115.

Gudi, N. A., Swandi and Hilman, Y. (1988). The effects of the application of stable manure and different trace to elements on garlic. Buletin Penelitiar Hirtukultura, Indonesia, 16(4): 5-13. [Cited from Hort. Abst. 54(4): 4779, 1991].

Gunadi, N. and A. A. Asandhi. (1986). Effect of source and dosage of nitrogen fertilizer and source of potash fertilizer on growth and yield of garlic. Buletin Penelitian Hortikultura, Indonesia, 13(3): 23-32. [Cited from Hort. Abst., 58(4): 321, 1988].

Gunadi and Asandhi. (1986). The eflect of rate and time ot N application on the growth and yield of garlic. Buletion peneletion Hort., 18(1)._-*8*[Cited from soil and Fertilizers, *54*(*8*): 129,1987]

Gupta, G.S.S. and Gallar, M.A.(1980). Effect of row spacing and different combinations of NPK fertilizer on the yield of onion Bangladesh Hort., 8(2): 8-12.

Gupta, R.P., Sharma, V.P., Singh, D.K. and Srivadtava, K.J. (1999). Effect of organic manures and inorganic fertilizers on growth, yield and quality of onion variety Agri found Dark Red. *National Hort. Res. and Dev. F., India*. 19(2-3): 7-11.

Haider, K. R. (2001). Effect of plant spacing, number of plats per hill and mulching on the growth and yield of carrot. M. S. Thesis, Dept, of Hort. BAU, Mymensingh. PP. 1-75.

Harun-or-Rashid, A.R.M. (1998). Effects of NPKS on growth and yield of onion at different plant spacing. M.S. thesis, Department of Horticulture, BAU, Mymensingh, 72 p.

Herison, C., Masabni, J. G. and Zandstra, B. H. (1993). Increasing seedling density, age and nitrogen fertilization increases onion yield. *Hort. Sci. (USA).* 28 (1): 23-25.

Hossain, M. M. (1997). Ettect of different levels nitrogen and potash on the growth and yield of garlic. MS thesis, Dept, of Horticulture, BAU, Mymensingh. 65p.

Hedge, D M. (1988). Effect of irrigation and nitrogen fertilizers on yield, quality, nutrient uptake and water use of onion *(.Allium cepa* L.). *Singapore J. Pri. Ind.,* 16(2): 111-123.

Hilman, Y. and Noordiyata, I. (1988). Equilibrium N, P and K fertilization trial on garlic in rice field. Buletin Peneletian Horticulture, 16(1): 48-53. [Cited from Hort. Abstr., 60(7): 5116, 1990].

Hussena, S., Medhinbs, F. and Tadesse, A. (2014). Effect of intra-row spacing on growth performance of garlic (Allium sativum) at the experimental site of wollo university, south wollo, Ethiopia. European Journal of Agriculture and Forestory Research. Vol.2,No.4,pp.54-61.

Islam, M.K. (1998). Effects of set size, plant spacing and nitrogen levels on the growth and yield of onion cv. Taherpuri. M.S. thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh. 131 p.

Islam, M.T. and Haque, M.A. ( 1977). Effect of nitrogen, phosphorus and potash on the yield of onion. Bangladesh Hort., 5(1): 5-8.

Jana, B.K. and Kabir, J. (1990). Effect of sulphur on growth and yield of onion cv. Nasik Red. *Crop Res., Hisar*., 3(2): 241-243.

Jalil, M.A. (1998). Effect of planting time, paclobutrazol and S fertilizers on the growth yield and S content of garlic. MS Thesis, Bangladesh Agril. Univ., Mymensingh. p. 88.

Katwale, T.R. and Saraf, R.K.(1994). Studies on response of onion to varying levels ol fertilizer doses during monsoon season in satpura Plateau. *Orissa J. Hort.,* 22(1-2): 13-18.

Khalaf, S.M. and Taha, E.M.(1988). Response of garlic plants grown on calcareous soil to organic manuring and sulphur application. *Annals of Agril. Sci. Egypt,* 33(2): 1219-1232. [Cited from Soils and Fertilizers, 53(10): 1615, 1990],

Khalaf, S.M. and E.M. *1* aha. (1988). Response of garlic plants grown on calcareous soil to organic manuring and sulphur application. Ann. Agril. Sci., Cairo, 33(2): 1219-1232

Khalil, F.A.,Hamd, A.S.A., Mohamed, E.I. and Hassan, M.A.M. (2002). Response of onion crop var. Shandaweel 1 to some sources of organic fertilizers. *Assiut. J. Agril. Sci., Egypt*, 33 (5): 73-83.

Koltunov, V.A. (1984). Effect of different fertilizer rates on garlic productivity and storability. Ref. Zhumal, 55:4, 55, 374. [Cited from Hort. Abst., 55(8): 612, 1985].

Koltunob, V. A. (1984). Effect ot different fertilizer rates on garlic productivity and storability. *Ref. Journal*, 55: 4, [Cited from Abst., 55(8): 612, 1985].

Kropisz. A. (1992). Influence of fertilization with compost on yield of vegetables and their content of mineral elements. *Annals of Warsaw Agril. Univ.,* 16:9-13.

Kurian, J.C.(1995). Plant that Heal (1st edn), Oriental Watchman Publishing House, Pune., India, p. 31.

Kusomo, S. and Widiajanto, D.D. (1973). Fertilizer use in garlic.Bulletin Horticulture 'Tgahort', 11:2-7. [Cited from Hort. Abstr., 46(3): 2096, 1979].

Lachica, J. F. (1982). The effect of tillage, NPK levels and population density on the growth and yield of garlic. *CLSU Sci. J.,* 3 (2): 9-19.

Lazo, F.D., Queddeng, A. and Caliwag, C.M.(1969). The effect of varying amounts ol commercial fertilizers on the yield of Granex onion. *Philipp. J. Plant Ind*., 34:39-44.

Lazzari, M.A., Rosell, R.A. and Landriscini, M R. (1978). Garlic production. I. Nitrogen fertilizers and irrigation. Turrialba, 28(3): 245-251. [Cited from Soil and Fertilizers, 42(12): 8401, 1979].

Limat, J. DE. A., Souza, A.F., Castor, O.S. and Menezes Sabrinho, J.A. DE. (1984). Effect of organic matter and vermiculite on garlic productivity. Agropecuaria Brasileira, 19(1): 41-45. [Cited from Hort. Abst. 54(8): 5298, 1984],

Madan, S.P.S. and Sandh, J.S.(1985). Influence of nitrogen, phosphorus and potash levels on the growth of bulb yield and dry matter production of white onion variety. Punjab Vegetable Grower, 20:1974.

Mallanagouda, B., Sulikeri, G.S., Hulamari, N.C., Murthy, B.G. and Madalgeri B.B.(1995). Effect of NPK and FYM on growth parameters of onion, garlic and coriander. Current Research University of Agricultural Sciences, India. 24(11): 212-213. [Cited from Hort. Abst. 66(4): 3083, 1996].

Mandal, R. C., Singh, K. D. and Maini, S. B.(1973). Effect of plant density, fertility level and shoot number on tuber yield and quality of tapioca hybrids. *Indian J. Agron*., 18 (4) : 494-503.

Maurya, A.N. and Lai, S. (1975). Boron in relation to the growth and development of onion *(Allium cepa* L.). *Bangladesh Hort.*, 3( 1): 1-7.

Maureya, K. R. and Bhuiyan, P. B. (1982). Effect of nitrogen and plant density on growth and yield of garlic in acid soil of Assam, *India Cocoa. Arecanut Spices J.,* 6 (1): 10-11.

Menezes, S. M. J. A. D. E., Novais, R. E. D. E., Santos, H. L.and Dos, L. M. A. (1974). The effect of nitrogen fertilization, plant spacing and mulching on the yield of garlic cultivar Amarante. Tevista Res., 21 (115): 203- 212 [Cited from Hort. Abstr., 45 (9): 568, 1975].

Minard, H.R.O. (1978). Effect of clove size, spacing, fertilizers and lime on >ield and nutrient ot garlic *{Allium sativum* L.). *New Zealand J. Expt. Agric.*, 6(2): 139-143.

Mondol, M. F., Pramanik, M. H. R. and Salam, M. A. (1988). Effect ot urea N on growth and yield of garlic *(Allium sativum* L.) under irrigated and rainfed condition. *Bangladesh Hort*., 19 (1) . 1 16.

Naik, B**.** H. and Hosamani, R. M. (2003). Standardisation of fertilization for garlic production under transitional tract of Karnataka. *J. Agril. Sci., India,* 16(1): 103-107.

Nasiruddin, K.M., Farooque, A.M. and Baten, M.A. (1993). Effect ot potassium and sulphur on growth and yield ot onion. *Bangladesh J. Agril. Sci.,* 20(1): 35-40.

Nelson, M. (1983). Garlic fertilizer trial. New Zealand Com. Grower, 38(2): 28. [Cited from Hort., Abst., 53(9):628, 1983].

Nelson, M. (1983). Garlic fertilizer trial. New Zealand Comm. Grow., 38(2): 28.

Om,H.and Srivastava,R. P. (1977).Performance of different locally selected garlic clove. *Prog. Hort*. 8(4): 69-76

Pande, R.C. and Mundra, R.S. (1971). Note on response of onion (*Allium cepa* L.) to varying levels of N, P and K. *Indian J. Agril. Sci.*, 41(2): 107-108.

Pandey, U.B., Singh, L., Kumar, R., Singh, L., Kumar, R. and Raychaudhury, S.P. (1991). Response of different levels of N, P, K on the yield and quality of Kharif onion. Recent Advances in Medicinal, Aromatic and Spice Crops, 1: 231-34.

Pandey, U. B. and Singh, D. K. (1993). Response of garlic to different levels ot irrigation and nitrogen. News letter National Horticultural Research and Development Foundation, 13(3-4): 10-12.

Patel, B. G., Khanpara, V. D. and Kaneria, B. B. (19960. Performance of drip and surface methods of irrigation for garlic under varying nitrogen levels. *Indian J. Agron*., 44( 1): 174-176.

Paterson, D R. (1979). Sulphur fertilization effects on yield and pungency of onion. Progress Report No. PR-3551, Texas Agril. Expt. Stat., p.2.

Paul. R.K. and Pandey, D.(1986). Effect of different levels of nitrogen, phosphorus and potassium on the growth and yield of garlic. *Progressive Hort*., 18(3-4): 256-259.

Pereira, E.B., Fomazier, J.L., Souja, J.A. Ventura and Nogueira, (1987). Effects of organic fertilization with compost on the garlic c F.D. rop. Hirtcultura Brassileira, 5(1): 36-38. [Cited from Hort. Abst., 59(4): 2857, 1989].

Pimpin, F.(1970). Studies on the mineral fertilizing of garlic. Rivista Di Agronomia, Italy, 3: 182-188. [Cited from Hort. Abst., 42(2): 477, 1972]

Pruthi, J.S. (1976). Spices and condiments. National Book Trust of India, New Delhi, pp. 125-132.

Purewal, S.S. and Daragan, K.S. (1961). Effect of fertilizers and spacing on the development and yield of garlic *{Allium sativum)*. *Indian J. Agron*., 5:262-268.

Purseglove, J. W. (1972). Tropical Crops: Monocotyledons 1 and 2. Longman Group Ltd., London, pp. 32-50.

Purseglove, J.W. (1975). Tropical Crops. Mono Cotylendons. Longman Group Ltd. London, pp.52-56.

Rahim, M.A.(1992). Spices and plantation crops in national economy. In: Horticulture in National Development. Proceedings of the sixth National Horticulture Convention and Symposium. Bangladesh Soc. Hort. Sci., pp. 24-29.

Rahim, M. A., Siddique, M. A. and Hossain, M. M. (1984). Effect of time of planting, mother bulb size and plant density on the yield of garlic. Bangladesh J. Agril. Res. 9 (2): 112-118.

Rahman, M.M. and Faruque, A.H.M. (1975). Effect of different doses of NPK on the yield of onion *{Allium cepa* L.). *Bangladesh Hort*., 3(1): 41-44.59

Rahman, S.M.R. Talukder and Miah, A.M. (1976). Effect of mtrogen, phosphoric acid and potash on the bulb size and yield of onion. *Bangladesh Hort*., 4(1): 7-11.

Rajas, R.N., Ghulaxe, S.N. and Iayde, S.R. (1993). Effect of varying levels of sulphur and spacing S.N. compared with frequencies of irrigation on yield of onion grown in Vidarbha. *J. Soils Crops*, 3( 1): 37-40.

Rashid, M.M. (1983). Shabjir Chash (in Bangla). Begum Shaila Rashid, BARI, Residential Area, Joydebpur, Gazipur. p. 185.

Rizk, F.A. (1997). Productivity of onion plant *(allium cepa* L.) as affected by method of planting and NPK application. *Egyptian J. Ho*rt., 24(2): 219-238.

Rosell, M. E., Grela,M. J. and Diazvaldes, O.(1987). Study of the optimum number of tomato plants per plating hill following direct sowing. *Centro Agricola,* 14 (1): 63-67. [Cited from Hort. Abstr. 48 (10): 6727, 1988].

Saladaga E. P and Rodolfa, G. E. (1987). Comparative evaluation of traditional methods and recommended practice of planting sweet potato. *Ann. Trop. Res.,* 9 (2): 104-109. (Cited from Biological Abstr. 84 (10): 104-109, 1987].

Saimbhi, M.S., Gill, B.S. and Sandhu, K.S.(1987). Fertilizer requirement of processing onion *(Allium cepa* L.). cv. Punjab-48. *J. Res., Punjab Agric. Univ.,* 24(3): 407-410.

Sardar, Singh., Singh, S.K. and Singh, S.(1999). Effect of fertilizers on garlic *(Allium sativum* L.). *Crop Res., India,* 18(3): 387-389.

Sarvananan. A. and Nambisan, K. M.P. (1994). Effect of fertilizer application on soil available nutrients, yield and nutrient uptake of garlic in acidic latcrite soils of Kodaikanal. *Madras Agril. J.,* 81(8): 434-436.

Selvaraj, N.I. Irulappan and Vedamuthue, P.G.B. (1930). Effect of N, K and Mg fertilization on the uptake of nutrients in garlic *(Allium sativum* L.). *South Indian Hort.,* 41(5): 278-281. [Cited from Hort. Abstr., 57(9): 8290, 1994].

Seno. S., Saliba, G. G., Paula, F.J. DE., Koga, P. S. and Paula, F. J. De. (1996). Effect ol phosphorus and chicken manure on the garlic culture (*Allium sativum* L.) Roxo Perola de Cacador". *Cientifica-Jaboticabal, Brazil,* 24(1): 127-133.

Setty, B. S., Sulikeri, G. S. and Hulamani, N.C. ( 1989). Effect of N, P and K on growth and yield ol garlic *(.Allium sativum* L.). *Karnataka J. Agril. Sci.,* 2(3): 160-164.

Siddique, M. A. and Rabbani, M. G. (1987). Effect of length of vine cutting part of vine inserted into the soil at planting and number of vines planted per hill in sweet potato. *Thai J. Agric. Sci*., 20 (4): 315-221.

Singh J. V., Ajay, K. and Sirohi, H. S. (1994). Effect of different levels of nitrogen on the growth and yield of garlic *(Allium sativum* L,). *Agril .Sci. Digest (Kamal), India,* 14(3/4): 149-152.

Sing, S. K. and Singh, R. K. (2004). Interaction effect of nitrogen, planting time and spacing on the performance of garlic, *(Allium sativum* L.) cv. Yamuna safed(G-l). 4 (2) : 123-128. [cited from CAB Abstr. 2000/08-2002/07]

Singh, J. and Dhankhar.(1998). Effect of nitrogen, potash and zinc on growth, yield and quality of onion. *Indian Agric*., 32(3): 163-170.

Singh, J.V., Ajay, B. S. and Sirohi, H. S. (1994). Effect of different levels of nitrogen on the growth and yield of garlic *{allium sativum* L.). *Agril. Sci. Digest (Kamal) India,* 14(3/4): 149-152. [Cited from Hort. Abstr., 66(7): 5786, 1996],

Singh, U. V. (1987). Note on the effect of N P and K on yield ol onion. *Plant Sci. 10: 159-161.*

Singh, D. P. and Riwari, R. S. (1996). Effect of micro-nutrients on yield and quality of onion *(Allium cepa* L.) variety Pusa Red. *Recent Hort*.. 3(1): 1 1 1-117.

Soto, J. A. (1988). Nutritional requirements ol onion (*Allum cepa* L.) in the soils of Northern Cartage ti. Critical leaves for P 1C and S and response to N. *Agron. Costarricense*, 12(1): 53-57.

Steward, F. C. (1963). Plant Physiology. Vol. III. *Academic Press. New York, pp. 183-190.*

Tarafder, M. E. H. (1999). Effect of plant spacing and number of plants per hill on the growth and yield of Carrot. MS Thesis, Dept, of Hort. BAU, Mymensingh. pp. 25-54.

Thompson, H.C. and Kelly, W. C. (1957). Vegetable crops. *McGraw Hill Book Co., New York*. pp. 368-370.

UNDP (United Nations Development Programme). (1988). Land Resources Appraisal of Bangladesh for Agricultural Development. *Rep. 2. Agro-ecological Regions of Bangladesh*, pp. 212-221.

Vachhani, M.U. and Patel, Z. G .(1993). Growth and yield of onion (*Allum cepa*) influenced b> nitrogen, phosphorus and potash under South Gujrat condition. Prog. Hort., 25(3-4): 166-167.

Varu, D. K., Vhora, P. H. and Kikani, K. P. (1997). Effect of organic and inorganic fertilizers on onion. *Gujarat Agric. Univ., Res. J*., 22(2): 116-118.

Verma, D. P., Sharma, B. R,Chakha, A. P. S., Bajpai, H. K. and Bhadauria, U.P.S (1996). Response ot garlic *(Allium Sativum* L) to nitrogen, Phosphorus & Potassium levels. *Adances in plant Sci*., 9 (2): 39-41

Vinay, S. and Singh, R. K. (1995). Response of onion (*Allium cepa* L.) to N, P, Zn and FYM. Annals of Agril. Res., 16(1): 79-81. [Cited from Hort. Abst. 65(2): 10663, 1995],

Vvedensky, A. I. (1946). *The genus Allium in USSR. Herbertia*, 11: 65-218.

Wang, S. S. (1995). Response of garlic to combined application of bio-fertilizers and fertilizer nitrogen. *N Soils Crops*, 5 (2): 115-116. [Cited from Hort. Abstr. 66 (9): 963, 1996].

Wang, X. Y., Hou, J. W., Zhang, X. and XU, W. C. (1992). Study on the pattern of fertilizer requirement for garlic bulbs. *Northern Hort*., 1: 10-12. [cited from Hort. Abst., 64(5), 470, 1994].

Wang, X. Y., Hou, J. W., Zhang, X. and Xu, W. C. (1992). Study on the pattern of fertilizer requirement for garlic bulbs. *Northern Ilort*., 1:10-12. [Cited from Hort. Abstr., 64(5): 7657, 1994].

Wani, P.V. and Konde, B. K. (1998). Effects of glomus mosseae inoculation using different P-sources on galric. *J.Maharashtra Agril. Univ. India*, 23(1): 39-42.

Warade. S. D.; Desale, S. D. and Shinde, K. G. (1996). Effect of organic, inorganic and biofertilizers on yield of onion bulbs cv. B-780. *Maharashtra J. Agril. Univ., India*, 20(3): 467-468.

Vinay-Singh, Aneg., Singh, V. S., Mehta, V. and Singh, A. (1995). Effect of sulphur sources and levels on yield and uptake of nutrients by garlic. *Fertilizer News*. 40(8): 47-49.

Yadav, V. S. and Yadav, B. D. (2001). Effect of NICAST (organic manure) in comparison to recommended doses of manure and fertilizers in onion. South Indian Hort., 49(Special): 160-161.

Zaharah, A., Vimala, P., Zainab, R. S., Salbiah, H. and Midmore, D. J. (1994). Studies on response of onion and shallot to organic fertilizer on bris soil. *Acta Hort.* 358:439-432. [Cited from Hort. Abst., 66(5-7): 5821, 1996].

Zhang, X-iang., Zhu, Hong. Xun., Sun, Chun. He., Zhang, X., Zhu, H. X. and Sun, C. H. (1998). Study on balanced fertilization and NPK nutrients absorption of garlic. *Soils and fertilizers, China*, 1: 10-13.

# APPENDICES

**Appendix I. Monthly records of Temperature, Rainfall, and Relative humidity of the experiment site during the period from November 2013 to April 2014**

| Year | Month | Air Temperature ($^0$c) | | | Relative humidity (%) | Rainfall (mm) | Sunshine (hr) |
|---|---|---|---|---|---|---|---|
| | | Maximum | Minimum | Mean | | | |
| 2013 | November | 29.5 | 18.6 | 24.0 | 69.5 | 0.0 | 233.2 |
| | December | 26.9 | 16.2 | 21.5 | 70.6 | 0.0 | 210.5 |
| 2014 | January | 24.5 | 13.9 | 19.2 | 68.5 | 1.0 | 194.1 |
| | February | 28.9 | 18.0 | 23.4 | 61.0 | 2.0 | 221.5 |
| | March | 33.6 | 29.5 | 31.6 | 72.7 | 3.0 | 227.0 |
| | April | 33.5 | 25.90 | 29.20 | 70.0 | 1 | 194.10 |

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

**Appendix II. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation**

Particle size constitution:

| | | |
|---|---|---|
| Sand | : | 40 % |
| Silt | : | 40 % |
| Clay | : | 20 % |
| Texture | : | Loamy |

Chemical composition:

| Constituents | : | 0-15 cm depth |
|---|---|---|
| $P^H$ | : | 5.45-5.61 |
| Total N (%) | : | 0.07 |
| Available P (µ gm/gm) | : | 18.49 |
| Exchangeable K (meq) | : | 0.07 |
| Available S (µ gm/gm) | : | 20.82 |
| Available Fe (µ gm/gm) | : | 229 |
| Available Zn (µ gm/gm) | : | 4.48 |
| Available Mg (µ gm/gm) | : | 0.825 |
| Available Na (µ gm/gm) | : | 0.32 |
| Available B (µ gm/gm) | : | 0.94 |
| Organic matter (%) | : | 0.83 |

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

**Appendix III. Analysis of variance of the data of plant height affected by combined effect of different nutrient and spacing of garlic**

| Source of variation | Degrees of freedom | Mean square of plant height (cm) | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| Replication | 2 | 0.018 | 0.850 | 0.917 | 1.064 | 1.012 |
| Factor A | 2 | 4.27** | 4.840* | 4.434* | 5.264** | 6.211* |
| Factor B | 3 | 7.514* | 8.221* | 6.412* | 8.322* | 8.432* |
| AB | 6 | 1.622** | 1.238** | 2.247** | 2.612** | 1.845** |
| Error | 22 | 1.131 | 2.016 | 2.722 | 1.946 | 1.714 |

**Appendix IV. Analysis of variance of the data on leaves plant$^{-1}$ affected by combined effect of different nutrient and spacing of garlic**

| Source of variation | Degrees of freedom | Mean square of number of leaves plant$^{-1}$ | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| Replication | 2 | 0.362 | 0.412 | 0.534 | 0.728 | 0.847 |
| Factor A | 2 | 2.312** | 4.118* | 3.345** | 3.288* | 4.624* |
| Factor B | 3 | 4.029* | 9.272* | 10.684* | 8.287* | 9.377* |
| AB | 6 | 1.016* | 1.138** | 0.489* | 1.015* | 1.112** |
| Error | 22 | 1.374 | 1.066 | 2.1115 | 1.246 | 1.327 |

**Appendix V. Analysis of variance of the data on neck diameter plant$^{-1}$ affected by combined effect of different nutrient and spacing of garlic**

| Source of variation | Degrees of freedom | Mean square of neck diameter plant$^{-1}$ (cm) | | | | |
|---|---|---|---|---|---|---|
| | | 30 DAS | 45 DAS | 60 DAS | 75 DAS | 90 DAS |
| Replication | 2 | 0.620 | 0.531 | 0.446 | 0.312 | 0.356 |
| Factor A | 2 | 2.413* | 3.414* | 3.448* | 2.467** | 2.336* |
| Factor B | 3 | 6.825* | 7.427** | 8.668* | 7.474* | 8.152* |
| AB | 6 | 1.034** | 1.277* | 1.243** | 1.259* | 1.184** |
| Error | 22 | 1.122 | 1.284 | 1.147 | 1.347 | 1.048 |

**Appendix VI. Analysis of variance of the data on .Combined effect of different nutrients and spacing on bulb height, bulb diameter, dry matter content of bulb (%) and dry matter content of leaves (%) of garlic**

| Source of variation | Degrees of freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Bulb height (cm) | Bulb diameter (cm) | Dry matter content of bulb (%) | Dry matter content of leaves (%) |
| Replication | 2 | 0.538 | 0.726 | 0.076 | 0.323 |
| Factor A | 2 | 0.414* | 0.459** | 4.228** | 3.344** |
| Factor B | 3 | 8.826** | 11.343* | 8.454* | 7.646* |
| AB | 6 | 1.734* | 4.294* | 2.125* | 2.378** |
| Error | 22 | 1.112 | 3.436 | 3.236 | 2.136 |

**Appendix VII. Analysis of variance of the data on Combined effect of different nutrient and spacing on bulb weight plant$^{-1}$, number of cloves bulb$^{-1}$, yield plot$^{-1}$ and yield ton per hectare of garlic**

| Source of variation | Degrees of freedom | Mean square | | | |
|---|---|---|---|---|---|
| | | Bulb weight per plant (g) | Number of cloves bulb$^{-1}$ | Yield plot$^{-1}$ (g) | Yield (t ha$^{-1}$) |
| Replication | 2 | 0.229 | 0.428 | 1.116 | 1.542 |
| Factor A | 2 | 4.208* | 6.616* | 4.263* | 3.382** |
| Factor B | 3 | 9.521* | 12.722** | 8.724* | 7.644* |
| AB | 6 | 3.322** | 2.564** | 2.162** | 2.252* |
| Error | 22 | 2.213 | 3.213 | 3.247 | 2.126 |

## Appendix VIII. Production cost of garlic per hectare

### A. Input cost

| Treatment combination | Labour cost | Ploughing cost | Clove of garlic cost | Water for plant establishment | Cost of manure and fertilizers | | | | | Insecticide/ pesticides | Sub-total (A) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cowdung | Urea | TSP | MP | S, B, Zn | | |
| $T_0S_1$ | 16,000 | 7,000 | 22,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 0 | 2,000 | 71,357 |
| $T_0S_2$ | 15,000 | 7,000 | 15,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 0 | 2,000 | 63,357 |
| $T_0S_3$ | 14,000 | 7,000 | 10,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 0 | 2,000 | 57,357 |
| $T_1S_1$ | 16,000 | 7,000 | 22,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 1,720 | 2,000 | 73,077 |
| $T_1S_2$ | 15,000 | 7,000 | 15,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 1,720 | 2,000 | 65,077 |
| $T_1S_3$ | 14,000 | 7,000 | 1,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 1,720 | 2,000 | 50,077 |
| $T_2S_1$ | 16,000 | 7,000 | 22,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 3,440 | 2,000 | 74,797 |
| $T_2S_2$ | 15,000 | 7,000 | 15,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 3,440 | 2,000 | 66,797 |
| $T_2S_3$ | 14,000 | 7,000 | 10,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 3,440 | 2,000 | 60,797 |
| $T_3S_1$ | 16,000 | 7,000 | 22,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 5,160 | 2,000 | 76,517 |
| $T_3S_2$ | 15,000 | 7,000 | 15,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 5,160 | 2,000 | 68,517 |
| $T_3S_3$ | 14,000 | 7,000 | 10,000 | 5,000 | 4,000 | 3,488 | 6525 | 5,344 | 5,160 | 2,000 | 62,517 |

$T_0 = S_0B_0Zn_O$ (kg/ha)
$T_1 = S_{15}B_2Zn_5$ (kg/ha)
$T_2 = S_{20}B_4Zn_{10}$ (kg/ha)
$T_3 = S_{25}B_6Zn_{15}$ (kg/ha)

$S_1$ = 10 cm × 10 cm
$S_2$ = 15 cm × 10 cm
$S_3$ = 15 cm × 15 cm

Labor cost =300 TK/day

Ploughing (4 times) =1750 TK/ cultivation

Seed rate =300-400 kg/ha (for the expt. about 350 kg/ha)

Urea=16 tk/kg
TSP=24 tk/kg
MOP=16 tk/kg
Gypsum=20tk/kg
Zinc Sulphate=160 tk/kg
Boric acid=140 tk/kg

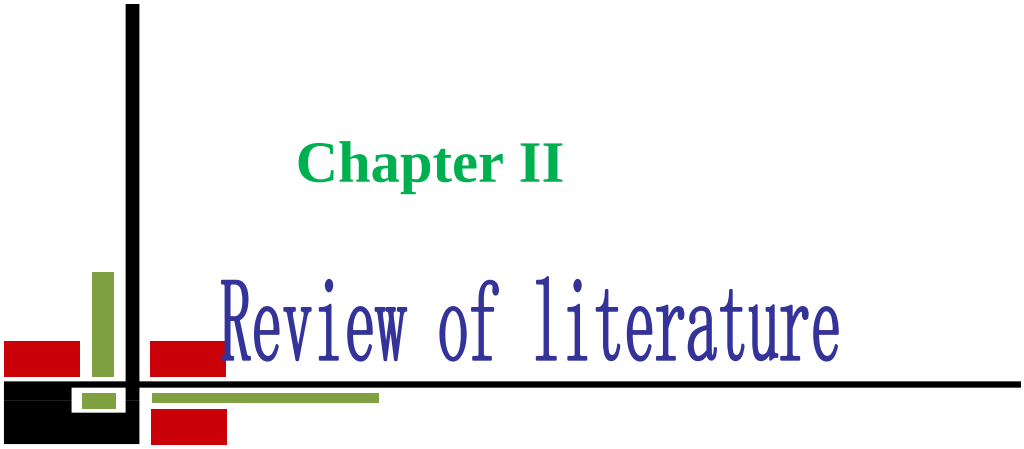
**B. Overhead cost (Tk./ha)**

| Treatment combination | Cost of lease of land (Tk.8% of value of land cost/4 months) | Miscellaneous cost (Tk. 7% of the input cost | Interest on running capital for 6 months (Tk. 14% of cost/year) | Sub-total (Tk.) (B) | Total cost of production (Tk./ha) [Input cost (A) + overhead cost (B)] |
|---|---|---|---|---|---|
| $T_0S_1$ | 19,000 | 4,995 | 3,297 | 27,292 | 98,649 |
| $T_0S_2$ | 19,000 | 4,435 | 2,927 | 26,362 | 89,719 |
| $T_0S_3$ | 19,000 | 4,015 | 2,650 | 25,665 | 83,022 |
| $T_1S_1$ | 19,000 | 5,115 | 3,376 | 27,492 | 100,569 |
| $T_1S_2$ | 19,000 | 4,555 | 3,007 | 26,562 | 91,639 |
| $T_1S_3$ | 19,000 | 3,505 | 2,314 | 24,819 | 74,896 |
| $T_2S_1$ | 19,000 | 5,236 | 3,456 | 27,691 | 102,488 |
| $T_2S_2$ | 19,000 | 4,676 | 3,086 | 26,762 | 93,559 |
| $T_2S_3$ | 19,000 | 4,256 | 2,809 | 26,065 | 86,862 |
| $T_3S_1$ | 19,000 | 5,356 | 3,535 | 27,891 | 104,408 |
| $T_3S_2$ | 19,000 | 4,796 | 3,165 | 26,962 | 95,479 |
| $T_3S_3$ | 19,000 | 4,376 | 2,888 | 26,264 | 88,781 |

# Chapter I

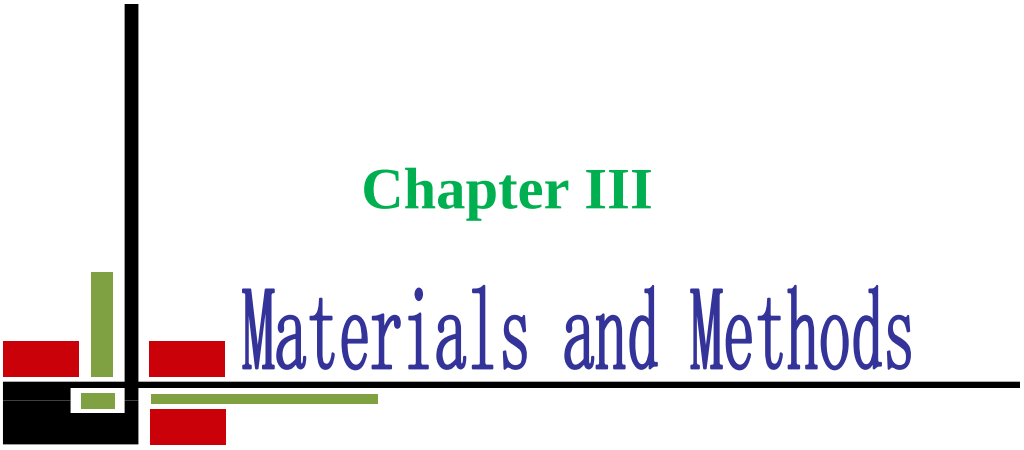
# Introduction

# Chapter II

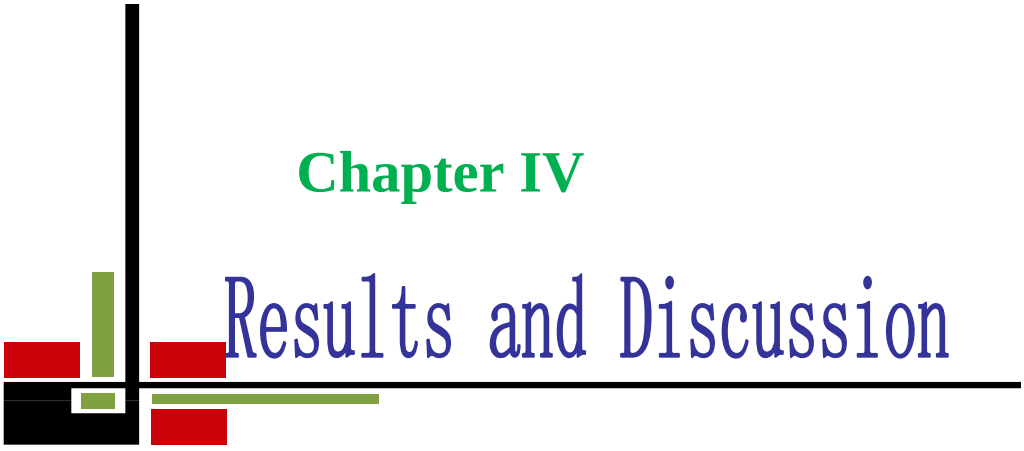


# Review of literature

# Chapter III

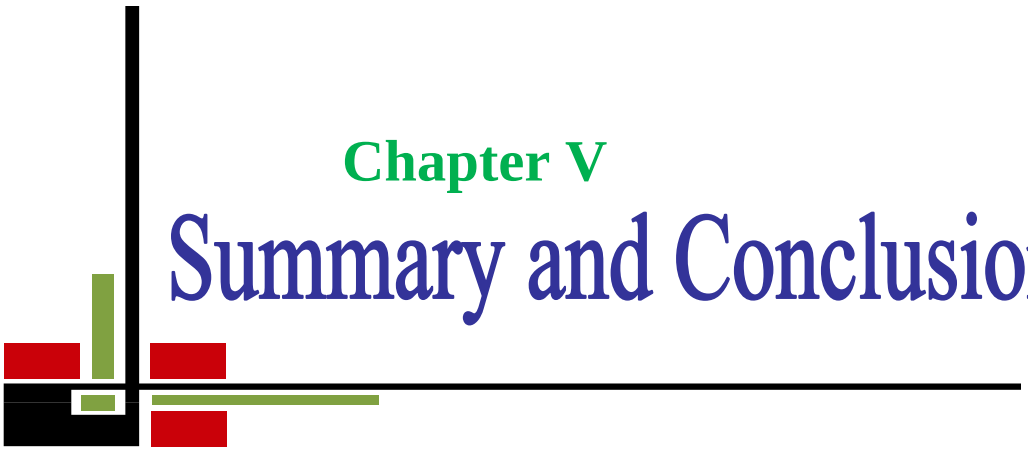


# Materials and Methods



# Chapter IV

# Results and Discussion



## Chapter V

# Summary and Conclusion

# References

# Appendices

**Plate 1: Experimental plot**

**Spacing $S_1$ (10cmx10cm)** **Spacing $S_2$ (10cmx15cm)** **Spacing $S_3$ (15cmx15cm)**

**Plate 2: Effect of different spacing on garlic field**

**Plate 3: After intercultural Operation**

**$T_0S_1$ treatment combination**

**$T_0S_2$ treatment combination**

**$T_0S_3$ treatment combination**

**Plate 4:Variation observe on control $T_0$ ($S_0B_0Zn_0$) treatment with different spacing**

**$T_1S_1$ treatment combination**

**$T_1S_2$ treatment combination**

**$T_1S_3$ treatment combination**

**Plate 5:Variation observe on $T_1$ ($S_{15}B_2Zn_5$) treatment with different spacing**

**$T_2S_1$ treatment combination**

**$T_2S_2$ treatment combination**

**$T_2S_3$ treatment combination**

**Plate 6:Variation observe on $T_2$ ($S_{20}B_4Zn_{10}$) treatment with different spacing**

**$T_3S_1$ treatment combination**

**$T_3S_2$ treatment combination**

$T_3S_3$ **treatment combination**

**Plate 7:Variation observe on $T_3$ ($S_{25}B_6Zn_{15}$) treatment with different spacing**