EFFECT OF SPACING AND FERTILIZER AMENDMENT ON GROWTH AND SEED YIELD OF ONION

MD. ABUL KHAYER

INSTITUTE OF SEED TECHNOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

DECEMBER, 2017

EFFECT OF SPACING AND FERTILIZER AMENDMENTON GROWTH AND SEED YIELD OF ONION

BY

Md. Abul Khayer

Reg. No. 16-07586

A Thesis

Submitted to the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka,

In partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE (MS)
IN SEED TECHNOLOGY
SEMESTER: JULY-DECEMBER, 2017

Approved by:

Dr. Jasim Uddain	**Dr. Noor Alam Chowdhury**
Associate Professor	Senior Scientific Officer (SSO)
Department of Horticulture	Spices Research Centre Shibgonj, Bogura
SAU, Dhaka	**Co-supervisor**
Supervisor	

Prof. Dr. Mohammed Ali
Director
Examination Committee

Dedicated To

My Beloved Parents

Institute of Seed Technology
Sher-e Bangla Agricultural University
Dhaka-1207, Bangladesh

Ref: Date:…………..

CERTIFICATE

This is to certify that thesis entitled, "**EFFECT OF SPACING AND FERTILIZER AMENDMENT ON GROWTH AND SEED YIELD OF ONION"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **SEED TECHNOLOGY,** embodies the result of a piece of bona fide research work carried out by **MD. ABUL KHAYER**, **Reg. No. 16-07586** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.

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

Dated: December, 2017

Place: Dhaka, Bangladesh

Dr. Jasim Uddain
Associate Professor
Department of Horticulture
Sher-e-Bangla Agricultural University
Supervisor

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author feels proud to express his deep sense of gratitude, sincere appreciation and immense indebtedness to his ***Supervisor Associate Prof. Dr. Jasim Uddain, Department of Horticulture****, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.*

The author feels proud to express his deepest respect; sincere appreciation and immense indebtedness to his ***Co-supervisor Dr. Md. Noor Alam Chowdhury****, Senior Scientific Officer, Spices Research Centre, BARI. Shibganj Bogura for his scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.*

The author expresses his sincere respect to ***Prof. Dr. Mohammad Ali****,* ***Director,*** *Institute of Seed Technology.*

The author expresses his sincere appreciation to his father and beloved mother and all of his well-wishers.

The Author

EFFECT OF SPACING AND FERTILIZER AMENDMENT ON GROWTH AND SEED YIELD OF ONION

ABSTRACT

A field experiment was conducted in the field of Sher-e - Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to April 2018 . The experiment consisted of four levels of spacing (viz. S_1 = 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm) and four levels of fertilizer (viz. T_0 = No application (control), T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha, T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha, and T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha). The two-factor experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. There were 16 treatment combinations in this study. A unit plot was 1.0 m×1.2 m and the treatments were distributed randomly in each block. Data on growth and yield parameters were recorded and analyzed statistically. The differences were evaluated by Duncans Multiple Range Test (DMRT). Growth and yield of onion were influenced by the different spacing and fertilizer amendment. The 25cm×20cm spacing resulted in the highest number of leaves, diameter of bulb, length of bulb, weight of blub per plant and thousand seed weight. The maximum seed yield per hectare (394.9) was observed in 20cm×15cm spacing. NPKS had also significant influence on yield of onion. The highest plant height, number of leaves, diameter of bulb, length of bulb, weight of blub per plant, yield per plot and yield per hectare (1.99 kg/plot and 16.57 t/ha, respectively), number of flowers per umbel, weight of seeds per plant, thousand seed weight were applied $N_{80}P_{50}K_{100}S_{30}$ kg/ha. The maximum seed yield per hectare (374.30 kg) was obtained from $N_{80}P_{50}K_{100}S_{30}$ kg/ha. In respect of combined effect, application of $N_{80}P_{50}K_{100}S_{30}$ kg/ha with 20cm×15cm produced the highest seed yield per hectare (404.20). Considering above findings, the application of $N_{80}P_{50}K_{100}S_{30}$ kg/ha and 20cm×15cm spacing may be used for onion cultivation.

CONTENT

CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
LAI	=	Leaf area index
Ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MoP	=	Muriate of Potash
RCBD	=	Randomized complete block design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
G	=	gram (s)
Kg	=	Kilogram
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Not significant
Mm	=	millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Per cent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) is an important herbaceous bulb and spice crop in the world which belongs to the family Alliaceae. Onion is mainly used as spices but it is also used as condiments for flavoring food and also as delicious vegetables and salad crop. It increases the taste and flavor of the dish, when used in gravies, soups, stew, stuffing, dried fish and meat. Onion contains high medicinal properties having adequate vitamin B and C, iron and calcium (Vohora et al., 1974). Central Asia is the primary center of its origin and the Mediterranean is the second center for large type onion (McCullum, 1976). Now, it's growing all over the world. The leading onion growing countries of the world are the China, Netherlands, Korea, Israel, Japan, Turkey, Syria, Iran, Egypt, USA, Lebanon, Austria and India (FAO, 2012). In Bangladesh it is commercially cultivated in the greater districts of Dhaka, Mymensingh, Rajshahi, Rangpur, Rajbari, Khustia, Khulna, Barisal and Pabna (BBS, 2015). Among the spice crops grown in Bangladesh, onion ranks top in respect of production and second in respect of area (BBS, 2012).

Onion is a thermo-photosensitive crop and optimum temperature for its cultivation is 13-240C (Rashid, 1983). The total production of onion in Bangladesh is about 170 thousand metric tons under the total cultivated area 4,19,122 acres (BBS, 2015). On an average, the total annual requirement of onion in Bangladesh is about 16,50,000 metric tons but production is 10,52,000 metric tons (Anonymous, 2012). This production does not fulfill the country's demand so Bangladesh has to import onion from India and China every year (Hossain and Islam, 2006). This situation can be overcome mainly in two ways-firstly, extended the cultivable land and secondly, increases the yield of the crop. In Bangladesh, the cultivable land area is limited, it is not possible to extend the land under onion cultivation but yield per hectare can be increased the efficient use of macro nutrients (NPKS), high yielding variety and intercultural operation (especially pre harvest neck bending processes).

Fertilizer management is one of the important factors that contribute in the production and yield of onion. Among the nutrients nitrogen, phosphorus, potassium and sulphur play the most important role for vegetative growth of the crop, which ultimately helps in increasing bulb size and total yield of onion. Application of nitrogen increases the dry matter production and added maximum uptake of nutrient elements by onion bulb from soil (Halder *et al*., 1998). Maximum bulb weight and bulb yield produced with the application of nitrogen (Islam, 1998). Excess nitrogen also causes onions to be more easily able to be harmed or influenced by storage pathogens.

Phosphorus plays an important role in root development of onion crops but not any effects on photosynthesis. It helps to the formation of nucleic acid and phospholipids, enzyme activation, production of ADP and ATP. It also increases bulb formation and development of onion (Jones and Mann, 1963). Excess phosphorus inhibits the uptake of other extremely important nutrients.

Onion is shallow rooted and potash loving crop and like other tuber and root crops onion is very quick responsive to potash. Potassium is very important element due to its influence for translocation photosynthesis, storage quality, bulb size, bulb numbers and yield per plant (Sangakkara and Piyadasa, 2003). The highest K rate showed the highest plant height, maximum leaf number per plant, highest leaf fresh weight, leaf dry weight, maximum neck thickness, bulb equatorial diameter, bulb polar diameter, fresh weight of bulb and yield of bulb.

Sulphur is essential in the early stage of plant growth for building up sulphur containing amino acids in plant cells. Sulphur has been reported to be extremely important for a good vegetative growth and bulb development in onion (Balasubramonian *et al*., 1979; Paterson, 1979). Reduction of yield depends upon the lacking optimum supply of sulphur in the different plant parts limit the crop growth at any stage. Sulphur application as gypsum consistently increased onion pungency and usually resulting in a lower preference for the bulbs (Smittle, 1984). It also improves the quality especially pungency, flavors and increased bulb yield.

In addition to nitrogen, plant spacing is an important factor determining onion yield and quality. An essential aspect of any crop production system is the development of a crop canopy that optimizes the interception of light, photosynthesis, and the allocation of dry matter to harvestable parts. A crop canopy is commonly managed by manipulating row spacing and plant population; as plant density increases, yield per unit area increases and will approach an upper limit, the plateau. Then, the yield per unit area declines since yield per plant tends to decrease with further increase in the plant density because of competition for growth factors between adjacent plants (Silvertooth, 2001). Thus, spacing is an important factor for the production of onion since it affects both bulb yield and quality. Plating density greatly influences quality, texture, taste and yield of onion even within a particular variety (Saud *et al*., 2013). Yield responses to plant population need to be known for practical purposes, as planting density is a major management variable used in matching crop requirements to the resources by the environment (Smith and Hamel, 1999). Coleo *et al.* (1996) reported that the highest commercial bulb yield was recorded at a higher planting density, but the highest proportion of large bulbs and average bulb weight at lower planting density.

Onion requires long-day length for production and maturation of bulb (Amin andRahim, 1995), but in Bangladesh short-day length prevails in the growing season of onion. So, to minimize the cultivation and production problems, emphasis must be given to improve cultivation methods of onion, such as proper planting geometry, optimum mother bulb size and planting time, accurate fertilization and other cultural practices viz., weeding and mulching and spacing. Many attempts were taken in the recent past to augment the yield and to improve the quality of onion seed (Bhonde et al., 1996). But no definite and profitable technology has yet been developed which can be recommended to the farmers for growing onion seed at a commercial scale. A few well adapted indigenous varieties, suchas Taherpuri, Zhitka, Faridpur Bhati are used to produce onion seeds in limited areas of Bangladesh. Workers of different onion growing countries of the world have identified the optimum time for raising seed crops in their own countries. Adjusting planting time is very important because of the short winter seasons of Bangladesh. Early planting is best for onion production (Badaruddin and Haque, 1977). Mondal (1980) considered last week of October as the best planting time for the highest yield and best quality onion seeds. Mother bulb size has also a pronounced effects on growth and yield of onion. Karim et. al. (1999) observed the best yield of onion with large size mother bulb (20 g). The present investigation was, therefore, undertaken to find out the optimum fertilization and spacing needed to achieve the best possible growth and bulb and seed yields of onion under the existing agro-climatic conditions of Bangladesh. In consideration with the aforesaid idea, the present experiment was undertaken to assess the growth and seed yield of onion influence by plant density and fertilizer amendment. Keeping above facts in view, the present study was under taken with the following objectives:

i. To determine the optimum plant spacing for maximum growth and seed yield of onion
ii. To optimize the NPKS fertilizer for maximum growth and seed yield of onion
iii. To investigate the suitable combination of plant spacing and fertilizer for maximum growth and seed yield of onion.

CHAPTER II

REVIEW OF LITERATURE

Onion is an important spice crop in Bangladesh. The production of onion bulb and seed is influenced by many factors such as fertilizer treatment and spacing. Fertilizers play an important role on the growth and yield of onion. A huge number of research works on NPKS application and spacing in onion have been conducted in different parts of the worlds but their findings have little relevance to the agro-ecological situation of Bangladesh. The present study has been undertaken to investigate the growth and seed yield of onion influence by plant density and fertilizer amendment. The relevant literatures available have been reviewed in this chapter.

2.1 Effectss of NPKS on the growth and yield of onion

Abdissa *et al.* (2013) conducted a field experiment in North east Ethiopia to study the effects of different levels of nitrogen (N) and phosphorus (P) fertilizers on the growth, biomass yield and fresh bulb yield of onion. Five rates of N (0, 69, 92, 115, 138 kg ha-1) and five rates of P (0, 10, 20, 30, 40 kg ha^{-1}) were arranged in a Randomized Complete Block Design replicated three times. Nitrogen showed significant effectss in all of the parameters studied, while P fertilization and its interaction with N did not. The proportion of bolters per plot decreased by about 11 and 22% in response to the application of 69 and 92 kg N ha-1, respectively over the control. Regardless of the rate, N fertilization day extended days to physiological maturity by about 6 days over the control. Application of 69 kg N ha^{-1} increased plant height and leaf length by about 10 and 11.5%, respectively over the unfertilized check. Number of leaves increased by about 8% in response was not influenced by N fertilization. Regardless of the rate of application, N fertilization increased bulb diameter and average bulb weight by about 12 and 21.5%, respectively over the control. Application of 69 kg N ha^{-1}increased the development of splitted bulbs by about 45%, average bulb weight by 24%, total dry biomass by 20%, harvest index by about 4%, total bulb yield by 18%, and marketable bulb yield by 17% over the control. Application of 69 kg N ha^{-1}enhanced the growth of onion plant and resulted in optimum fresh total and marketable bulb yield on the vertisol of Shewa Robit, North east Ethiopia. The lack of significant response in onion to P fertilization could be attributed tothe presence of adequate amounts of available P (16.02 ppm) in the soil and henceP fertilization for onion production is not advisable.

Mishu *et al*. (2013) was carried out an experiment to study the effects of different doses of sulphur on growth and yield performances of onion. The experiment comprised of five levels of sulphur (0, 20, 40, 60 and 80 kg S ha^{-1}). Individual bulb weight, dry weight of root, dry weight of bulb, dry weight of shoot, dry weight of leaf, total dry matter (TDM), leaf area index (LAI), absolute growth rate (AGR), relative growth rate (RGR), net assimilation rate (NAR), individual bulb weight, bulb yield of onion and sulphur content were increased significantly with the application of sulphur fertilizer. Application of 40 kg S ha^{-1}resulted in the highest yield (10.65 t ha^{-1}) among the different doses of sulphur.

Rashid (2010) observed an experiment at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh to evaluate the effectss of sulphur and GA3on the growth and yield performance of onion cv. BARI Peaj-1. The experiment included four levels of sulphur viz., 0 (control), 15, 30 and 45 kg/ha and four concentrations of GA3 viz., 0 (control), 50, 75, 100 ppm. The experimental findings revealed that sulphur and GA3 had significant influence on plant height, number of leaves per plant, bulb diameter and length, individual bulb weight, splitted and rotten bulb, bulb dry matter content and bulb yield. The highest bulb yield (13.85 t/ha) was recorded from 30 kg S/ha, while the lowest bulb yield (11.20 t/ha) was obtained from control. The maximum bulb dry matter content (13.50%) and bulb yield (17.10 t/ha) were produced from the application of sulphur @ 30 kg/ha with 100 ppm GA3, while the minimum bulb dry matter content (9.23%) and bulb yield (9.33 t/ha) were recorded from control treatment of sulphur with GA3.

Seran *et al.* (2010) carried out an experiment to find out suitable ratio of inorganic fertilizer and compost, which could give an economic yield of onion. Treatments were recommended dosage of inorganic fertilizers as a control (T1), ¾ fold of the control treatment + compost (2 t ha-1) (T2), ½ fold of the control treatment + compost (4 t ha-1) (T3), ¼ fold of the control treatment + compost (6 t ha-1) (T4) and the compost alone (8 t ha-1) (T5). These were applied as basal application of fertilizer in this experiment. The results of this study revealed that there were significant ($P<0.05$) differences in the numbers of leaves and roots between the different treatments during the early stage of growth. Relatively higher yield (5.03 t ha^{-1}) was obtained from the plants treated with inorganic fertilizers alone (T1), whereas compost alone (T5) produced the lowest yield (3.43 t ha^{-1}). It was also noted that there were no significant ($P>0.05$) differences in the yields between T1and T2 as well as T1 and T3. The inorganic fertilizers appear to have compensated with slow release of nutrients from the compost and their combined effectss would have increased the yield. From this study, it could be stated that half fold of the inorganic fertilizer and compost at the rate of 4 t ha^{-1}(T3) could give profitable yield (4.75 t ha^{-1}) and this combination could possibly reduce the cost of production in the cultivation of onion.

Huque (2008) reported a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka to study the effects of spacing and potassium on the growth and yield of summer onion (Allium cepa). She found that highest doses potassium fertilizer 120 kg/ha gave the highest growth and yield of summer onion.

Mishu (2008) carried out a field experiment at the Bangladesh Agricultural University, Mymensingh, to find out the effects of S on the growth and yield of onion (cv. Faridpuri Bhati). He used five levels of sulphur (0, 20, 40, 60 and

80kg/ha). Application of higher doses of sulphur gave the highest plant height, highest number of leaves. Bulb length, bulb weight and yield of onion plant over control.

Rahman (2008) conducted an field experiment was carried out at the Sher-e-Bangla Agricultural University Farm, Dhaka, to study the effects of nitrogen and number of plants per hill on growth and yield of onion (*Allium cepa* L.). He found that three plants per hill with 180 kg N/ha can be used to obtain higher growth as well as higher yield.

Islam (2007) carried out a field experiment at the Sher-e-Bangla Agricultural University Farm, Dhaka during summer season 2007 to study the effects of combined application of vermin compost and fertilizers on the yield of summer onion. Four levels of vermin compost (0, 1.5, 3, 5 t/ha) and three levels of NPKS. Application of highest doses of vermin compost and NPKS fertilizers increase the growth and yield of summer onion.

Ansary et al. (2006) carried out a field experiment on application of fertilizer rates (no fertilizer, N: K: S at 100:120:40 and 150:180:60 kg/ha) to investigate the growth and yield of onion. The fertilizer rates of 150 kg N, 180 kg K and 60 kg S /ha gave highest result in case of maximum yield of quality bulbs.

Kumar et al. (2006) studied an experiment during summer season to determine the effectss of N and K levels (0, 50,100 and 150 kg/ha each) on the growth of onion bulb, nutrient uptake and yield. The bulb yield was significantly maximum at 150 kg N/ha and it increased by 27.40% over the control. The bulb yield was significantly increased with the application rate of K 100kg /ha (14.85% over the control).

Girigowda *et al*. (2005) carried out an experiment on the effects of fertilizer treatments on the performance of 4 genotypes of onion (Arka Kalyan, Arka Kirthimanand Arka Lamila and Hybrid -3 as control). The fertilizers consisted of 125:50:125, 156:63:156 and 188:75:188 kg N: P_2O_5: K_2O /ha. The uptake of

N (182.72 kg/ha), P_2O_5 (32.50 kg/ha) and K_2O (157.45 kg/ha) were highest under 188kg N, 75kg P_2O_5, 188kg K_2O/ha. Among the genotypes, the highest yields were obtained with (41.69 t/ha), Arka Kirthiman (44.73 t/ha) and (41.18 t /ha) and Arka Lalima (43.20 t/ha). The highest uptake of N (191.19 kg/ha), P_2O_5 (34.59 kg/ha) and K2O (162.52 kg/ha) recorded at Arka Kirthiman.

Santhi *et al.* (2005) conducted a field experiment to investigate the effectss of soil fertility and an integrated plant nutrition system composed of different rates of N (30, 60, 90 and 120 kg/ha) on the yield of onion. Crop yield as well as nutrient uptake by the crops increased with increasing rates of N.

Ullah *et al.* (2004) carried out an experiment to study the response of onion cv. Taherpuri to a range of doses NPK under irrigated condition. Five levels of N (0, 50, 100, 150 and 200 kg/ha) and four levels of P2O5 (0, 40, 80 and 120 kg/ha) and K_2O (0, 50, 100 and 150 kg/ha) was applied. The highest bulb yield of 19.2 t /ha and highest marginal return was produced by the combined effects of 150:80:100 of N: P_2O_5: K_2O. The diameter of the bulb, weight of individual bulb and bulb yield were significantly increased by NPK.

Haque *et al.* (2004) carried out an experiment to investigate the effectss of nitrogen (100, 125 and 150 kg/ha) and irrigation (irrigation at 7, 14 and 21 Day intervals) on the growth and yield of onion cv. BARI Piaz-1. Plant height, number of leaves per plant, bulb length, bulb diameter, neck thickness, single bulb weight and crop yield increased with increasing rates of N up to 125 kg/ha and decreased 7 day intervals except for number of leaves per plant and single bulb weight, which were highest with the irrigation at 14-day intervals. Interaction effectss between N rates and irrigation were significant for all the parameters measured except for bulb diameter.

Singh *et al.* (2004) conducted an experiment to determine the optimum level of nitrogen and potassium for obtaining maximum growth and bulb yield of onion crop in Rajasthan, India. Treatments comprised: 0, 50,100 and 150 kg N/ha and 0, 40, 80 and 120 kg K /ha. Plant height at harvest (51.43 cm), leaf length

(28.22 cm), fresh weight of leaves (25.21 g) and total chlorophyll content at 45 DAT (1.33mg) and 90 DAT (1.67mg) were highest upon treatment with the highest nitrogen rate. The maximum plant height at harvest (152 cm), leaf length (29 cm), fresh weight of leaves (24.60 g), total chlorophyll content at 45 DAT (1.31 mg) and 90 DAT (1.69 mg) were observed upon treatment with 120 kg K/ha. The number of leaves increased significantly up to 80 kg K/ha but maximum upon treatment with 120 kg/ha. Neck thickness (0.92 cm), number of scales (7.73), bulb diameter (5.03 cm), fresh weight of bulb (48.89 g) and bulb yield (211.50q/ha) were highest upon treatment with the highest potassium rate. The number of leaves per plant was significantly higher up to 100 kg N/ha. Neck thickness (0.93cm), number of scales per bulb (8.39), bulb diameter (5.02 cm), fresh weight of bulb (47.48 g) and bulb yield (206.93 q/ha) showed increasing trends up to the highest nitrogen rate.

Lee *et al*. (2003) conducted an experiment to determine the effectss of different application rates of N (0, 120, 180 and 240 kg/ha), P_2O_5 (0, 40,80 and 120 kg /ha) and K2O (0,60,120 and 180 kg/ha) and different top dressing times (1, 1.5 and 1+ 2 months after transplanting) on the growth and yield of onion. At plant maturity, the highest values for plant height (73.2cm) and bulb diameter (55.6 mm) were obtained with 240 and 180 kg N/ha, respectively but no significantly differences in growth were observed among P_2O_5 and K_2O application rates. The highest marketable yields obtained with 120 kg N/ha, 80 kg P_2O_5/ha and 120 kg K_2O/ha, respectively.

Mandira and Khan (2003) carried out an experiment in Tripura, India to study different nitrogen levels (0,100, 150 and 200 kg/ha) and potassium (0, 75 and 150 kg/ha) given as soil application to study their effects on the growth of plant, yield and yield attributes of onion cv. N-53. Application of nitrogen at 150 kg/ha, potassium at 75 kg/ha and their combination effectss shows the best performance in terms of growth and yield. All other treatments and their combination were superior to control.

Sharma *et al*. (2003) observed a field experiment to study the effects of combined use of NPK and farmyard manure (FYM) on yield attributes of onion in Leo, Himachal Pradesh, India in 1998 and 1999. The treatments combination was 3 levels of FYM (0, 10 and 20 t/ha) and 4 levels of NPK (0, 50, 100 and 150 % of the recommended dose, which was 125 kg N, 33 kg P and 50 kg K/ha).Application of NPK fertilizers at the rate of 100% (125 kg N, 33 kg P and 50 kg K/ha) and 150% (187 kg N, 49 kg P and 75 kg K/ha) of recommended dose registered an increase of 42% and 56% over 50% NPK level in the yield of onion bulb. Similarly, application of FYM at 10 and 20 t/ha increased yield of bulb by 9 and 19% over 100% NPK alone, respectively. Bulb yield recorded in the case of 100% NPK along with 20 t FYM /ha (19.87 t/ha) was at par with 150% NPK alone (18.82 t/ha) thereby signifying the savings of chemical fertilizers of 52 kg N, 16 kg P and 25 kg K/ha. Use of NPK fertilizers along with FYM also result significant improvement in available N, P and K status of the soil.

Singh et al. (2003) studied at Dhaulakuan, Himachal Pradesh, India during the rabi seasons to the effectss of K fertilizer (30, 60, 90 or 120 kg/ha) applied as split dressings (1/2 as basal + ½ as top dressing at 45 days after transplanting or DAT or 1/3 as basal + 1/3 top dressing at 45 DAT + 1/3 top dressing at 90 DAT) on the seed yield of onion cv. N-53. The application of K at 60, 90 and 120 kg/ha in three split doses (1/3 as basal, 1/3 as top dressing at 45 DAT + 1/3 as top dressing at 90 DAT) induced early bolting, and resulted in the maximum height of flowered stalks and seed yield. Thus the application of 60 kg/ha in three splits was the most economical rate for onion.

Tiwari *et al*. (2003) conducted a field experiment to determine the effectss of nitrogen on the growth of onion cv. Pusa Red. Three levels of N (50, 75, 100 kg/ha) was applied and found that bulb yield of onion cv. Pusa Red significantly affected by the N levels. The application of 75 kg N/ha gave higher yield than 100 kg N/ha.

Yadav *et al*. (2003) conducted an experiment to obtain maximum and good quality of onion bulb to determine the optimum rate of potassium. Four cultivars (Pusa red, White Marglobe, Nasik Red and Rasidpura Local) were given with three potassium rates (50, 100 and 150 kg/ha). The highest K rate showed the highest plant height, maximum leaf number per plant, highest leaf fresh weight, leaf dry weight, maximum neck thickness, bulb equatorial diameter, bulb polar diameter, fresh weight of bulb and yield of bulb. The lowest K rate showed the lowest neck thickness.

Anonymous (2001) conducted a field experiment with four levels of N (0, 100, 125 and 150 kg/ha) at Spices Research Centre, BARI, Joydebpur. They found that bulb yield of onion significantly affected by Nitrogen. The application of 125 kg N/ha gave better yield than 150 kg N /ha.

Mohanty and Das (2001) observed that 30 kg/ha each of N and K_2O was suggested to realize medium bulbs with moderate yield and better keeping quality in long term storage, while the application of 90 kg N and 60 kg K_2O/ ha was better for obtaining higher yield with larger bulbs, but short-term storage.

Singh *et al*. (2000) studied an experiment with Onion cv. N-53 at Rajasthan during summer season of 1993-1995. Onion cv. N-53 was grown under factorial combinations of 3 levels each of nitrogen (50, 75 and 100 kg N/ha), phosphate (13.2, 22 and 30.8 kg P/ha) and potash (41.5, 62.2 and 83.0 kg K/ha). It was concluded that onion productivity could be increased considerably by the application of 100 kg N, 30.8 kg P and 83.0 kg K_2O/ha.

Nagaich *et al.* (1999) conducted an experiment in Madhya Pradesh, India with 4 rates of potassium (0, 40, 80 and 120 kg /ha) on growth characters, yield and quality of onion on a sandy loam soil. Application of 80 kg K_2O per ha significantly increased horizontal diameter of the bulb and bulb weight per plant.

Rodriguez *et al*. (1999) carried out an experiment of onion to find out the effects of different nitrogen, phosphorus and potassium rates, sources and forms upon onion (*Allium cepa*) bulb yield and quality. Plant height, leaf number, polar and equatorial diameters and yield were measured in treatments with different rates, sources and forms of N, P and K. Significant effectss of P and K rates (applied up to 98.2 and 200 kg/ha, respectively) could not be detected, non-significant interactions between N and P.

Anwar *et al.* (1998) observed an experiment in Jessore to study the effects of nitrogen, phosphorus, potassium, sulphur and zinc on the growth and yield of onion. The application of nitrogen, phosphorus, potassium, sulphur and zinc increased number of leaves /plant along with higher bulb yield of onion with the increasing rates up to 150 kg N/ ha, 120 kg P_2O_5/ ha, 20 kg S/ ha and 5 kg Zn/ ha at Jessore area.

Harun-or-Rashid (1998) carried out a field experiment at the Bangladesh Agricultural University, Mymensingh on the effects of NPKS on growth and yield of onion with different plant spacing. He reported that the maximum bulb weight (40.50g) and bulb yield (20.75 t/ha) were found from the treatment combination of 125-150-150-30 kg N, P_2O_5, K_2O, S /ha, respectively whereas the minimum bulb yield (16.75 t/ha) was recorded from the control treatment. Application of NPKS increased the plant height, leaf number, length of bulb, bulb diameter, and bulb weight as well as bulb yield. For the cultivation of BARI peaj-1 at BAU Farm conditions he recommended 100-150-200-30 kg /ha N, P_2O_5, K_2O, S, respectively.

Islam (1998) found that the maximum bulb weight (25.5 t/ha) produced with the application of nitrogen at 120 kg/ha.

Dixit (1997) carried out an experiment at Lari, Himachal Pradish, India during the summer season of 1994. He worked with five levels of nitrogen (0, 40, 80, 120 and 160 kg/ha) and two levels of Farm Yard Manure (10 and 20 t/ha) and reported that increasing nitrogen application rates increased bulb yields up to

120 kg N/ha. Higher yields were also obtained with the higher rate of farmyard manure.

Rizk (1997) carried out an experiment to investigate the effects of plant density and NPK fertilizers on the productivity of onion. Maximum number of leaves per plant, higher fresh and dry weight of leaves, higher leaf areas, higher average bulb weights and higher uptake of N was found where lower planting density. Total bulb yield and yield of marketable bulbs were highest with higher planting density. Increasing the NPK rate increased all vegetative growth parameters measured and increased the yields of bulbs. The best application method for NP was two equal doses applied at 30 and 60 days after transplanting.

Singh *et al.* (1996) carried out an experiment in Agra, India. He reported that the effectss of N (0, 60,120 or 180 kg/ha) and S (0, 20, 40 or 80 kg/ha) on the growth of onions (cv. Pusa red). The yield and plant N content significantly increase with increasing rate of N. Yield and growth significantly increased with increasing rate of S up to 40 kg/ha. Combined application of N+S significantly affected yield.

Amin *et al.* (1995) worked with different rates of N on onion cv. Taherpuri in sandy loam soil at Mymensingh. They planted on 20 December or 20 January and gave 0, 25,50 or 100 kg N/ha. Yields were highest from the planting of 20 December supplied with 100 kg N/ha. Individual bulb weight was also greater in this treatment.

Katwale and Saraf (1994) reported that application of NPK @ 125:60:100 kg/ha gave the maximum bulb yield of onion. The rate also gave the highest economic return.

Nasiruddin *et al.* (1993) conducted an experiment to study the effects of potassium and sulphur on growth and yield of onion in Mymensingh, Bangladesh. They found that application of both potassium and sulphur either individually or combined increased the plant height, leaf production ability of the plant, bulb diameter, bulb weight as well as the bulb yield. They recommended that 100 kg MP and 30 kg sulphur per hectare were produced higher yield.

Vachhani and Patel (1993) studied the effects of different levels NPK on the growth and yield of onion. They found that application of K increased only the number of leaves per plants. Increasing phosphorus application increased the number of leaves per plant and weight, size and yield of bulbs. Plant height, number of leaves/ plant, bulb weight and yield were highest with 150 kg N/ha, although bulb weight and yield with 100 kg N/ha were not significantly different.

2.2. Effectss of plant spacing on onion yield and yield components

Ngullie and Biswas (2017) was undertaken to determine the effects of different plant and row spacing on growth and yield of onion.8 different spacing's were taken viz., 20×10 cm, 20×15 cm, 20×20 cm, 25×10cm, 25×15 cm, 25×20 cm, 30×10 and 30×15cm.Variety Nasik Red was used for the study. The results demonstrated that plant spacing had significant effectss on growth, yield components and yield of onion. Significantly wider spacing produced higher size of plant height, leaf length and number of leaves. Bulb diameter, circumference and weight also have the same trend in wider spacing. The weight of individual onion bulb (53.0 g) was increased with the widest spacing of 30x15 cm. On the contrary, the overall yield/haw's the highest (17.69 t/ha) at the closest spacing (20 ×10cm) and the lowest (9.51 t/ha) was at widest spacing (30×15 cm).

Woldeselassie *et al* (2014) was conducted at Humbo Larena, wolaita zone during the 2012/2013 dry season, to study the effects of bulb treatment and spacing patterns on seed yield and quality of onion in the semi-arid zone of Ethiopia. Treatments consisted of a factorial combination of four levels of bulb types [whole bulbs, cut (topped) bulbs, ash-treated cut (topped) bulbs, and fungicide-treated cut (topped) bulbs] and four levels of spacing patterns (50 × 30 × 20 cm, 60 × 30 × 20 cm, 40 × 20 cm, and 50 × 20 cm) laid out in randomized complete block design replicated three times. The onion variety known as Bombay Red was used as a test crop. Results revealed that the main effectss of both bulb treatment and spacing significantly influenced, seed weight per umbel, standard germination, vigor Index I and vigor index II. However, bulb treatment and spacing interacted to significantly influence seed yield. The highest seed yield was obtained in response to planting fungicide-treated topped bulbs at the both double-row spacing. However, significantly higher values of all seed quality parameters were obtained from both single-row spacing.

Elhag and Osman (2013) conducted to evaluate the effects of plant spacing on onion seed quality, The experiments were executed at the nursery of Horticulture Administration, Ministry of Agriculture and Animal Resources and the laboratory of the Agricultural Research Station , Northern State, Sudan, in two successive seasons (2010 -2011and 2011-2012). In the nursery the bulbs of cultivar “Bafetaim (s)” were planted on both sides of 70cm ridges at 2.5, 5, 10 and 12.5 cm within ridge spacing. The cultural practices were followed as recommended till seed harvest. The experimental units were in completely randomized block design with four replications. After harvest the seeds were tested directly for germination (germination percentage, rate and uniformity) in petri dishes and emergence (emergence percentage, rate and uniformity) in soil in plastic seeds were again tested for germination after one and two years storage in paper bags at room temperature. All seed tests experiments were in completely randomized design with three replications. The results showed that the widest spacing had positive effectss on germination and emergence percentage and rate. The closest spacing had positive effectss on germination and emergence uniformity as well as ageing or deterioration rate. It could be concluded that closer plant spacing has no significant effects on onion seed quality moreover, it may reduce ageing rate during storage under normal storage conditions. However, the closest within row spacing (2.5 and 5cm) might be tedious and laborious compared to medium ones (10 cm). So medium within row spacing (10 cm) could be recommended for high onion seed yield (data not shown) and quality in the Northern State, Sudan and areas of similar environmental conditions.

Dereje *et al*. (2012) also reported that high unmarketable yield of shallot was recorded in closely spaced plants. Seck and Baldeh (2009) also concluded that plant density has an impact on marketable bulb size. The smaller the marketable size is an issue for high plant densities and needs to be improved.

According to Dorcas *et al*. (2012) reported that with increasing plant density of onion from lower 100,000 plants ha-1to higher plant density of 500,000 plants ha-1then average bulb weight and bulb diameter decreases from 58.22 g to 40.04 g and 4.56 cm to 2.83 cm respectively. The authors also reported that highest and lowest yield was obtained in the higher plant density of 500,000 plants ha-1and lower plant density of 100,000 plants ha^{-1}. Yemane *et al.* (2013) indicated that with increasing intra-row spacing from 5 to 10 cm, statistically bulb diameter and bulb neck diameter of onion increased from 4.66 to 5.63 cm and 1.48 1.74 cm respectively. Dawar*et al*., (2005) indicated that as plant population increased from 40 to 80 plants m-2onion neck diameter declined significantly. Jilani *et al*. (2009) indicate that bulbs of thick neck of onion were found in plots of lowest plant density (20 plants m-2). Bulb neck diameter decreased as population density increased. Mean bulb weight and plant height decreased as population density increased (Kantona *et al*., 2003).

Sikder *et al*. (2010) was conducted at the Horticulture farm of Bangladesh Agricultural University, Mymensingh during the period from October 2001 to January 2002 to study the effectss of spacing, and depth of planting on the growth and yield of two varieties of onion. There were three levels of plant spacing (viz., 20 cm × 20 cm, 20 cm × 15 cm and 20 cm × 10 cm) and two levels of depth of planting (viz., 2 cm and 4 cm). The experiment was laid out in RCBD with 3 replications. The plant spacing showed significant effectss on most of the growth and yield characteristics. Wider spacing produced the maximum number of leaves per plant, longest plant height, maximum diameter and fresh weight of bulb while the closer spacing produced maximum yield of bulb (12.08 t/ha). Bulb yield was significantly higher at lesser depth of planting. The combined effects of spacing and depth of planting was found to be significant on most of the growth and yield parameters. The combination of 20cm × 10cm spacing with 2cm depth of planting gave significant higher yield (12.82 t/ha) compared with other treatment combinations.

Sikder *et al*. (2010) evaluated three intra-row spacing (20×20, 20×15 and 20 cm×10 cm) of onion. Based on this, the maximum yield were recorded from 20 cm × 10 cm spacing and the narrow plant spacing produced comparatively lower values on fresh weight of leaves per plant, plant height, leaves number per plant, bulb diameter and fresh weight of bulb. Stoffela (1996) also found that as number of rows per bed increased, marketable onion yield linearly increased and mean bulb size decreased. Latif *et al*. (2010) showed that yield of onion bulbs produced at the spacing of 20 cm × 10 cm was recorded as the highest compared to 20 cm × 20 cm spacing. Mahadeen, (2008) also reported that narrow intra-row spacing produced higher yield.

Jilani et al. (2010) studied the performance of Naurang Local and Phulkara cultivars with respect to different plant spacing (10, 15, 20 and 25 cm). The data on number of leaves/plant, plant height, leaf length, bulb weight, bulb diameter, bulb yield/plot and total yield (t/ha) were recorded. Significant variations were recorded for two onion cultivars and different plant spacing for all the parameters studied. Phulkara excelled in all the parameters against Naurang Local as it produce d maximum leaves per plant (9.63), plant height (52.98 cm), leaf length (46.32 cm), bulb weight (56.40 g), bulb diameter (5.25 cm), bulb yield per plot (2.89 kg) and total yield (10.78 t/ha). Among plant spacing, although the widest plant spacing (25 cm) produced the maximum leaves per plant, plant height, bulb weight and bulb diameter, but it reduced the yield per plot and total yield. However, closest plant spacing (10 cm) produced significantly maximum yield per plot and total yield. For better yield of onion, Phulkara cultivar with closet plant spacing of 10 cm is highly recommended.

According to Balraj et al. (1998) with increase in plant spacing, the bulb weight and size increased, but the yield ha-1decreased. Kumar et al. (1998) indicated that the spacing has a direct effects on the quality and production of onion. Lower planting density was the best with regard to leaf length. Latif et al. (2010) indicated that the numbers of leaves per plant, bulb weight, foliage dry weight, plant height was highest when the plants were grown at wider spacing of 20 x 20 cm. However, yield per unit area was higher in the narrow spacing. Nasir et al. (2007) also stated that the highest leaf number per plant was recorded at lower planting density. Planting of onion at 20 and 25 cm spacing produced larger bulbs compared with planting at 10 and 15 cm spacing (Mahadeen, 2008). Jilani (2004) reported that onion plants from the lowest plant population (20 plants m-2) recorded the highest number of leaves and leaf length.

Bijaya Devi et al . (2008) observed that the maximum yield of onion was obtained with closer spacing (10 x 10 cm) and bigger bulb size (B3). Among different spacing, 20 x 10 cm recorded maximum number of leaves per hill, number of bulbs per hill and also in most of the bulb characters, but the highest yield (184 quintal per ha) was recorded in closer spacing (10 x 10 cm). Bulb size also influence significantly the growth parameters like number of leaves per hill, leaf length and bulb characters.

Minimum planting density attained the highest number of leaves which decreased with increasing planting density. Minimum plant population (20 plants m-2) had larger bulb diameter against smaller bulb diameter of higher plants density (40 plants m-2) (Jilani et al., 2009). A report by Hyder et al. (2007) who indicated that plant height, bulb length, bulb diameter and days to harvest were the most important yield contributing factors. There is indirect effects on bulb yield of each trait. Plant height revealed a positive indirect effects on yield and was favorable through bulb length, bulb neck thickness, TSS in Brix and dry matter content. Akoun (2005) reported that bulb diameter was greatest (8.18cm) at the lowest population density. Seid et al. (2014) indicated that lowest leaf width (0.73 cm) of garlic was recorded in higher plant density.

According to Nasir et al. (2007) maximum weight of small and medium sized of onion was obtained at higher population density, However, the highest weights of large bulbs were found at the lowest planting density. Dawar et al. (2007) also reported that maximum weight of medium and small sized bulb was achieved at higher planting density of 80 plants 4m-2. However, maximum weight of large bulbs was found at the lowest planting density of 40 plants 4m-2. Rumpel et al. (2000) showed that yield of medium bulbs increased with density but, the yield of large bulbs decreased as plant density increased. Yemane et al. (2013) stated that the highest percentage of small and medium size bulbs yield was scored at narrow intra-row spacing of 5 cm as compared to 7.5 cm and 10 cm. However, as the intra-row spacing increased from 5 to 10 cm, the percentage of large size bulbs increased from 9.3 to 20.3%.

Generally, yield of onion increases with an increase in plant population because plant densities allowed the canopy to close quickly reducing the ability of weeds to compete, but only up to an optimal limit and yield will decrease beyond this optimum. Appropriate spacing enables the farmers to keep appropriate plant population in their field. Hence, a farmer can avoid over and less population in a given plot of land, which has negative effects on yield. Therefore, to avoid nutrient competition due to inappropriate use of plant spacing and N fertilizer, sufficient spacing between plants and rows and optimum amount N fertilizer application is vital to get highest yield in a given plot of land (AVRDC, 2004).

Singh and Singh (2003) studied the combined effects of onion mother sets and planting distance on growth, quality, storage weight loss and yield attributes of variety N - 53 during kharif 1998 -99 and 1999 - 2000. The maximum number of leaves (9.00 and 9.88), neck thickness of plant (2.13 and 2.39 cm), fresh weight (61.10 and 65.67 g), diameter (5.07 and 5.l5 cm), neck thickness of bulb (1.85 and 2.05 cm), recovery percentage of 'A' grade bulb (10.93 and12.53 %), juice content in bulb (25.47 and 28.04 %) and ambient storage weight loss of bulb (29.02 and 27.92 %) were found with combination of larger set size (2.1 - 2.5cm) and wider planting distance (15 x 15 cm) compared to all treatment combinations during both the years. However, highest recovery percentage of 'B' grade bulb (86.15 - 88.78 %), gross yield (342.33 - 364.54 q/ha) and yield of marketable bulbs (327.06 - 344.14 q/ha) were obtained with combination of bigger size of sets (2.1 - 2.5 cm) and closer planting distance (15 x 10 cm).

Kantona et al. (2003) observed that onion yield increased from 17.4 to 39.5 t ha-1as plant population per square meter increased from 50 to 150. Yemane et al. (2013) mentioned that the highest unmarketable bulb yield of onion was produced by the narrow intra-row spacing.

According to Jan et al. (2003), the highest yield (40.44 t ha-1) was found at spacing of 17 x 4.5 cm, and the lowest yield (19.95 t ha-1) at 27 x 14.5 cm spacing. Yemane et al. (2013) also indicated that the highest total bulb yields were achieved at 5 and 7.5 cm intra-row spacing, respectively as compared to the 10 cm intra-row spacing. Dereje et al. (2012) also indicated that total yield per hectare increased as plant density increased although yield of the individual plants and their components were significantly reduced suggesting a compensation of higher plant densities on yield in shallot.

Khan et al. (2002) reported that various plant spacing leads to the increase in plant height, onion bulb size, and weight of the bulbs, bulbs ha-1and yield of the bulbs. Khan et al. (2003) reported that wider spacing (20 x 10 cm) produced higher size of plant height, leaf length and number of leaves, bulb length, diameter and weight of onion. On the contrary, highest yield was observed at the closest spacing and the lowest yield at widest spacing. Yamane et al. (2013) also indicated that as intra-row spacing increased from 5 to 10 cm, marketable bulb yield in t ha-1decreased from 34.49 to 28.10. Seck and Baldeh (2009) reported that plant density has an impact on marketable bulb size and the higher the plant density the smaller the marketable size. Kantona et al. (2003) also reported that as plant density increased number of marketable bulbs increased.

Khan et al. (2002) observed that spacing 20 x 12 cm and Nitrogen 100 kg/ha gave best result. Maximum yield of onion bulb (22.90 t/ha) was obtained from 20 x 12 cm plant spacing with 100 kg N/ha.

The ideal spacing and plant population are those that maximize yield, vegetable quality and profits to farmers without excessively increasing costs. An essential aspect of any crop production system is the development of a crop canopy that optimizes the interception of light, photosynthesis, and the allocation of dry matter to harvestable parts. A crop canopy is commonly managed by manipulating row spacing and plant population; as plant density increases, yield per unit area will approach an upper limit, plateau, and then decline while yield per plant tend to decrease with increasing plant density because of competition for growth factors between adjacent plants (Silvertooth, 2001).

Kumar et al. (2001) conducted an experiment to study the effects of spacing (20 x l0, 20 x 15 and 20 x 20 cm) on the growth and yield of onion during 1992 - 93 and 1993 - 94. The wider spacing (20 x 20 cm) showed maximum plant height, number of green leaves, diameter of longest leaf, diameter of pseudo stem, number of roots, bulb length, diameter of bulb and fresh weight of bulb in comparison with closer spacing of 20x15 and 20xl0 cm. However, the maximum yield of bulbs was obtained when the plants were spaced at 20x10 cm.

Bosch and Olivé (1999) in Spain conducted two experiments, one under natural light condition and another one under black neutral shade, with the aim of investigating an influence of plant population (20, 40, 80 and 160 plants m-2) on bolting percentage using a long day cultivar. Based on this, under natural light condition, as plant population increased from 20 to 160 plants m-2, number of bolters significantly increased from 8 to 75.Onions have a high harvest index with 70 to 80% of the shoot dry weight found in the bulb at maturity. As compared to other crops, onions are poor at intercepting radiation, average at converting radiation to dry matter but good at partitioning the dry matter to harvestable material (Brewster, 1990). Dereje et al. (2012) reported that lower harvest index of shallot in wider intra-row spacing. Kabir and Sarkar (2008) also reported highest value of harvest index of mungbean recorded from closer spacing probably due to the reduced vegetative biomass.

In an experiment trial at Meerut, seedlings were spaced at 20 cm x 10 cm, 20 cm x 15 cm and 20 cm x 20 cm. The 20 cm x 20 cm spacing was best with regards to plant height , length and diameter of the thickest stem, number of leaves per plant and bulb diameter. However, the highest bulb yield was obtained when plants were spaced at 20 cm x 10 cm, Kumar et al. (1998).

Mehla and Mangat (1995) reported that plant spacing with 10 cm x 10 cm gave the tallest plant as compared to other spacing treatments.

Plant population refers to number of plants per square meter (plants m^{-2}) or hectare (plants ha-1) and is important in onion production since it has an influence on growth, yield and quality of onion bulbs (Brewster, 1994). Plant and row spacing are considered important to the optimum plant population which may be reflected in higher yield and quality. Onion bulb size can be controlled to a certain extent by plant population. In order to produce large bulbs (> 70 mm in diameter) a plant population of between 25 and 50 plants m-2is required, for medium bulbs (25-50 mm) between 50 and 100 plants m-2and for small bulbs (< 50 mm) more than 100 plants m-2are required (Brewster, 1994).

Rajas et al. (1993) reported that onion Cv. Pusa Red gave the highest yield (28.11 t/ha) with plant spacing 10 cm x 15 cm as compared to other plant spacings (15 cm x 15 cm; 20 cm x 15 cm).

Mc Geary (1985) arranged 178, 400, 625, 816, 1000 or 1600 plants per m2in his experiment and reported that an increase in plant density resulted in reduction in plant size, mean bulb weight, number of leaves per plant, cumulative leaf length and also the maturity time of onion bulb crop.

Hassan (1978) observed a reduction in the average bulb weight, percentage of large bulbs and bolters with an increase in the number of row per ridges, however, the total yield increased under higher plant population.

Churate*et al*. (1976) observed reduction in average bulb weight of onion fr om 190 g to 135 g and 80 g with the reduction in spacing from 25 x 20 cm to 20 x 15 and 15 x 10 cm, respectively in cv. Texas Early Grano.

Randhawa and Singh (1974) also observed that the closer spacing of 15 cm x 10 cm produced maximum number of marketable bulbs and total bulb yield (116.96 q/ha) than the wider spacing in onion Cv. Punjab Selection.

Ahlawat and Singh (1973) reported that various spacing had significantly influenced the yield of onion bulbs Cv. Pusa Red. The spacing of 10 cm and 20 cm produced significantly higher yield over the wider spacing of 30 cm.

Singh (1972) also observed that the wider spacing of onionplants resulted in bigger sized bulbs and also higher dry weight.

Das et al. (1972) observed that in onion Cv. Red Globe though 20 cm x 10 cm spacing had a stimulating effects in the number of leaves per plot, the plant height did not shown any significant effects due to different spacing. However, the stem thickness increased with the wider spacing's. They also indicated that the wider spacing of onion plants seemed to have helped the individual plant to utilize more soil water, nutrition, air and light to help into put up better growth than those having closer spacing, where the plant population per unit area increased.

CHAPTER-3

MATERIALS AND METHODS

A field experiment was conducted in the field of Sher-e - Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to April 2018 to find out the effects of growth and seed yield of onion influence by plant density and fertilizer amendment. The materials and methods for conducting of the experiment were presented in this chapter under the following headings :

3.1 Experimental Site

The experiment was conducted in order to study the growth and seed yield of onion influence by plant density and fertilizer amendment at the field of Central Farm of Sher-e- Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^0 74^'$ N latitude and $90^0 35^'$ E longitude an elevation of 8.2m from sea level (Anon., 1989).

3.2 Soil

The soil experimental area belongs to the Madhupur Tract (UNDP, 1988) under AEZ No. 28 and was shallow and brown terrace soil . The selected plot was high land and the series Tejgaon (FAO, 1988) . The characteristics of the soil under the experimental plot were analyzed in the Soil testing Laboratory, SRDI, Dhaka and details of the recorded soil characteristics were presented in Appendix II.

3.3 Climate

The experimental area was under the sub-tropical climate which was characters by characterized by heavy rainfall during the months from April to September (Kharif season) and scanty in the months from October to March (Rabi season). Details of the metrological data related to the temperature, relative humidity and rainfall during the period of the experiment was collected from the Bangladesh Meteorological Department (climate division) Agargaon, Dhaka.

3.4 Onion variety

An approved onion variety released by Spices Research Centre, BARI, Shibganj, Bogura as BARI Piaz-1 was selected for the present study. The variety produces plants 35-50 cm tall with 9-10 leaves plant^{-1}. The diameter of bulb is 4-5 cm, mature within 90-120days and yield of bulb is about 15 to 19 t ha^{-1} (Anon., 2000). The germination of the seed was 85%. Seed were collected from BARI, Joydebpur, Gazipur.

3.5 Design and layout of the experiment

The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The total number of plots was 48. The treatment combination of the experiment was assigned at random into 16 plots of each at 3 replications.

3.6 Treatment of the experiment

The experiment consists of 2 factors fertilizer and spacing. Each fertilizer has four levels. Details of factors and their combinations are presented below:

Factor: 2 factors

Factor A: spacing (4spacing)	Factor B: Fertilizers application (4 levels)
S_1 = 20cm×15cm	T_0 = No application (control)
S_2 = 25cm×15cm	$T_1 = N_{60}P_{30}K_{80}S_{20}$ kg/ha
S_3 =20cm×20cm	$T_2 = N_{80}P_{50}K_{100}S_{30}$ kg/ha
S_4 = 25cm×20cm	$T_3 = N_{100}P_{70}K_{120}S_{40}$ kg/ha

3.7 Seedbed preparation

The land selected for raising seedlings was fine texture and well drained. The land was opened and drying for 10 days. Large sized clods were broken into pieces and finally the soil was made loose, friable, until good tilts. All weeds and stubbles were removed and the soil was mixed with decomposed cow dung during final land preparation. Applying Furadan 3 G @ 20 kg ha^{-1} was covered by polythene for two days. The seedbed was 3 m × 1 m in size with a height of about 20 cm. Onion seeds were soaked overnight (twelve hours) in water and allowed to sprout in a piece of moist cloth keeping in the sunshade for one day.

3.8 Seed sowing

The first date of seed sowing was 7th October 2017. The seeds (3-4 in number) were sown directly in the raised seedbed for raising seedling which will be transplanted. The young seedlings were exposed to dew by night and mid sunshine in the morning and evening. Shade was given over the seedbeds to retain soil moisture and to save the seedlings from direct sun and rain.

3.9 Land preparation

The experimental plot was opened in the month of November, 2017 with the help of a tractor. Thereafter, the land was prepared by several ploughings and cross ploughing with a power tiller followed by laddering. Weeds and stubbles were removed and the large clods were broken into smaller pieces to obtain a desirable tilh of friable soil for transplanting the seedlings.

3.10 Fertilizers:

Fertilizers were used in the experiment according to as per treatment.

3.11 Application of fertilizers and manure

Full amount of TSP + full amount of MP + full amount of Zypsum are applied in the field as basal dose during final land preparation. Ureas were applied as top dressing in 3 equal splits at 15 days intervals.

3.12 Transplanting of seedlings

Healthy and disease free uniform sized 40 days old seedlings were uprooted from the seedbeds and transplanted in the main field with the line to line of spacing as per treatment in the afternoon on 16 November 2017. The seedbed was watered before uprooting the seedlings so as to minimize the damage of roots. The seedlings were watered immediately after transplanting. Some seedlings were also transplanted adjacent to the experimental area to be used for gap filling.

3.13 Intercultural operation

After transplanting the seedlings, intercultural operations were done whenever required for getting better growth and development of the plants. So the crop was always kept under careful observation.

3.14 Gap filling

Damaged or dead seedlings were replaced by healthy plant within one week of transplantation.

3.15 Weeding and mulching

Weeding was done three times after transplanting to keep the crop free from weeds and mulching was done by breaking the crust of the soil for easy aeration and to conserve soil moisture, when needed especially after irrigation.

3.16 Irrigation and drainage

Irrigation was given when needed. First irrigation was given just after transplanting and also at 20 days after transplanting. During this time care was taken so that irrigated water could not pass from one plot to another. Mulching was also done after each irrigation at appropriate time by breaking the soil crust. During each irrigation, the soil was made saturated with water. After rainfall excess water was drained out when necessary.

3.17 Plant protection

Insects: Preventive measure was taken against soil borne insects. For the prevention of cutworm, Furadan 3 G @ 20 kg ha^{-1} was applied. No insect pest infestation was found in the field after pesticide application.

Disease: Few days after transplanting some plants were attacked by purple blotch disease caused by *Alternaria puri.* It was controlled by spraying Ruvral 50 WP four times at 10 days interval after transplanting.

3.18 Harvesting

The umbels were harvested on 20-28 April, 2018 according to their attainment of maturity of seeds. After harvest seeds were processed and stored in the cool room with maintaining proper temperature and humidity.

3.19 Sampling at harvest

For additional collection of bulb yield parameter, ten plants were randomly selected from each plot to record data at bulb maturity stage, i.e. diameter of bulb per plant (cm), length of bulb per plant (cm), single weight of bulb (g) and yield of bulb (t ha^{-1}).

3.20 Collection of data

Data were recorded on the following parameters from the sample plants during the course of experiment. Five plants were randomly selected from each plot to record data, in such a way the border effects was avoided for the highest precision.

1. Plant height (cm)
2. Leaf height (cm)
3. Number of leaves per plant
4. Length of bulb per plant (cm)
5. Fresh weight of single bulb (g)
6. Diameter of bulb per plant (cm)
7. Yield of bulb per plot(kg)
8. Yield of bulb per hectare (t)
9. Number of flower per plant
10. Weight of seed per plant
11. 1000 seed weight
12. Seed yield (kg/ha)

3.20.1 Plant height (cm)

The height of the randomly selected 10 plants in each plot was recorded at harvest. The height was measured in centimeters (cm) from the neck of the bulb to the tip of the longest leaf and average heights of the selected ten plants were taken to observe the rate of growth.

3.20.2 Number of leaves per plant

The numbers of leaves per plant from randomly selected plants were recorded and the average of 10 plants was taken as the number of leaves per plant.

3.20.3 Length of bulb per plant (cm)

At harvest the length of bulb was measured with a slide caliper from the neck to the bottom of the bulb from ten randomly selected plants from each plot and their average was taken.

3.20.4 Diameter of bulb (cm)

At harvest the diameter of bulb was measured at the middle portion of bulb from 10 randomly selected plants from each plot with a slide caliper and their average was recorded.

3.20.5 Weight of single bulb

Ten randomly selected plants from each unit plot were harvested. The top was removed by cutting pseudo stem keeping only 2.5 cm with the bulb. Ten bulbs were weighed by an electric balance and their average was considered as the individual bulb weight.

3.20.6 Yield of bulb per plot (kg)

All the leaves along with pseudo stem were removed from the plant keeping only 2.5 cm neck. Then the weight of the bulbs was taken by a simple balance in kilogram (kg) from each unit plot separately.

3.20.7 Yield of bulb per hectare (ton)

The yield of bulb per plot was converted to get yield in tons per hectare.

3.20.8 Number of flowers umbel^{-1}

Number of total flowers of ten umbels from each unit plot was noted and the mean number was expressed as per umbels basis.

3.20.9 Seed weight per plant (g)

A composite sample was taken from the yield of ten plants. The weight of seeds per plant each plot were counted and weighed with a digital electric balance. The weight of seeds per plant was recorded in g.

3.20.10Thousand seed weight (g)

A composite sample was taken from the yield of ten plants. The thousand seeds of each plot were counted and weighed with a digital electric balance. The thousand seed weight was recorded in g.

3.20.11 seed yield (Kg/ha)

After threshing, cleaning and drying, total seed from harvested area were recorded and was converted to kg/ha.

3.21. Statistical analysis

The collected data on various parameters under study were statistically analyzed to find out the statistical significance of the experimental results The means of all the treatments were calculated and analyses of variance or all the characters were performed by F-test variance . The significance of the difference among the mean was evaluated by Duncann's Multiple Range Test (DMRT) (Gomez and Gomez .1984).

CHAPTER -4

RESULTS AND DISCUSSION

The experiment was conducted to investigate the growth and seed yield of onion influence by plant density and fertilizer amendment. Data on different parameters were analyzed statistically and results have been presented in tables 1 to 7 and figures 1 to 4. The results of the present study have been presented and discussed in this chapter under the following heading.

4.1 Plant height

Plant height was not significantly varied due to the application of different spacing treatment. The longest (48.87 cm) plant was obtained from S_1 (20cm×15cm) when as the shortest (42.25cm) plant was found from S_4 (spacing 25cm×20cm). The plant height was decreased with increasing in row spacing. The increased plant height at closer spacing was due to more competition for air and light. This is in agreement with the results of Rashid (1998), who obtained taller plants from closer spacing. But this is contradictory with the findings of Badaruddin and Haque (1997), Khushk *et al.* (1990) and Kumar *et al.* (1998) they found taller plant height at the wider spacing.

Plant height was not significantly variation was found due to the application of different levels of Fertilizers. The tallest plant (45.80cm) was produced by T_2 ($N_{80}P_{50}K_{100}S_{30}$ kg/ha) and the shortest plant (44.68 cm) was recorded from T_0 (control treatment). The plant height increased with increasing fertilizer at certain level. Vacchani and patel (1993) reported that the height of plant increased with increasing levels of nutrients.

Due to combined effects of different spacing and fertilizers treatment showed significant variation on plant height. The highest plant height (54.70cm) was obtained from S_1T_2 (20cm×15cm and $N_{80}P_{50}K_{100}S_{30}$ kg/ha) treatment while the lowest plant height (34.37 cm) was obtained from the treatment combination of S_1T_0 (20cm×15cm and control) treatment.

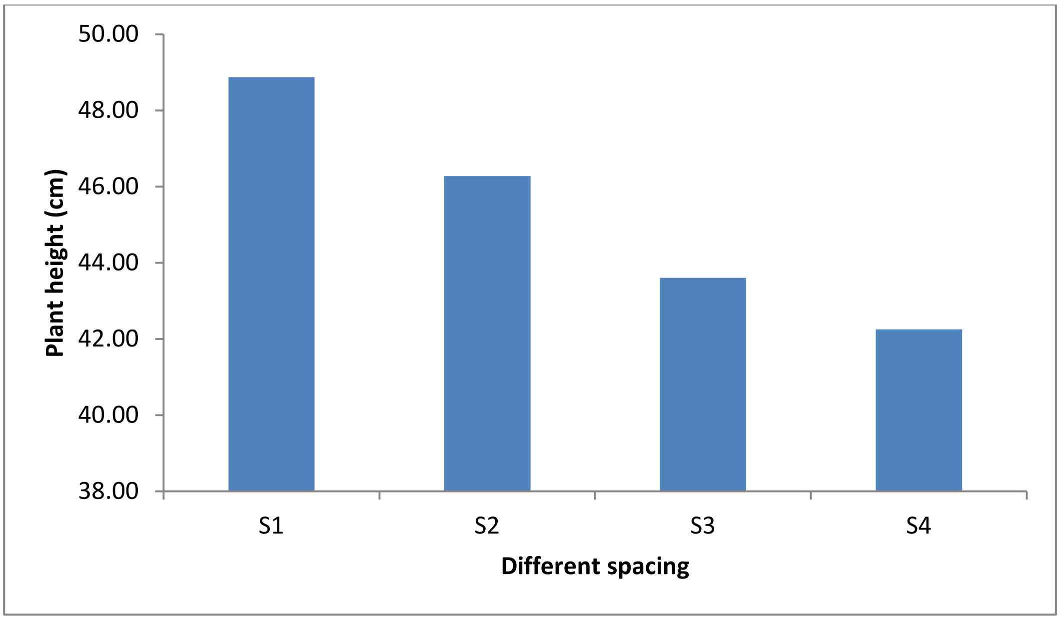


Figure1. Effectss of different spacing on the plant height of onion

S_1= 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm

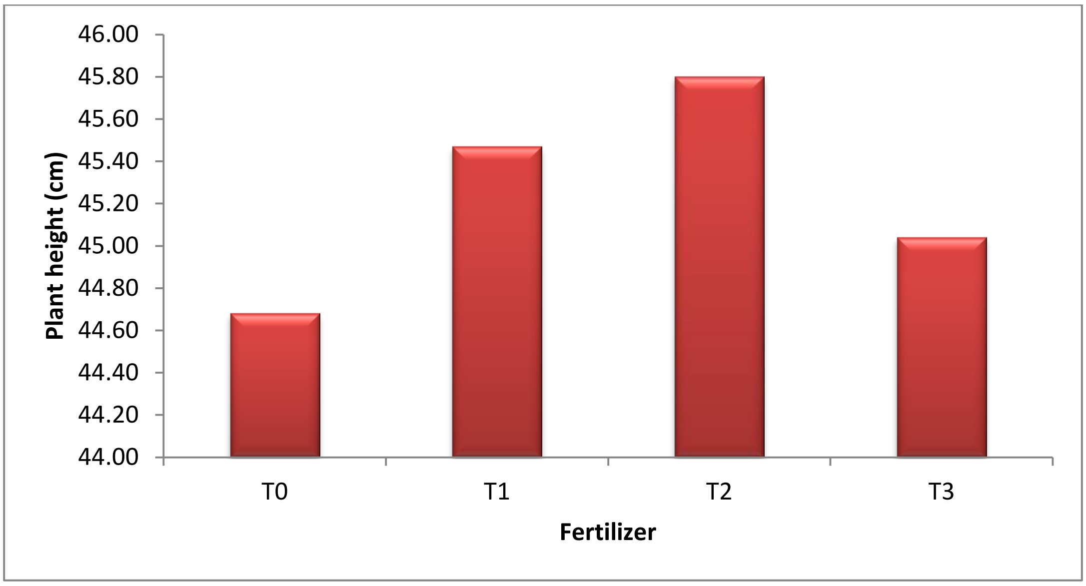


Figure 2 Effects of Fertilizers on the plant height of onion

T_0 = No application (control), T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha, T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha

Table1. Combined effects of spacing and fertilizer on plant height and Number of leaf per plant of onion

Treatment	Plant height (cm)		Number of Leaf	
S_1T_0	50.70	ab	4.44	e
S_1T_1	46.02	bcde	5.92	bcd
S_1T_2	54.70	a	6.05	bc
S_1T_3	44.08	cdef	4.96	de
S_2T_0	49.26	abc	5.40	bcde
S_2T_1	47.61	bcd	5.71	bcd
S_2T_2	42.85	def	6.31	b
S_2T_3	45.36	bcdef	6.24	b
S_3T_0	44.03	cdef	5.05	cde
S_3T_1	41.30	ef	6.24	b
S_3T_2	39.62	fg	5.62	bcd
S_3T_3	49.43	abc	5.51	bcd
S_4T_0	34.73	g	5.80	bcd
S_4T_1	46.95	bcde	5.98	bcd
S_4T_2	46.02	bcde	8.22	a
S_4T_3	41.31	ef	5.59	bcd
LSD(0.05)	5.18		0.89	
CV (%)	6.87		9.16	

In a column same letter(s) do not significantly differ at 0.05 level of

S_1= 20cm×15cm

S_2 = 25cm×15cm

S_3 =20cm×20cm

S_4 = 25cm×20cm

T_0 = No application (control)

$T_1 = N_{60}P_{30}K_{80}S_{20}$ kg/ha

$T_2 = N_{80}P_{50}K_{100}S_{30}$ kg/ha

$T_3 = N_{100}P_{70}K_{120}S_{40}$ kg/ha

4.2 Number of leaves per plant

Number of leaves was significantly varied due to different spacing treatment (Fig. 3). Maximum number (6.40) of leaves produced by S_4 when the minimum number of leaves (5.34) from S_1 treatment. Latif *et al*. (2010), Sikder *et al*. (2010), Kumar *et al*. (1998) and Jilani *et al*. (2009) also showed that higher leaf numbers per plant of onion were recorded in response to wider plant spacing.

Number of leaves was significantly variation was found due to the application of different levels of fertilizers treatment (Fig. 4). The number of leaves per plant was the maximum (6.55) number of leaves produced by T_2 treatment when the minimum number of leaves (5.17) from T_0 (control condition). The results indicate that optimum levels of NPKS application lead to a linear increase in the number of leaves per plant. The photosynthesis and other physiological process of plant depend on nitrogen and potassium. Number of leaves per plant is an important yield contributing factor of onion. Optimum level of NPKS might have increase the availability of plant nutrients resulting in increased better performance of crop growth and ultimately produced more number of leaves per plant. Rizk (1997) found that the increasing levels of NPK increased the number of leaves. Vachhani and patel (1993) found the highest number of leaves from 150 kg N/ha. Nasiruddin *et al.* (1993) also reported that the number of leaves per plant increased due to application of K and S.

Due to combined effects of different spacing and fertilizers treatment showed significant variation on number of leaves per plant. The maximum (8.22) number of leaves was found was obtained from S_4T_2 treatment while the minimum (4.44) number of leaves was obtained from the treatment combination of S_1T_0 treatment (table 1). This result is concordant with the findings of Rao *et al*. (2013) who reported that highest leaf number per plant of onion was recorded with the highest combination of 75 kg N $ha^{-1}$and 20 cm x 12.50 cm spacing. Consistent with the results of this study, Khan *et al*. (2002) also indicated that lower leaf number per plant of onion was recorded from the treatment interaction effects of control nitrogen level and narrow intra-row spacing.

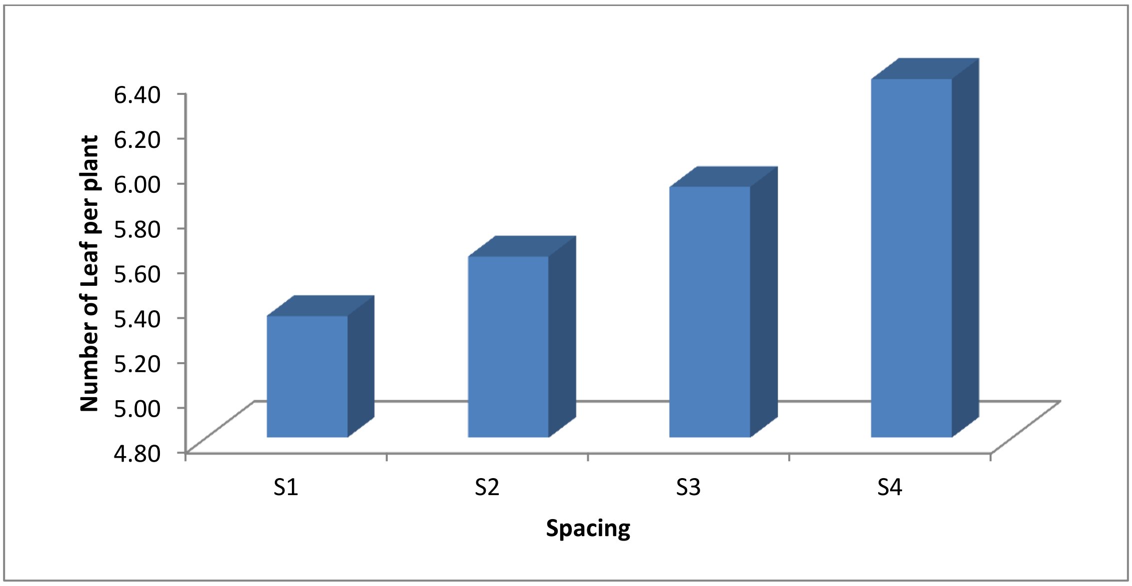


Figure 3. Effectss of spacing on the number of leaves of onion

S_1= 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm

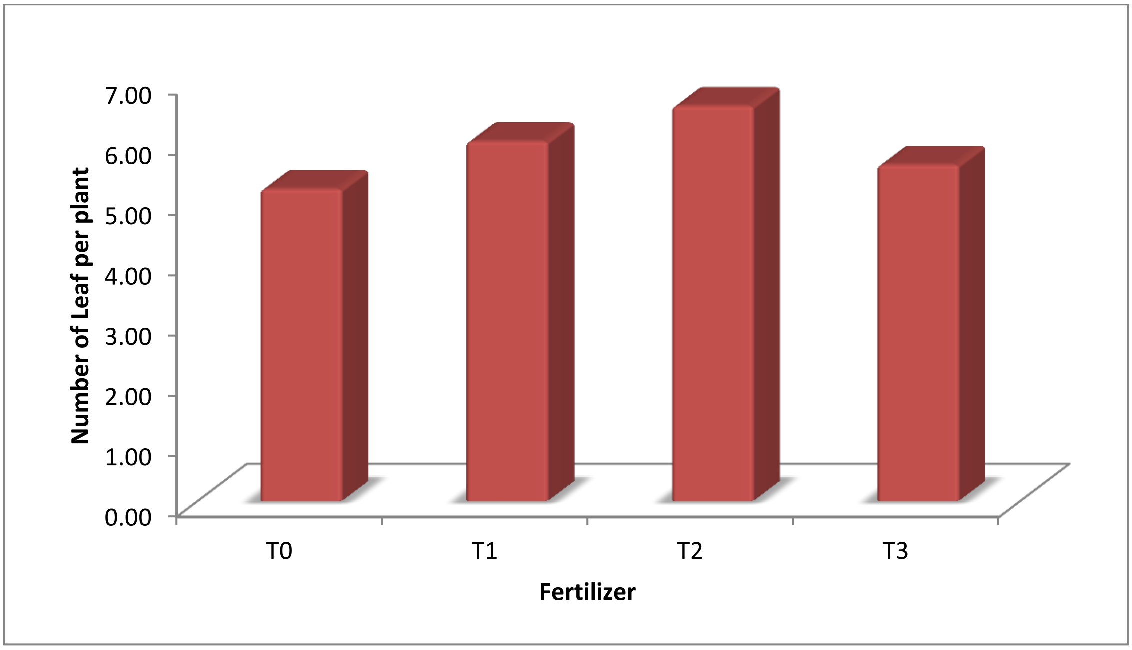


Figure 4 Effects of Fertilizers on the number of leaves of onion.

T_0 = No application (control), T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha, T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha

4.3 Diameter of bulb

There is significant variation on diameter of bulb of onion due to application of different spacing. The highest (4.07 cm) diameter of bulb was recorded from 25cm×20cm spacing (S_4) and the lowest (3.28 cm) by the 20cm×15cm spacing (S_1) treatment, which was statistically similar with S_2 treatment (Table 2). The current results are supported by the findings of Jilani *et al*. (2009), Akoun (2005) and Muhammad *et al*. (2011) who stated that higher bulb diameter was achieved for the wider plant spacing as compared to the closer spacing of onion.

A significant variation was found in the diameter of bulb of onion due to application of different levels of fertilizers. The highest (3.95 cm) diameter of bulb was recorded obtained from $N_{80}P_{50}K_{100}S_{30}$ kg/ha, T_2 and the lowest (3.18 cm) was found from control (T_0) treatment (Table 3). The diameter of bulb increased with the increase in the level of fertilizers at certain level. Rahman *et al.* (1976) found that the increasing levels of NPKS increased the diameter of bulb. Vacchani and Patel (1993) observed the highest bulb diameter from 100kg MP and 30 kg Sulphur/ha.

The combined effects showed significant effects of on diameter of bulb due to application of different plant spacing and fertilizers. The diameter of bulb ranged from 2.28 to 5.03 cm. The highest (5.03cm) diameter of bulb was recorded from the treatment combination of S_4T_2 treatment, whereas the lowest (2.28 cm) bulb diameter was observed from S_1T_0 treatment (Table 4). The development of wider bulb diameter with increasing intra-row spacing and rate of N fertilizer could be associated with the availability of more growth resources due to less competition and with application of N, which could be associated with promoting nature of nitrogen in cell elongation, above ground vegetative growth and synthesis of chlorophyll to impart dark green color of leaves. This may be linked to metabolic processes which increase dry matter production and translocation to the bulbs (Brady, 1985).

Table 2. Main effects of spacing on the growth and yield of onion

Treatment	Diameter of bulb (cm)	Bulb length (cm)	weight of bulb (g)	Yield (kg/plot)	Yield (t/ha)
S_1	3.28 c	3.54 b	46.12 d	1.87 a	15.56 a
S_2	3.43 c	3.60 b	47.42 c	1.85 a	15.38 a
S_3	3.88 b	3.67 b	49.33 b	1.84 a	15.33 a
S_4	4.07 a	4.42 a	50.88 a	1.63 b	13.60 b
LSD(0.05)	0.18	0.14	0.39	0.18	1.06
CV (%)	6.86	8.60	6.68	9.07	6.57

In a column same letter(s) do not significantly differ at 0.05 level of probability.

S_1= 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm

Table 3. Main effects of Fertilizers on the growth and yield of onion

Treatment	Diameter of bulb (cm)	Bulb length (cm)	weight of bulb (g)	Yield (kg/plot)	Yield (t/ha)
T_0	3.18 c	3.34 d	44.02 d	1.63 b	13.61 c
T_1	3.84 ab	3.64 c	49.92 b	1.79 ab	14.93 b
T_2	3.95 a	4.24 a	51.47 a	1.99 a	16.57 a
T_3	3.69 b	4.01 b	48.35 c	1.77 ab	14.76 b
$LSD_{(0.05)}$	0.20	0.12	0.54	0.30	0.66
CV (%)	6.86	8.60	6.68	9.07	6.57

In a column same letter(s) do not significantly differ at 0.05 level of probability.

T_0 = No application (control), T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha, T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha

Table 4.Combined effectss of spacing and Fertilizers on the yield components and yield of onion

Treatment	Diameter of bulb (cm)		Bulb length (cm)		weight of bulb (g)		Yield (kg/plot)		Yield (t/ha)	
S_1T_0	2.28	i	3.11	i	35.47	k	1.66	g	13.86	g
S_1T_1	3.53	fg	3.76	f	43.53	j	2.00	bc	16.64	bc
S_1T_2	3.96	cd	3.79	f	45.87	h	2.16	a	17.97	a
S_1T_3	3.37	gh	3.49	g	50.20	e	1.65	g	13.75	g
S_2T_0	3.48	g	3.33	h	44.86	i	1.78	ef	14.86	ef
S_2T_1	3.16	h	3.13	i	53.70	b	1.63	g	13.56	g
S_2T_2	3.22	h	3.48	g	53.20	bc	2.06	b	17.20	ab
S_2T_3	3.84	d	4.46	b	47.33	g	1.91	cd	15.89	cd
S_3T_0	3.59	efg	3.01	j	45.47	h	1.69	fg	14.12	fg
S_3T_1	4.54	b	3.51	g	49.53	f	1.88	d	15.70	cde
S_3T_2	3.58	fg	4.02	d	51.20	d	1.88	de	15.63	de
S_3T_3	3.81	de	4.13	c	51.13	d	1.91	cd	15.89	cd
S_4T_0	3.37	gh	3.89	e	50.27	e	1.39	h	11.60	h
S_4T_1	4.13	c	4.16	c	52.93	c	1.66	g	13.81	g
S_4T_2	5.03	a	5.66	a	55.60	a	1.86	de	15.50	de
S_4T_3	3.75	def	3.97	d	44.73	i	1.62	g	13.50	g
LSD(0.05)	0.21		0.05		0.55		0.09		0.89	
CV (%)	6.86		8.60		6.68		9.07		6.57	

In a column same letter(s) do not significantly differ at 0.05 level of

S_1= 20cm×15cm

S_2 = 25cm×15cm

S_3 =20cm×20cm

S_4 = 25cm×20cm

T_0 = No application (control)

T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha

T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha

T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha

4.4 Length of bulb

The length of bulb of onion was no significantly influenced by the application of different spacing. The bulb of onion was observed to be gradually increased with increasing different spacing. The length of bulb was produced the highest (4.42 cm) when S_4. However, the lowest length of bulb (3.54 cm) was obtained from S_1 treatment, which was statistically similar with, $S_1$and S_2 (Table 2).

The variation in length of bulb among different levels of fertilizers was found to be statistically significant. The maximum (4.24 cm) length of bulb was found from the rate of $N_{80}P_{50}K_{100}S_{30}$ kg/ha and the minimum (3.34 cm) was observed from control (Table 3). This result is similar results find out of Yadav et al.(2003), who noticed that highest K resulted increase length of bulb than control. Rizk (1997) found that increasing the NPK rate increased all vegetative growth parameters measured and increased the yields of bulbs. Mandira and Khan (2003) also found that all treatments and their combination were superior to control in case of Bulb equatorial diameter and bulb polar diameter. Rodriguez *et al.* (1999) also found the similar results.

A significant variation was found on the length of bulb of onion due to combined effectss different spacing and fertilizers application. The length of bulb was produced the highest (5.66 cm) from the treatment combination of S_4T_2, whereas the lowest (3.01 cm) length of bulb was noted from S_2T_0 treatment (Table 4).

4.5 Weight of bulb per plant

The weight of blub per plant was observed to be significantly influenced by the different spacing. The maximum (50.88 g) weight of blub per plant was recorded from S_4 and the minimum (46.33 g) gave the S_1 treatment (Table 2).

Significant variation was observed due to application of different levels of Fertilizers on weight of bulb. The maximum (51.47 g) weight of blub per plant was obtain at T_2, while the minimum (44.02 g) weight of blub per plant was obtained from control treatment (Table 3). The weight of blub per plant was increased gradually with the level of Fertilizers. Vacchani and Patel (1993) observed the highest bulb weight from the application of 150 kg N/ha. From the above results it was noted that increase of bulb weight with the application of optimum dose of NPKS fertilizers may be due to available soil nutrients supported proper vegetative growth and better synthesis of carbohydrates and their translocation to the bulb. This result is similar to Singh and Sharma (1991), who noticed that application of 80 kg N/ha resulted a 38% increase in bulb weight than control.

The significant combined effects between different spacing and levels of fertilizers treatment was observed on fresh weight of blub per plant. The highest (55.60 g) weight of blub per plant was recorded from the treatment combination of S_4T_2, while the lowest (35.47 g) weight of blub per plant was observed from S_1T_0 treatment (Table 4).

Increasing the rate of nitrogen application progressively increased the average bulb weight of the onion plants across the increasing intra-row spacing. The wider spacing accommodated less number of plants which received adequate nutrient, moisture and light which helped to increase the average weight of bulb per plant (Khan *et al*., 2002). However, the lowest average bulb weight was obtained at the lowest nitrogen rate (0 kg ha-1) and smallest intra-row spacing (2.5 cm) due to absence of external supply of nitrogen, which is an important element needed for proper growth and development of every plant including onion (Brady, 1985).

In harmony with this result, Muhammad *et al*. (2011), Mahadeen, (2008), Dorcas *et al*. (2012) and Jilani et al. (2010) found that the lowest average bulb weight was obtained for narrowly spaced onion plants. Corroborating the results of this study, Suleiman and Shahrajabian (2012), Aliyu *et al*. (2008) and

Morsy *et al*. (2012) mentioned that average bulb weight of onion increased with nitrogen rate.

4.6 Yield of bulbs

The yield of bulb was significantly influenced due to the different spacing. The highest (1.87 kg/plot and 15.56 t/ha, respectively) yield was obtained from S_1 (20cm×15cm) treatment, whereas the lowest yield of onion (1.63 kg/plot and 13.60 t/ha, respectively) was found from S_4 treatment. (Table 2).

The yield of bulb was significantly varied due to application of different levels of fertilizers. The highest (1.99 kg/plot and 16.57 t/ha, respectively) yield was obtained from T_2 ($N_{80}P_{50}K_{100}S_{30}$ kg/ha) treatment while the control treatment (T_0) was produced the lowest (1.63 kg/plot and 13.61 t/ha, respectively) (Table 3). It was clearly observed that yield increased with increasing level of fertilizers at certain level.

The combined effects of different spacing and fertilizers showed signification variation on yield. The highest (2.16 kg/plot and 17.97 t/ha, respectively) yield of bulb was recorded from the treatment combination of S_1T_2 (20cm×15cm spacing with $N_{80}P_{50}K_{100}S_{30}$ kg/ha), while the lowest (1.62 kg/plot and 11.60 t/ha, respectively) yield of bulb was observed from S_4T_0 (25cm×20cm with control) (Table 4).

The maximum bulb yield of onion obtained at treatment combination of 520cm×15cm spacing and $N_{80}P_{50}K_{100}S_{30}$ kg/ha might be attributed to optimum number of plant population per unit area which leads to maximum number of bulbs due to closer spacing and optimal supply of nitrogen in the soil. Although plant height, number of leaves per plant and leaf length increased with increasing spacing, it could not be compensated for the yield of closely spaced plants due to higher plant population. Thus, the marketable bulb yield of onion per unit area does not completely depend up on the performance of individual plants but also related with the total number of plants per unit area and yield contributing parameters (Latif *et al*., 2010 and Aliyu *et al*., 2008).

Similar observations were reported by Latif *et al*. (2010), Jan *et al*. (2003), Sikder *et al*.(2010), Dorcas *et al*. (2012) and Mahadeen (2008) who reported that maximum marketable bulb yields of onion were obtained at lower intra-row spacing. Islam *et al.* (1999) and Naik and Hosamani (2003) also stated that maximum bulb yield of onion was recorded in treatment combination of narrow intra-row spacing and optimum nitrogen fertilizer level. Similarly, Soleymani and Shahrajabian (2012) and Balemi *et al*. (2007) also showed that the higher value of marketable yield was achieved under higher rate of nitrogen fertilization (120 kg ha^{-1}).

4.7 Number of flowers per umbel

Number of flowers per umbel is one of the most important yield contributing characters in onion seed production. Spacing had a significant variation on the number of flowers per umbel. The highest number of flowers per umbel (235.50) was recorded in S_3 and the lowest (216.40) in S_1 (Table 5).

However, there was significant variation in the number of flowers per umbel due to the application of fertilizer. Numerically maximum number of flowers per umbel (234.40) was obtained from T_2 treatment, which was statistically similar with T_3 and the minimum (222.10) was obtained in T_0 treatment (Table 6).

Interaction effects of different spacing and different level of fertilizer had a significant variation on number of flowers per umbel. The highest number of flowers per umbel (240.60) was obtained from S_4T_2 treatment, which was statistically similar with S_3T_2 S_4T_3while, the minimum (209.80) from S_1T_0 combination (Table 7).

4.8 weight of seeds per plant (g)

The weight of seeds per plant was significantly affected by spacing. The highest weight of seeds per plant (2.34g) was recorded in $S_{3,}$ which was statistically similar with S_4 and S_2 and the minimum (1.55g) in S_1 (Table 5).

Table 5. Main effects of spacing on the seed yield of onion

Treatment	Number of flowers per umbel	Weight of seeds per plant	1000-seed weight	Seed yield (kg/ha)
S_1	216.40 b	1.55 b	3.14 c	394.90 a
S_2	230.60 a	2.16 a	7.89 b	361.10 b
S_3	235.50 a	2.34 a	9.67 ab	348.00 bc
S_4	234.60 a	2.27 a	10.92 a	338.80 c
LSD(0.05)	8.32	0.01	2.75	18.67
CV (%)	6.25	10.12	5.48	7.09

S_1= 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm

Table 6. Main effects of Fertilizers on the seed yield of onion

Treatment	Number of flowers per umbel	Weight of seeds per plant	1000-seed weight	Seed yield (kg/ha)
T_0	222.10 b	1.66 c	6.44 b	352.00 b
T_1	228.60 ab	2.04 b	7.39 ab	362.80 ab
T_2	234.40 a	2.42 a	9.14 a	374.30 a
T_3	232.00 a	2.20 ab	8.64 ab	353.60 b
LSD(0.05)	8.72	0.38	2.62	19.38
CV (%)	6.25	10.12	5.48	7.09

T_0 = No application (control), T_1 = $N_{60}P_{30}K_{80}S_{20}$ kg/ha, T_2 = $N_{80}P_{50}K_{100}S_{30}$ kg/ha T_3 = $N_{100}P_{70}K_{120}S_{40}$ kg/ha

Table7. Combined effects of spacing and fertilizer on seed yield and number of leaf per plant of onion

Treatment	Number of flowers per umbel	Weight of seeds per plant	1000-seed weight	Seed yield (kg/ha)
S_1T_0	209.80 e	1.12 f	2.27 g	379.60 b
S_1T_1	214.90 de	1.45 ef	2.77 g	397.40 a
S_1T_2	222.00 b-e	1.91 cd	4.27 fg	404.20 a
S_1T_3	218.90 c-e	1.73 de	3.27 g	398.30 a
S_2T_0	222.90 b-e	1.79 de	5.97 ef	353.50 cd
S_2T_1	230.20 a-c	2.07 b-d	7.97 de	366.60 bc
S_2T_2	235.70 ab	2.53 a	9.37 cd	397.50 a
S_2T_3	233.70 ab	2.25 a-c	8.27 d	326.70 f
S_3T_0	231.80 a-c	1.95 cd	8.27 d	341.40 d-f
S_3T_1	234.40 ab	2.37 ab	9.17 cd	348.70 de
S_3T_2	239.10 a	2.61 a	10.97 abc	352.20 d
S_3T_3	236.50 ab	2.42 ab	10.27 bcd	349.70 d
S_4T_0	224.10 b-d	1.79 de	9.27 cd	333.40 ef
S_4T_1	234.90 ab	2.27 a-c	9.67 cd	338.70 d-f
S_4T_2	240.60 a	2.62 a	12.77 a	343.20 de
S_4T_3	238.80 a	2.38 ab	11.97 ab	339.70 d-f
LSD(0.05)	55.51	0.35	2.08	13.61
CV (%)	6.25	10.12	5.48	7.09

In a column same letter(s) do not significantly differ at 0.05 level of probability.

S_1= 20cm×15cm

S_2 = 25cm×15cm

S_3 =20cm×20cm

S_4 = 25cm×20cm

T_0 = No application (control)

$T_1 = N_{60}P_{30}K_{80}S_{20}$ kg/ha

$T_2 = N_{80}P_{50}K_{100}S_{30}$ kg/ha

$T_3 = N_{100}P_{70}K_{120}S_{40}$ kg/ha

There was significant variation in the weight of seeds per plant due to the different levels of fertilizer. The maximum weight of seeds per plant (2.42g) was obtained from T_2 treatment and the minimum (1.66) was from T_1 treatment (Table 8).

Interaction effects of different spacing and application of fertilizer had a significant effects on weight of seeds per plant. The highest weight of seeds per plant (2.62g) was obtained from S_4T_2 treatment while the lowest (1.12g) from S_1T_0 (Table 8).

4.9 1000 seed weight

Thousand seed weight of onion differed significantly due to spacing. The highest thousand seed weight (10.92 g) was obtained from S_4 and the minimum (3.14 g) from S_1 treatment (Table 5).

There was significant variation in the thousand seed weight due to the application of fertilizer. The maximum thousand seed weight (9.14) was obtained from T_2 treatment and the minimum (6.44 g) from T_0 (Table 6).

Combined effects of different spacing and application of fertilizer had a significant variation on thousand seed weight. The highest thousand seed weight (12.77 g) was obtained from S_4T_2 treatment while the lowest (2.27 g) from S_1T_0 combination (Table 7.

4.10 Seed yield (kg ha $^{-1}$)

The seed yield per hectare was significantly affected by spacing (Table 8). The maximum seed yield per hectare (394.9) was observed in S_1. The lowest yield per hectare (338.80 kg) was observed from S_4 (Table 5).

There was significant variation in the seed yield per hectare due to the application of fertilizer. The maximum seed yield per hectare (374.30 kg) was obtained from T_2 treatment and the minimum (352.00) was obtained in $T_.$ treatment (Table 6).

Combined effects of different spacing and application of fertilizer had a significant on seed yield per hectare. The highest seed yield per hectare (404.20) was obtained from S_1T_2 treatment while the lowest (379.60 ton) from S_0T_0 combination (Table 7).

CHAPTER- 5

SUMMARY AND CONCLUSION

A field experiment was conducted in the field of Sher-e - Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2017 to April 2018 to find out the effects of growth and seed yield of onion influence by plant density and fertilizer amendment. The experiment consisted of four levels of spacing (viz. S_1 = 20cm×15cm, S_2 = 25cm×15cm, S_3 =20cm×20cm, S_4 = 25cm×20cm) and four levels of fertilizer (viz. T_0 = No application (control), $T_1 = N_{60}P_{30}K_{80}S_{20}$ kg/ha, $T_2 = N_{80}P_{50}K_{100}S_{30}$ kg/ha, and $T_3 = N_{100}P_{70}K_{120}S_{40}$ kg/ha). The two-factor experiment was carried out in Randomized Complete Block Design (RCBD) with three replications. There were 16 treatment combinations in this study. A unit plot was 1.0 m×1.2 m and the treatments were distributed randomly in each block. Data on growth and yield parameters were recorded and analyzed statistically. The differences were evaluated by Duncans Multiple Range Test (DMRT).

Spacing had significant effects on the growth and seed yield contributing characters of onion. The highest plant height (48.87) was obtained from S_1 (20cm×15cm) treatment. The highest number of leaves (6.40), diameter of bulb (4.07 cm), length of bulb (4.42 cm) and weight of blub per plant (50.88 g) were obtained from spacing 25cm×20cm (S_4). The highest (1.87 kg/plot and 15.56 t/ha, respectively) yield was obtained from S_1 (20cm×15cm) treatment. The highest number of flowers per umbel (235.50) was recorded in $S_{3.}$ The highest weight of seeds per plant (2.34g) was recorded in $S_{3.}$ The highest thousand seed weight (30.92 g) was obtained from S_4 treatment. The maximum seed yield per hectare (394.9) was observed in S_1. The lowest yield per hectare (338.80 kg) was observed from $S_{4.}$

Fertilizer has significant effects on the growth and seed yield contributing characters of onion. The highest plant height (5.80cm), number of leaves

(6.55), diameter of bulb (3.95 cm), length of bulb (4.24 cm) and weight of blub per plant (51.47 g), were obtained from application of $N_{80}P_{50}K_{100}S_{30}$ kg/ha (T_2). The highest (1.99 kg/plot and 16.57 t/ha, respectively) yield was obtained from T_2 ($N_{80}P_{50}K_{100}S_{30}$ kg/ha) treatment. The maximum number of flowers per umbel (234.40) was obtained from T_2 treatment. The maximum weight of seeds per plant (2.42g) was obtained from T_2 treatment. The maximum thousand seed weight (29.14) was obtained from T_2 treatment. The maximum seed yield per hectare (374.30 kg) was obtained from T_2 treatment and the minimum (352.00) was obtained in T_0 treatment.

Combined effects of spacing and fertilizer levels produced significant variation in respect of yield and seed yield contributing characters. The highest plant height (54.70cm) was obtained from S_1T_2 (20cm×15cm and $N_{80}P_{50}K_{100}S_{30}$ kg/ha) treatment. The highest number of leaves (8.22), diameter of bulb (5.03cm), length of bulb (5.66 cm) were obtained from the treatment combination of S_4T_2 (25cm×20cm and $N_{80}P_{50}K_{100}S_{30}$ kg/ha) treatment.. The highest (2.16 kg/plot and 17.97 t/ha, respectively) yield of bulb was recorded from the treatment combination of S_1T_2 (20cm×15cm spacing with $N_{80}P_{50}K_{100}S_{30}$ kg/ha). The highest number of flowers per umbel (240.60) was obtained from S_4T_2 treatment. The highest weight of seeds per plant (2.62g) was obtained from S_4T_2 treatment. The highest thousand seed weight (32.77 g) was obtained from S_4T_2 treatment. The highest seed yield per hectare (404.20 kg) was obtained from S_1T_2 treatment while the lowest (379.60 ton) from S_0T_0 combination.

Conclusion:

In considering the above results of this experiment, further studies in the following conclusion and recommendation can be drawn

- ❖ The (20cm×15cm) Spacing gave highest seed yield of onion.

- ❖ Combination of 80 kg nitrogen + 50 kg phosphorus + 100 kg potassium + 30 kg sulphur (T_2) treated plants gave highest growth and seed yield of onion bulb.

However, from the present study it may be concluded that, the most suitable combination for a higher yield of onion cv. BARI Peaj-1 was S_1 (20cm×15cm) with T_2 ($N_{80}P_{50}K_{100}S_{30}$ kg/ha).

The study was conducted under AEZ NO 28. So such type of trail may be studied in different agrological zones of Bangladesh for final recommendation.

REFERENCES

Abdissa, Y., Tekalign, T. and Pant, L.M. (2013). Growth, bulb yield and quality of onion (Allium cepa L.) as influenced by nitrogen and phosphorus fertilization on vertisol I. growth attributes, biomass production and bulb yield. School of Plant Sciences, College of Agriculture and Environmental Sciences, Haramaya University, Australian J. Crop Sci. 7(9): 1416-1422.

Akoun, J. (2005). Effects of plant density and manure on the yield and yield components of the common onion (Allium cepa L.) var. Nsukka red. *Nigerian J. Hort.. Sci. ,* **9**:43-48.

Aliyu, U. Dikko, A.U. Magaji, M.U. and Singh, A. (2008). Nitrogen and intra-row spacing effectss on growth and yield of onion (*Allium cepa* L.). *J. Plant Sci.*, **3**(3): 188-193.

Amin, M.M.U., Hashem, M.A. (1995). Influences of planting time and nitrogen on the growth and yield of onion. *Bangladesh J. Sci. and Ind. Res*. **30**(2-3): 275-279.

Anonymous. (2001). Effects of nitrogen and irrigation on the growth and yield of onion. Research Report of Spices Research Centre, Bangladesh Agricultural Research Institute, Bogra. pp. 51-53.

Ansary, S.H., Choudhury, J. and Sarar, S. (2006). Post-harvest studies of onion (*Allium cepa* L.) grown under different moisture regimes and fertilizer levels. Crop Res. Hisar. 31(3): 404-407.

Ansary, S.H., Choudhury, J. and Sarar, S. (2006). Post-harvest studies of onion (Allium cepa L.) grown under different moisture regimes and fertilizer levels. Crop Res. Hisar. 31(3): 404-407.

Anwar, M.N., Huq, M.S., Sarker, M.J.U., Hoque, A.K.M.S. and Islam, M.S. (1998). Influence of nitrogen, phosphorus, potassium, sulphur and zinc on onion. *Bangladesh J. Agril. Res*. **16**(2): 181-186

Badaruddin, M. and Haque, M. A. (1997). Effects of time of planting and spacing on the yield of onion (*Alium cepa* L.). Bangladesh Hort., **5** (2): 23–29.

Balemi, T.P Netra and Anil, S.A. (2007). Response of onion (Allium cepa L.) to combined application of biological and chemical nitrogenous fertilizers. Acta agriculture Slovenica, **89**(1):107-114.

Brady, N.C. (1985). The nature and properties of soils. Ninth Edition. Macmillan, New York.

Dixit,S.P. (1997). Response of onion (*Allium cepa* L.) to nitrogen and farmyard manure in dry temperate high hills of Himachal Pradesh. *Indian J. Agril. Sci*. 67(5): 222-223.

Dorcas, A.O.A. Magaji, M.D. Singh, A. Ibrahim, R. and Siddiqu,Y. (2012). Irrigation scheduling for onion (Allium cepa L.) at various plant densities in a Semi-Arid environment. UMT 11thInternational Annual Symposium on Sustainability Science and Management, Terengganu, Malaysia.

Girigowda, J.R., Narasegowda, N.C. and Krishna, H.C. (2005). Effects of fertilizer levels on uptake of primary nutrients and bulb yield of onion hybrids. *Mysore J. Agric. Sci*. 39(4): 557-560.

Haque, M.I., Zaman, M.M., Hasan, M.K., Begum, M. and Pervin, F. (2004).Growth and yield of onion as influenced by nitrogen and irrigation. *J. Agric. Rural Dev*. **2**(1): 151-153.

Harun-or-Rashid, A.R.M. (1998). Effects of NPKS on the growth and yield of onion at different plant spacing. M. S. thesis, Dept. Hort., Bangladesh Agril. Univ., Mymensingh. p.72.

Huque, M.F. (2008). Effects of spacing and potassium on the growth and yield of summer onion (*Allium cepa*). M. S. (Ag.) thesis, Department of Horticulture, SAU, Dhaka.

Islam, M.Z. (2007). Effects of combined application of vermicompost and fertilizers on the yield of summer onion. M. S. (Ag.) thesis, Department of Soil Science, SAU, Dhaka

Islam, M.K. (1998). Effectss of set size, plant spacing and nitrogen levels on the growth and yield of onion cv. Taherpuri. M.S. Thesis, Dept. of Hort., BAU, Mymensingh. p.131.

Islam, M.K. Awal, M.A. Ahmed, S.U. and Baten, M.A. 1999. Effects of different set size, spacing and nitrogen levels on the growth and bulb yield of onion. *Pakistan J. Biological Sci*., **2**(4):1146.

Jan, N.E. Wazir, F.K. Ibrar, M. Mohammed, H. and Ali, A.R. (2003). Effects of different inter and intra-row spacing on the growth and yield of different cultivars of onion. Sarhad Journal of Agriculture, 19:4.

Jilani, M.S. Ghaffoor, A. Waseem, K. and Farooqi, J.I. (2004). Effects of different levels of nitrogen on growth and yield of three onion varieties. International *J.Agriculture and Biology*, **6**(3):507-510.

Jilani, M.S. Khan, M.Q. and Rahman, S. (2009). Planting densities effects on yield and yield components of onion (*Allium cepa* L.). *J. Sci. Agril. Res*., **47**(4):397-404.

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

Khan, H.B. Iqbal, M. Ghafoor, A. and Waseem, K. (2002). Effects of various plant spacing and different nitrogen levels on the growth and yield of Onion (*Allium cepa*.L). *J. Biological Sci*., **2**(8):545-547.

Khushk., A. M., Miano, N. M., Ansari, A. H., and Mari, M. I. (1990). Influence of inter and intra row spacing on the yield and the yield components on onion (*Alium cepa* L.). *Sarhad J. Agric.* **69** (2): 147-150.

Kumar, M., Chattopadhyay, T. K., Das, D. K. and Munsi, P. S. (1998). Effects of zinc and sulphur application on the yield and post harvest quality of onion (*Allium cepa* L.) under different methods of storage. *Indian. J. Interacademicia.,* **2** (3): 158-163.

Kumar, S., Sushant, R., Tiwari, C.P. and Singh, V. (2006). Bulb yield and quality of onion (*Allium cepa* L.) as affected by application rates of nitrogen and potassium fertilizer. *Agril. Sci. Digest*. 26(1):11-14.

Latif, M.A. Choudhury, M.S.H. Rahim, M.A. Hasan, M.K. and Pal, B.K. 2010. Effectss of spacing and age of seedling on the growth and yield of summer onion. *J. Agroforestry and Environment*, **3** (2):129-133.

Lee, J.T., Jong, I., Jung, L.C., Seong, M.J. and Cho, C.Y. (2003). Effects of N, P2O5 and K2O application rates and top dressing time on growth and yield of onion (Allium cepa L.) under spring culture in low land. *Korean J. Hort. Sci. Tech*. **21**(4):260-266.

Mahadeen, A.Y. (2008). Effects of planting date and plant spacing on onion (*Allium cepa*. L) yield under rain fed in Semi-Arid conditions of Jordan. Bull Faci. Agricultural, 59: 237-241.

Mandira, C. and Khan, A.H. (2003). Effects of nitrogen and potassium on growth, yield and yield attributes of onion. New- Agriculturist. 14(1/2): 9-11. ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra, West Tripura- 799210, India.

Mishu, H.M. (2008). Effects of sulphur fertilization on the growth and yield of onion.M.S. (Ag.) thesis, Department of Horticulture, BAU, Mymensingh

Mishu, H.M., Ahmed, F., Rafii, M. Y., Golam, F. and Latif, M. A. (2013). Effects of sulphur on growth, yield and yield attributes in onion (*Allium cepa* L.). Department of Crop Science, Faculty of Agriculture, Eastern University, Chenkalady, Sri Lanka

Mohanty, B.K. and Das, J.N. (2001). Response of rabi onion cv. Nasik Red to nitrogen and potassium fertilization. Vegetable- Science. University of Agriculture and Technology, Regional Research Station, Bhawanipatna 766001, Orissa, India. 28:1, 40-42.`

Morsy, M.G. Marey, R.A. Karam, S.S. and Abo-Dahab, A.M.A. (2012). Productivity and storability of onion as influenced by the different levels of NPK fertilization. *J. Agril. Res. Kafer El-Sheikh University*, 38(1):171-186.

Muhammad, A. Gambo, B.A. and Ibrahim, N.D. (2011). Response of onion (*Allium cepa* L.) to irrigation intervals and plant density in Zuru, Northern Guinea Savanna of Nigeria, *Nigerian J. Basic and Applied Sci.*, **19**(2):241-247.

Nagaich, K.N., Trivedi, S.K., Rajesh, L. and Lekhi, R. (1999). Effects of sulphur and potassium fertilization in onion (*Allium cepa* L.). *Horticultural J.*12(1):25-31.

Naik, B.H and Hosamani, R.M. (2003). Effects of spacing and nitrogen levels on growth and yield of Kharif onion. *Karnataka J. Agric. Sci.*, **16** (1):98-102.

Nasiruddin, K.M., Mondal, M.F., Farooque, A.M. and Baten, M.A.(1993). Effects of potassium and sulphur on growth and yield of onion. *Bangladesh J. Agric. Sci*. **20**(1): 35-40.

Rahman, M.Z. (2008). Effects of nitrogen and number of plants per hill on growth and yield of onion (*Allium cepa* L.). M. S. (Ag.) thesis, Department of Horticulture, SAU, Dhaka.

Rao, B.N. Roy, S.S. Jha, A.K. Singh, I. M. and Prakash, N. (2013). Influence of nitrogen and spacing on the performance of Alliuodorosum under mid-altitude foothill condition of Manipur. *Indian J. Farming*, 26(2):67-70.

Rashid, M.H.A. (2010). Effects of sulphur and GA3 on the growth and yieldof onion Department of Horticulture. Bangladesh Agricultural University. *Progress. Agric*. **21**(1 & 2): 57 – 63.

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

Rodriguez, S.N., Belmar, N.C. and Valenzuela, P.A. (1999). Effects of nitrogen, phosphorus and potassium rates, sources and forms upon onion (*Allium cepa* L.) bulb yield and quality. Agricultura Tecnica Santiago. 59(2): 122-132.

Santhi, R, Natesan, R. and Selvaumari, G. (2005). Effects of soil fertility and integrated plant nutrition system on yield, response and nutrient uptake by aggregatum onion. *Indian J. Agril. Res*. **39**(3): 231-216.

Seran, T.H., Srikrishnah, S. and Ahamed, M.M.Z. (2010). Effects of different levels of inorganic fertilizers and compost as basal application on the growth and yield of onion (*Allium cepa* L.). Department of Crop

Science, Faculty of Agriculture, Eastern University, Chenkalady, Sri Lanka.

Sharma, R.P., Datt, N. and Sharma, P.K. (2003). Combined application of nitrogen, phosphorus, potassium and farmyard manure in onion (Alliumcepa L.) under high hills, dry temperate conditions of north-western Himalayas. *Indian J. Agril. Sci*. **73**(4): 225-227.

Sikder, M. Mondal, F. Mohammed, D. Alam, M.S. and Amin, M.B. (2010). Effects of spacing and depth of planting on growth and yield of onion. *J. Agroforestry Environment*, **4** (2):105-108.

Singh, S., Yadav, P.K. and Singh, B. (2004). Effects of nitrogen and potassium on growth and yield of onion (*Allium cepa* L.) cv. Pusa Red. *Haryana J. Hort. Sci*. 33(3/4): 308-309.

Singh, A.K., Akhilesh, S. and Singh, A. (2003). Seed production of onion as influenced by potassium and its method of application. *Indian J. Horticulture*. 60(3): 287-289.

Singh, H., Singh, S. and Singh, V.(1996). Response of onion (*Allium cepa* L.) to nitrogen and sulphur. Ann. Agric. Res. **17**(4): 441-444.

Singh, R.P., Jain, N.K. and Poonia, B.L. (2000). Response of kharif onion to nitrogen, phosphorus and potash in eastern plains of Rajasthan. *Indian J. Agril. Sci.* **70**(12): 871-872.

Soleymani, A. and Shahrajabian, M. H. (2012). Effectss of different levels of nitrogen on yield and nitrate content of four spring onion genotypes. *International J. Agril. Crop Sci*, **4** (4):179-182

Tiwari, R.S., Ankur, A. and Sengar, S.C. (2003). Effects of bio regulators on growth, bulb yield, quality and storability of onion cv. Pusa Red. *Indian J. Plant Physiol*. 8(4): 411-413.

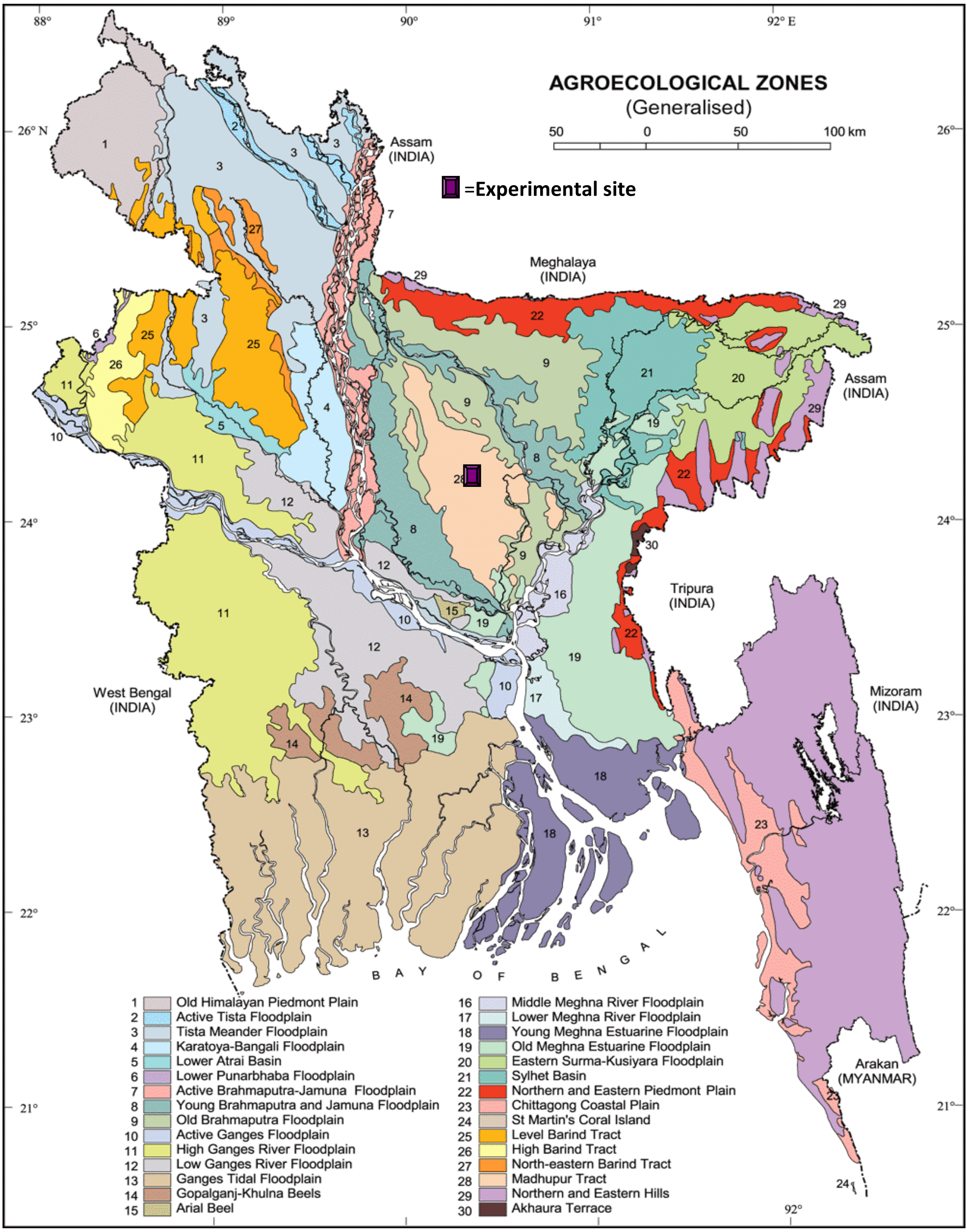
Ullah, M.H., Haq, S.M.I., Alam, M.D.U. and Rahman, M.A. (2004). Response of onion to nitrogen, phosphorus, and potassium fertilization. Bangladesh J. Agril. Res. 29(3): 431-436.

Vachhani, M.U. and Patel, Z.G. (1993). Growth and yield of onion (*Allium cepa* L.) as influenced by nitrogen, phosphorus and potash under South Gujratcondition. Prog. Hort. 25(3-4): 166-167.

Yadav, R.L., Sen, N.L. and Yadav, B.L. (2003). Response of onion to nitrogen, and potassium fertilization under semi-arid condition of Rajasthan. *Indian J. Hort*. **60**(2): 176-178.

APPENDICES

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



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

(0- 15 cm depth)

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

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

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