GROWTH AND SEED YIELD OF ONION AS INFLUENCED BY GA_3 AND PLANT SPACING

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CERTIFICATE

This is to certify that the thesis entitled *"GROWTH AND SEED YIELD OF ONION AS INFLUENCED BY GA3 AND PLANT SPACING"* ***submitted to Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of*** *MASTER OF SCIENCE (MS)* ***in*** *Seed Technology,* ***embodies the results of a piece of bona fide research work carried out by*** *Md. Saifur Rahman,* ***Registration. No.*** *12-05078* ***under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.***

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

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GROWTH AND SEED YIELD OF ONION AS INFLUENCED BY GA_3 AND PLANT SPACING

ABSTRACT

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during rabi (November, 2017 to March, 2018) to study growth and seed yield of onion as influenced by GA_3 and plant spacing .The experiment consisted of two factors. Factor A: Gibberellic acid management (4 levels) G_0= Control (0 ppm) G_1=80 ppm, G_2= 100 ppm, G_3= 120 ppm, and factor B: Spacing (3 levels) S_1: 30 cm ×10 cm, S_2: 30 cm ×15 cm, S_3: 30 cm × 20 cm were delineated in Randomized Block Design (RCBD) with three replications. The Taherpuri variety was used in this experiment as the test crop. There were 12 treatment combinations. Result showed that GA_3, plant spacing and their combination showed significant variation among the treatments on growth and yield parameters. In case of GA_3 the highest seed weight ha^{-1} (560.63 kg) was obtained from G_2 (100 ppm) where the lowest results on respected parameters were found from G_0 (Control) treatment. Regarding, plant spacing the highest seed yield ha^{-1} (439.98 kg) was attained from the treatment of S_2 (30 cm ×15 cm) where the lowest results on respected parameter was achieved from the S_1 (30 cm ×10 cm) treatment. In terms of combined effect of GA_3 and plant spacing, the highest number of seeds $plant^{-1}$ (3.37 g), highest seed yield $plot^{-1}$ (108.08 g) and highest seeds ha^{-1} (750.54 kg) were found from the treatment combination of G_2S_2 where the lowest results were obtained from the treatment combination of G_0S_1 per plant and G_0S_3 for per plot and per hectare. Among the treatment combination G_2S_2 (100 ppm with 30 cm×15 cm) seemed to be more suitable for getting higher seed yield in onion.

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LIST OF ACRONYMS

AEZ = Agro-Ecological Zone
BARI = Bangladesh Agricultural Research Institute
BAU = Bangladesh Agricultural University
BBS = Bangladesh Bureau of Statistics
CV% = Percentage of coefficient of variance
DAE = Department of Agricultural Extension
DAS = Days after sowing
et al. =And others
FAO = Food and Agriculture Organization
g = Gram
ha^{-1} = Per Hectare
kg = Kilogram
LSD = Least Significant Difference
Max = Maximum
mg = milligram
Min = Minimum
MoP = Muriate of Potash
N = Nitrogen
No. = Number
GA_3 = Gibberellic acid
NS = Not significant
SAU = Sher-e-Bangla Agricultural University
SRDI = Soil Resources and Development Institute
TSP = Triple Super Phosphate
wt. = Weight
% = Percent
^0C = Degree Celsius

CHAPTER I

INTRODUCTION

Onion (*Allium cepa* L.) rightly called as "queen of kitchen" is one of the oldest and an important spice crop grown in Bangladesh as well as in the world. It belongs to the family Alliaceae. According to Vavilov (1951) the primary center of origin of onion lies in central Asia. The near east and Mediterranean are the secondary centers of origin. The genus Allium is very large comprising of more than 500 plant species usually perennial bulbous plants. Out of these, *Allium cepa* (onion) is the major cultivated spice grown all over the world. Onion bulb provides vitamin C 19.7%, fiber 10.8%, molybdenum 10.6%, manganese 10.5%, vitamin B 69.5%, potassium 6.6%, and tryptophane 6.2%.Onions are very low in calories (just 40 cal^{-1} 100 g) and fats but rich in soluble dietary fiber. Onion is one of the most widely used vegetable due to its flavoring and food seasoning actions particularly at mature and immature bulb stages. Besides, it has been used for the manufacture of soups, ketchups, salads and pickles. To a lesser extent, it is used by the processing industries for dehydration in the form of onion flakes and powder, which are in great demand in the markets.

Spices are important constituents in preparation of food items in Bangladesh. A good number of spices crops are grown in Bangladesh. The major ones are onion, garlic, zinger, turmeric, coriander, chili, etc. The major onion producing countries like Korea Republic tops the list with bulb yield of 65.25 t ha^{-1} followed by USA 53.91 t ha^{-1}, Spain 52.06t/ha, Japan 47.55t/ha (FAO, 2008), whereas the productivity of onion in Bangladesh is 8.95 t ha^{-1} (AIS, 2011) which is remarkably lower than other onion producing countries due to lack of high yielding vigorus seed.

In Bangladesh, onion bulbs are grown almost in all districts and its cultivation in commercial scale is found in the greater Faridpur, Pabna, Jessore, Rajshahi, Dhaka, Mymensingh, Comilla and Rangpur (BBS, 2017).Onion ranks first in terms of production and second with respect to acreage amongst all spices grown and the total requirement was 680 thousand ton with a shortage of 290 thousand ton per year (BBS, 2017). However, to meet the demand of Bangladesh has to import onion bulb and seed every year from India and Pakistan at high cost of foreign currency (Hossain and Islam, 1994).The reason behind such low yield may possibly due to practice of

unimproved production technology, low quality seed, less number of umbel, poor flower development, unfavourable environment for onion growth.

Plant growth regulators (PGRs) are new generation agro chemicals and are expected to play an important role in overcoming the hurdles in manifestation of biological yield PGRs are used to overcome the factors that limiting the growth and yield to obtain maximum benefit. Growth regulators are considered as key factors for vegetative growth, flowering, fruit setting and seed production in plants including onion bulb yield.GA_3 at various concentrations had remarkable effects on bulb initiation, plant height, leaf production, bulb size and quality of onion (Habbasha *et al*., 1985). Exogenous application of growth regulators increases the seed yield. These growth hormones regulate the physiological processes and balance the source and sink, thereby increase the productivity and quality of many crop species.

On the other hand, the information on the effect of spacing on the growth and yield of onion is scanty. Proper spacing ensures optimum plant growth through adequate utilization of moisture, light, spacing and nutrients (Zubeldia and Gases, 1977).Planting of onion at optimum density gives the best economic return (Rashid and Rashid, 1976). Badaruddin and Haque (1977), Hoque *et al*. (1979), Gupta and Gaffer (1980), reported yield increased with the plant density up to a certain limit. Hoque *et al*. (1979) and Kumar *et al*. (1998) obtained the highest yield with a spacing of 20x10 cm, Gupta and Gaffer (1980) at 15x10 cm, Islam (1988) at 10x9 cm, Badaruddin and Haque (1977) at 10x30 cm and Rashid and Rashid (1976) at 20x10 cm with the single row system. On the other hand Rashid and Rashid (1976) also got the highest yield at 10x10 cm in a multiple row system. Singh and Jain (1984) observed that Patna Red onion planted at 10x30 cm spacing gave the highest yield ha^{-1} than those of 20x10 and 30x30 cm although wider spacing gave bigger and heavy bulbs.

However, information regarding the effectiveness of the combination of GA_3 and plant spacing on growth, seed yield of onion in Bangladesh condition is very limited. Therefore, the present experiment was undertaken to find out the effects of GA_3 and plant spacing on the growth, yield and quality of onion in Bangladesh.

Considering the above situation the present investigation was undertaken with the following specific objectives.

- To determine the effect of GA_3 on growth and seed yield of onion.
- To find the optimum plant spacing on the growth and seed yield of onion.
- To identify the combined effect of GA_3 and spacing on the growth and seed yield of onion.

CHAPTER II

REVIEW OF LITERATURE

Onion is an important spice as well as bulb crop grown all over the world. In Bangladesh, there are a little study on the influence of gibberellic acid and plant spacing on yield of onion seed. However, available literature and research findings related to the present study have been presented in this chapter.

Devi *et al*. (2018) reported that growth regulators are organic compounds other than nutrients, small amount of which are capable of modifying growth. Gibberellic acid and NAA are the important growth regulators which in little concentration stimulate growth and enhances yield. Gibberellin is such a compound that has gibbane skeleton and that stimulate cell division or cell elongation or both. NAA belongs to synthetic forms of auxins. It plays key role in cell elongation, cell division, vascular tissue differentiation, root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit setting and flowering. Onion is one of the important crop which gives good response to foliar application of GA_3 and NAA. The important principle like allicin, ajoene, allixine thiosulfnates and sulphites present in onion makes it a potential herb. There is a great need to increase the productivity of onion. Gibberellic acid when used for foliar spray, it increases the number of marketable bulbs in the total yield. Application of GA_3 @ 50 ppm increases plant height and improved leaf length and number of leaves per plant while GA_3 @ 100 ppm increases weight and volume of bulb. The highest bulb yield can be obtained with 200 ppm GA_3 followed by 200 ppm IAA. GA_3, NAA and combination treatments as pre-harvest foliar application have gained prominence.

Gebretsadik (2018) reported that Onion is important in the daily Ethiopian diet though the average yield obtained by farmers is very low. This is attributed to a number of constraints among which are poor agronomic practices. Therefore, field experiment was conducted at Tahtay Koraro district to study the effect of nitrogen fertilizer and intra-row spacing on growth and yield of onion. The treatments consisted of a factorial combination of four rates of nitrogen (0, 50, 100 and 150 kg N ha^{-1}) and four intra-row spacings (4, 6, 8, and 10 cm). Bombay Red was the variety of onion used in the experiment. The experiment was laid out as RCBD with three replications. The analysis of variance revealed that N and intra-row spacing were significant. Both N and intra-row spacing significantly affected percentage of Bolting plants, leaf length, bulb diameter and marketable yield.100 kg N ha^{-1} and a population of 833,300 plants $ha^{-1}$was found to be the optimum rate to obtain higher marketable bulb yield of 26.72 t ha^{-1} and economically attractive benefits. Therefore, the study concluded that Bombay red variety could be planted at an optimum spacing of 6 cm × 20 cm or 833,300 plant population density ha^{-1} in Tahtay koraro district of northern Ethiopia.

Ginoya (2018) was conducted at the Sagdividi Farm, Department of Seed Science and Technology College of Agriculture, Junagadh Agricultural University, Junagadh during rabi 2016-17 with an aim to study the effect of bulb size [B_1 (25 ± 5 g, small size), B_2 (50 ± 5 g, medium size) and B_3 (75 ± 5 g, large size)] and plant spacing [S_1 (30 cm × 30 cm), S_2 (30 cm × 40 cm), S_3 (45 cm × 30 cm), S_4 (45 cm × 40 cm), S_5 (60 cm × 30 cm) and S_6 (60 cm × 40 cm)] on seed yield and economics of onion seed production cv. Gujarat Junagadh White Onion 3 (GJWO 3). Significantly the highest seed yield per plant of 8.05 g and 7.55 g was obtained in the plants raised from the largest bulb size 75 ± 5 g (B_3) and at the spacing of 60 cm × 40 cm (S_6), respectively. Seed yield per hectare recorded

significantly high in largest bulb size (288.78 kg ha^{-1}) and in medium spacing of 45 cm × 30 cm (S_3) (435.09 kg ha^{-1}). The treatment combination $B_3 \times S_3$ (bulb size 75 ± 5 g planted at the spacing of 45 cm × 30 cm) produced the maximum seed yield per hectare (526.71 kg/ha). The highest gross return (421368 /ha) was obtained from the seed harvested from bulb size (75 ± 5 g) planted at a spacing of 45 cm ± 30 cm ($B_3 \times S_3$) and it was followed by ($B_3 \times S_1$) treatment combination (bulb size 75 ± 5 g and spacing (30 cm × 30 cm) with gross return 418496 ha^{-1}. The highest net return (288922 ha^{-1}) was obtained from the seed harvested from bulb size (75 ± 5 g) planted at a spacing of 45 cm × 40 cm ($B_3 \times S_4$) and it was followed by ($B_3 \times S_3$) treatment combination (bulb size 75 ± 5 g and spacing 45 cm × 30 cm) with net return 285245 ha^{-1}. The highest benefit cost ratio (3.39) was obtained from the seed harvested from bulb size (75 ± 5 g) planted at a spacing of 45 cm × 40 cm ($B_3 \times S_4$) and it was followed by ($B_3 \times S_6$) treatment combination (bulb size 75 ± 5 g and spacing 60 cm × 40 cm) with benefit cost ratio of 3.26.

Sarker *et al.*(2017*)* were undertaken to evaluate the effective planting method for onion production for motivating onion producing farmers in Faridpur region of Bangladesh during rabi season 2014-15 and 2015-16 at spices Research Su) b-centre, Faridpur. The number of treatment was four viz., Raised bed + Spices Research Centre (SRC) recommended practice, Raised bed + Farmer's practice, Flat method + Spices Research Centre (SRC) recommended practice and Flat method + Farmer's practice. The onion variety BARI Piaz-1 used as planting material. The SRC recommended practice consist of seed sowing at 2nd week of November + seedlings transplanting at the end of December + Spacing (10cm × 10cm) + Irrigation (4times) + weeding (four at 15, 25, 45 and 60 DAT) + Fungicide application with Rovral and Ridomil gold (four spray when disease appears) + Insecticide application (2-3 spray when/before thrips / insect appears)

+ Fertilizer doses (cow dung 5 ton ha^{-1}, N 120 kg ha^{-1}, P 54 kg ha^{-1}, K 75 kg ha^{-1} and S 20 kg ha^{-1}.On the other hand farmer's practice consist of seed sowing at last week of November in flat seed bed + seedling transplanting at 3rd week of January + Spacing (10cm × 7cm) + Irrigation (2-3 times) + Weeding (2times) + Fungicide application with Rovral, Score and other type of ineffective fungicide at 5-7 days interval + insecticide application with Confidor after thrips / insect appears + Fertilizer doses (N 46, P 45, K 30 and S 16 kg ha^{-1}). The results of the study revealed that planting method and management practices had significant impact on yield and yield attributes of onion and among the treatments the highest yield was found from Raised bed + SRC recommended practice. Significantly highest yield 14.42 t ha^{-1} in 2014-15 and 12.57 t ha^{-1} in 2015- 16 was recorded from SRC recommended practice. The lowest yield 8.05 t ha^{-1} in 2014-15 and 7.66 t h^{-1} in 2015-16 was recorded from Flat method + Farmer's practice. Therefore, the farmers of Faridpur region of Bangladesh are advised to adopt SRC recommended practice with raised bed method for increasing their annual average onion production.

Satish *et al. (*2017*)* were conducted at the Research Farm of College of Agriculture, Rewa (M.P.) during Rabi season of 2013-14. The study was conducted to investigate the Effect of various levels of nitrogen and planting distance on growth and seed yield of onion. For this study twelve treatment combinations were laid in factorial arrangement in randomized block design with four replications. Healthy bulbs with fairly uniform size of about 40-60g in weight were selected for planting. Four nitrogen levels (N_1-100 kg N ha^{-1}, N_2-120 kg N ha^{-1}, N_3-140 kg N ha^{-1} and N_4- kg N ha^{-1}) and three planting spacing (closest S_1- 60X10 cm, wider S_2-60X15 cm and widest S_3-60X20 cm) was considered in this experiment. The different nitrogen levels and planting distance had significant effect on growth parameters viz; plant height, number of leaves

per plant, days required for fifty percent flowering and seed yield per hectare. The results revealed that the highest plant height (66.77 cm), minimum number of days required for fifty percent flowering (81.63 days) and highest seed yield (17.153 q) per hectare was obtained from the higher dose of nitrogen (160 kg ha^{-1}, N_4) with the closest spacing of 60×10 cm (S_1), while maximum number of leaves per plant (59.52) was found with higher dose of nitrogen (160 kg ha^{-1}, N_4) and widest spacing of 60×20 cm (S_3). The maximum net returns and cost benefit ratio (C:B ratio) were obtained with nitrogen level @ 160 kg ha^{-1} (N_4) and with spacing level of 60x10 cm (S_1) followed by N @ 140 kg ha^{-1} (N_3) with same level of spacing. Hence, higher dose of nitrogen with closest plant spacing is suggested for onion seed production in Rewa district of Madhya Pradesh.

Renbomo *et al. (*2016) were undertaken to determine the effect of different plant and row spacing on growth and yield of onion. 8 different spacings were taken viz., 20x10 cm, 20x15 cm, 20x20 cm, 25x10cm, 25x15 cm, 25x20 cm, 30x10 and 30x15cm. Variety Nasik Red was used for the study. The results demonstrated that plant spacing had significant effects 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/ha was the highest (17.69 t ha^{-1}) at the closest spacing (20 x10cm) and the lowest (9.51 t ha^{-1}) was at widest spacing (30x15 cm).

Ahmad (2016) was conducted the gibberellic acid concentrations (0, 25, 50, 150, and 450 ppm) on stem length uniformity, umbel maturity, and seed quality and quantity of the onion cultivar Azarshahr were studied. The treatments were applied when the first flowering stems emerged. Results of ANOVA indicated that this growth regulator had its greatest effects on the mentioned characteristics

at 50 and 150 ppm, and that seed yield increased by about 25% through application of gibberellic acid at 50 ppm. However, in all, concentrations of 50, 150, and 450 ppm had the same level of effects. The effects of these treatments on the average number and length of emerged stems and on the time of umbel maturity were not significant, but the treatments had significant effects on seed quality and treated plants had higher percentages of normal seedlings and greater dry weights

Debashis *et al. (*2016*)* were conducted at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, West Bengal for consecutive two years during rabi seasons of 2012 and 2013 to study the influence of bulb size and date of planting on quality seed yield and economics of onion.In this experiment, two different factors were considered, factor: (P) three levels of planting time viz., 15th October, 30th October and 15th November; (B) three levels of bulb size viz, small (≤50g), medium (51- 65g) and large (66 -75g). The experiment consisting of nine treatments combination was laid out in "Factorial Randomized Block Design" with three replications. The results of over two years of experimentations revealed that 15th November planting of mother bulb exhibited significantly increased the vegetative characteristics viz, plant height (64.58 cm), number of leaves (41.85); flower and umbel characteristics viz., number of flower stalks per plant (3.86) and number of seeds per umbel (727.13); yield characteristics viz., seed yield per plant (9.58g) and seed yield per hectare (8.66q); quality characteristics of freshly harvested seeds viz, germination (92.92%) as compared to other date of planting. Regarding size of bulb, planting of large size bulb produced significantly better results in all the characteristics under the study than other medium and small size bulb. From economic point of view, the combination of large mother bulb planted in 15th November was most

suitable for quality seed production of onion cv. Sukhsagar under New Alluvial Zone of West Bengal.

Ali *et al.* (2015) conducted an experiment at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur during the year 2011 to 2012.The purpose of the study was to evaluate the performance of different doses of GA_3 on quality seed production of onion (CV. Taherpuri). The field experiment was laid out in Randomized complete Block Design (RCBD) with three replications. Bulbs were planted on November 16, 2011. The depth of planting was 5 cm from the surface of the soil. There were four different treatments viz. G_0 (0 ppm), G_1 (50 ppm), G_2 (100 ppm), G_3 (150 ppm) was sprayed at 45 and 60 days after planting. The seeds were harvested by cutting off the umbels when about 15-30% of the heads had black seeds exposed. After harvesting, the umbels were dried in scorching sun light for 3-4 days and then threshed manually. After threshing, seeds were cleaned and dried properly and kept in polyethylene bags, which were stored properly at room temperature. Data were recorded from randomly selected ten plants from each plot and their averages were taken for treating as per plant. In laboratory Thousand Seed weight, Germination and Electrical conductivity of the seeds were measured.GA_3 influenced the seed yield and quality of onion. Higher doses were more effective and showed a linear relationship in plant growth and seed yield of onion. The highest seed yield (1576.67 kg ha^{-1}) was obtained with application of 100 ppm GA_3.The present study clearly shows that almost all the plants treated with GA_3 performed better than control.GA_3 application significantly varied the scape length, umble diameter, seed yield per plant, thousand seed weight, germination percentage and electrical conductivity. However, application of Gibberellic acid has a positive impact on growth and seed yield of onion.

Frappell (2015) was experimented to study some effects of plant spacing on main crop onion production were carried out at Forthside Vegetable Research Farm, near Devonport, Tasmania over three consecutive seasons, using the cultivar Pukekohe Long Keeper. The yield-density relationship ω-θ = x+ßp (where ω = weight/plant, ρ = density and α, ß and θ are parameters) adequately described the data with θ = 1.0, i.e. this relationship was asymptotic. The value of α was found not to vary between seasons, whereas the value of ß varied. Some effects of plant arrangement were significant, and at 65 plants m-2; a rectangularity of 8:1 (inter-row spacing 360 mm × average intra-row spacing 43 mm) resulted in a yield reduction of 10 % compared with a square plant arrangement. At all densities there was a range of bulb sizes produced, and as density increased there was a progressive shift of the modal size grade to smaller grades.

Kumar *et al.(*2014) were conducted an investigation which was undertaken at Horticulture farm, Institute of Agriculture, Visva-Bharati University, West Bengal (India) during winter (robi) season from September 2012 to March 2013 to study the effect of nitrogen and spacing on growth and yield of onion. The experiment consisted of nine treatment combinations with three levels of nitrogen (100, 150 and 200 kg ha^{-1}) and three levels of spacing (10 cm x 10 cm, 15 cm x 10 cm, 15 cm x 15 cm). The experiment was laid out in randomized complete block design in factorial arrangement with three replications. Results of the experiment reviled that application of 200 kg N ha-1and 15cm x 15 cm produced the highest results for plant height, number of leaves, Bulb polar and equatorial diameter. Among combinations of different levels of nitrogen and spacing, application of 150 kg N ha^{-1} along with spacing of 15cm x 10cm was found to be the best combination in enhancing the onion yield (37 t/ha) with maximum (2.84) benefit cost ratio.

Rasid (2010) was conducted an experiment at the Horticulture Farm of the Bangladesh Agricultural University, Mymensingh to evaluate the effects of

sulphur and GA_3 on 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 GA_3 viz., 0 (control), 50, 75, 100 ppm. The experimental findings revealed that sulphur and GA_3 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. Most of the parameters showed increasing trend with the higher concentration of GA_3. Application of GA_3 @ 100 ppm gave the maximum bulb yield (15.23 t/ha), while the minimum value (10.10 t/ha) was observed from control. Almost all the parameters were significantly influenced by combined treatments of sulphur and GA_3 except bulb length of onion. 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 100ppm GA_3,while the minimum bulb dry matter content (9.23%) and bulb yield (9.33 t/ha) were recorded from control treatment of sulphur with GA_3.

Sikder *et al.* (2010) were conducted at the Horticulture farm of Bangladesh Agricultural University, Mymensingh during the period from October 2001 to January 2002 to study the effects of spacing, and depth of planting on the growth and yield of two varieties of onion. There were three levels of plant spacing (viz., 20cm × 20cm, 20cm × 15cm and 20cm × 10cm) and two levels of depth of planting (viz., 2cm and 4cm). The experiment was laid out in RCBD with 3 replications. The plant spacing showed significant effects 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^{-1}). Bulb yield was significantly higher at lesser depth of planting. The combined effect 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^{-1}) compared with other treatment combinations.

Asaduzzaman *et al.* (2010) were conducted at the `Research Farm` of Regional Seed Production Office of Lal Teer Seed Limited, Dinajpur, Bangladesh during November 2008 to April 2009. The study was conducted to investigate the effect of bulb size and planting spacing on seed production of cultivar Taherpuri onion. Three bulb sizes [small (5±2g), medium (10±2g), and large (15±2g)] and four planting spacing [closest 25×15, closer 25×20, wider 30×15, and widest 30×20cm] was considered in this experiment. Number of flowering stalks, length of flowering stalks, number of umbels per plant, number seeded fruits, seed weight per umbel, 1000-seed weight and seed yield per hectare were measured to assess the onion seeds. The results revealed that the highest seed yield (776.67 kg) per hectare was obtained from the large bulb (15±2g) with the closest spacing of 25×15cm followed by small bulb size of same spacing. The maximum number of flowers per umbel (371.39), seed weight per umbel (0.80g) and 1000-seed weight (3.92g) were obtained from the largest bulb size (15±2g) with widest (30×20cm) planting spacing. Hence, large bulb size with closest plant spacing is suggested for onion seed production in northern part of Bangladesh.

Mosleh *et al.(*2009) conducted a research in which cell size and mitotic index were decreased with increasing concentrations of growth regulators such as GA3, uniconazole, chlorocholine chloride (CCC) and 2,3,6-TBA while nuclear volume, interphase chromosome volume and abnormalities were found to increase during division of onion root tip cells. Formation of chromosome fragments, bridges, laggards, single and multiple chromatid bridges, irregular distribution and unequal separation of chromosomes were visualized as the main effects due to the

application of these growth regulators. Radiomimetic action of growth regulators such as hormones have been demonstrated by several workers (Prasad and Das 1977, Bebars 1987, Barrett and Nell 1992). Some of the growth regulators are used as growth promoters while others as growth retardants and herbicides. Uniconazole and CCC are plant growth retardants belonging to a group of triazoles. There is a little retarding effect of 2, 3, 6-TBA while GA_3 stimulates growth. Growth retardants are diverse in nature and have the common physiological effect of reducing stem growth by inhibiting cell division of the subapical meristem.

Geetharan *et el*. (2008) were carried out to study the effect of growth regulators and nutrients on onion seed production. Among the sprays, spraying of NAA (100 ppm) at first flower stalk emergence and second spray at 10 per cent flowering stage (i.e. 35 and 45 DAP) enhanced seed recovery and yield by 22.7 per cent. The improvement of seed germination and vigour index due to NAA over control was 16 and 55 per cent, respectively. The performance of GA_3 (100 ppm) as foliar spray was found to be the next best. The seed protein content was also 7 per cent higher in NAA (100 ppm) and GA_3 (100 ppm) spray treatments compared to the unsprayed plots. Panchagavya (3 %) spray caused scorching of flower stalk which reduced the formation of new umbellets.

Mondol *et al*. (2005) were conducted to evaluate the effects of three sizes of sets viz., small (2.25g), medium (5.5g) and large (9.00g), and five growth regulators, namely IAA (200 ppm), GA_3 (100 ppm), NAA (200 ppm), CCC (500 ppm) and a control on the growth and yield of onion cv. Taherpuri. Large bulb produced the highest bulb yield (12.86t ha-1) by increasing plant height, number of leaves per plant, bulb diameter and mean bulb weight. Smaller bulb produced higher proportion of single bulbs (62.53%) than larger ones. The growth regulators significantly increased the bulb yield compared with control treatment.

Application of IAA at 200 ppm gave the best results on all the parameters except plant height. The highest bulb yield was recorded as 12.57t ha-1 from the plants sprayed with IAA at 200 ppm. The interaction effect of bulb size and growth regulators was not significant. The combined treatment of large bulb x IAA gave rise to the highest bulb yield (14.23t ha-1). The highest gross income (TK.3, 13, 060 ha-1) and net return (TK. 1, 67, 445 ha-1) were obtained from the treatment combination of large bulb x IAA and large bulb x NAA. But the highest benefit cost ratio (2.52) was found in the treatment combination of small bulb x NAA. The effects of growth regulators were found in order of IAA>GA3>NAA>CCC.

Subimal *et al.*(2004) conducted a research in which GA3, and NAA each with three different doses (200, 300 and 400 ppm of NAA and 20, 40 and 60 ppm of GAJ. and each cbe MIS applied through three different methods (soaking of seeds for 8 hours, seedIing toot dipping for 18 hours and foliar spray).A11 the treated plants produced higher bulb diameter than c:ontrclI (no PGR) treatment whereas bulb length did not differ total Yield and marketable bulb yield.(uch ... weighing > 20 gram) of bulbs were positively influenced by the application of GA3 spec" in root dipping treatments.

Khan *et al.(*2003) were undertaken to determine the effect of spacing on onion cultivation of different varieties. Different spacings were taken 20x10 cm, 15x10 cm, 10x10 cm, 15x7.5 cm, 10x7.5 cm and 7.5x7.5 cm. Three varieties viz BARI Piaz-1, Taherpuri and Faridpur Bhati were used for study. Significantly wider spacing produced higher size of plant height, leaf length and number of leaves. Bulb length, diameter and weight also the same trend in wider spacing. The weight of individual bulb of onion (23.52 g) was increased with the widest spacing (20x10 cm). On the contrary, yield ha–1 was the highest (16.65 t ha–1) at the closest spacing (7.5x7.5 cm) and the lowest (10.05 t ha–1) was at widest spacing (20x10 cm). But in closer spacing, bulb size was so small that was not

suitable for the choice of consumer. On the other hand wider spacing produced the highest percentage (24.34%) multiplier bulbs that was not better for storing and consumers demand. So, in respect of economic point of view 15x10 cm spacing recommended in onion cultivation. It was found BARI Piaz-1 performed better in respect of yield and other parameters.

Abdul *et al.* (2002) conducted an application of gibberellic acid (GA_3) and indoleacetic acid (IAA) increased the root number, root length and root weight, bulb diameter and bulb weight of onion. The highest bulb diameter and bulb weight was found at 200 ppm each of GA_3 and IAA. Better increase in bulb diameter and bulb weight was achieved by the double dose than single dose. Application of GA_3 and IAA increased the bulb yield. The highest bulb yield (15.57 t ha-1) was observed at 200 ppm GA_3 followed by 200 ppm of IAA (15.53 t ha-1). In conclusion, the yield contributing characters and yield of onion could be manipulated by the application of GA_3 and IAA.

Shaikh *et al.* (2002) were carried out during rabi 2000 to evaluate the performance of three different size bulbs viz., large (>60g), medium (30-60g) and small (<30g) and five growth regulators each with two concentrations viz., GA_3 (25 and 50 ppm), miraculan (1000 and 2000 ppm), NAA (100 and 200 ppm), MH (10 and 20 ppm) and CCC (500 and 1000 ppm) and one control. The size of the mother bulb had significant effect on growth and yield parameters. Large size bulbs gave significantly higher plant height, number of leaves/plant, umbels/plant, umbel diameter,seed weight/umbel,seed yield/plant and per hectare,seed germination and seedling vigour over other sizes. Among the growth regulators,GA_3 50 ppm or miraculan 2000 ppm or MH 20 ppm sprayed at 30 DAP gave higher seed yield, germination and vigour values. Among the interaction, the large or medium size bulbs sprayed with GA_3 50 ppm or miraculan 2000 ppm or MH 20 ppm gave

significantly higher seed yield/ha, germinability and vigour values compared to other combinations.

Henry (1985) reported that uniconazole reduced plant height by inhibiting GA_3 biosynthesis. Coolbaugh and Hamilton (1976) showed that ancymidol (a growth retardant) also inhibited gibberellin biosynthesis. In this context it is necessary to study the comparative effects of different growth regulators under identical condition. Therefore, the aim of this work was to study the comparative effects of four growth regulators at different concentrations on cell division using onion root tip cell. A local variety of onion called "Taherpuri" was used as experimental materials and four growth regulators, namely Gibberellic acid-GA_3 (growth promoter), uniconazole (growth retardant), chlorocholine chloride (CCC, growth retardant) and 2,3,6-trichlorobenzoic acid-2,3,6 (TBA, growth retardant and herbicidal) were used. Each growth substance was applied at five different concentrations such as 100, 150, 200, 250 and 300 ppm. During the treatment the bulbs of onion were placed on the mouth of each specimen tubes until the roots grew up to 1.0 to 1.5 cm in length. One tube was filled with water as control. Root tips were collected and fixed in 1:3 acetic acid-alcohol for 48 hours and stored in 70% ethanol in a refrigerator. Chromosomes were stained with 0.5% haematoxylin following the method of Haque et al. (1976). The nuclear volume (NV) was calculated using the formula as suggested by Nayar *et al.* (1971). The recorded data were analyzed statistically following MSTAT-C package program. The comparative effects of four growth regulators on cell (differentiated) size, interphase chromosome volume (ICV), mitotic index and chromosome abnormalities are shown in Table 1 and Figs. 1-5. The mean data revealed that highest dose (300 ppm) of uniconazole produced lowest cell size and mitotic index while highest value of ICV and chromosomal abnormalities were observed compared to control and other growth regulators used.

Zee (1978) was conducted where GA_3 applied as a foliar spray on the Chinese flowering cabbage at 20 ppm, 10 days after transplanting, significantly enhanced the growth of the crop; but the transplanting date of the Chinese flowering cabbage has to be at about 20 days. Late transplanting, with or without GA_3 treatment, not only retarded the growth of the crop but also induced premature bolting of plants.

CHAPTER III

MATERIALS AND METHODS

A field experiment was conducted to study the effect of Gibberellic acid (GA_3) and spacing on the growth and seed yield of onion during the period from 20 November, 2017 to 20 April, 2018. The details of the experimental materials and methods used in this experiment have been described below:

3.1. Site Description

3.1.1. Geographical Location

The research work was conducted at the Central farm of Sher-e-Bangla agricultural University, Sher-e-Bangla Nagar, Dhaka-1207.The experimental area was situated at 23°77´N and $90^0$35´E longitude at an altitude of 8.6 meter above the sea label.

3.1.2. Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur tract leaving small hillocks of red soils as "islands" surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3. Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace soils under Tejgaon series. Soil pH was 7.1 and had organic matter 1.08%. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depth were collected from experimental fields. The soil analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The chemical properties of the soil are presented in Appendix II.

3.1.4. Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details of the metrological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar and presented in Appendix III.

3.2. Planting Materials

The research work was conducted with the onion bulb of Taherpuri variety. The average weight of the bulb is 8-10 g.

3.3. Experimental Details

3.3.1. Treatments

The experiment comprised as two factors.

Factor A: GA_3 (Four levels of GA_3)

i. G_0: Control
ii. G_1 : 80 ppm
iii. G_2 :100 ppm
iv. G_3 : 120 ppm

Factor B: **Plant Spacing (Three levels of spacing)**

i. S_1 : 30 cm ×10 cm
ii. S_2 : 30 cm ×15 cm
iii. S_3 :30 cm ×20 cm

There were 12 (4 × 3) treatment combinations viz., G_0S_1, G_0S_2, G_0S_3, G_1S_1, G_1S_2, G_1S_3, G_2S_1, G_2S_2, G_2S_3, G_3S_1, G_3S_2 and G_3S_3.

3.3.2. Experimental Design and Layout

The experiment was laid out in Randomized Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of doses of Gibberellic acid (GA_3) and plant spacing. The 12 treatment combinations of

the experiment were assigned at 36 plots. The size of each unit plot is (1.2×1.2) m^2. The spacing between blocks and plots were 1.0 m and 0.5 m, respectively.

3.4. Growing of Crops

3.4.1. Land Preparation

The land was first ploughed by a tractor drawn disc plough and subsequently cross ploughed four times with power tiller and ladder on 20 November,2017. The corners of the land were spaded. It was then harrowed to bring the soil in a good tilth condition. The land was then thoroughly leveled by a ladder. Weeds and stubbles were removed from the field. All the clods were broken into small pieces. The unit plots were also prepared smoothly with spade before sowing.

3.4.2. Fertilizer Application

The fertilizers were applied as basal dose at final land preparation where Urea, TSP, MP, gypsum were applied 360 kg ha^{-1},480 kg ha^{-1},160 kg ha^{-1} and 100 kg ha^{-1} respectively in all plots following the BARI recommendation. All fertilizers were applied by broadcasting and mixed thoroughly with soil.

3.4.3. Planting of Bulbs

The bulb of onion were sown in the research field on 28th Noverber, 2017.Bulbs were sown in rows by hand plough. The distances between row to row and bulb to bulb were as per treatment variables. One mature bulb was placed in each point at 2–3 cm depth from the soil surface.

3.5. Intercultural Operations

3.5.1. Thinning

The thinning was done 15 days after planting on 14 December, 2017 maintaining plant to plant distances following the treatment variables.

3.5.2. Weed Control

The crop was found to be infested with weeds during the early stage of crop establishment. Two hand weddings were done; first weeding was given at 15 days after sowing followed by second weeding at 15 days after first weeding.

3.5.3. Irrigation

The young plants were irrigated by a watering can and at later stage. Irrigation was done by flooding of each plot whenever necessary.

3.5.4. Plant Protection

The onion crops are normally found to be sustained purple blotch disease caused by *Alternaria porri*. Therefore, preventive measure was taken by spraying Ridomil MZ68 WP @ 2g L^{-1} of water at 20 DAP to keep the crops free from diseases. Second spraying was done with Dithen M-45 @ 2g per Liter of water and malathion 57 [2 ml L^{-1} of water to control onion thrips (*Thrips* sp.) at 45 days after planting (DAP). Third spraying was done with Rovral 50 WP (2g L^{-1} of water) at 60 days (DAP) to keep the diseases under control.

3.5.5. Stalking

Stalking was provided in each plot using bamboo and rope, to keep the plot erect and to protect them from the damage caused by storms and heavy winds.

3.6. Harvesting and Sampling

The matured umbels were harvested in 28th March when the fruit had black seed exposed. Umbels were harvested with a small portion of flowering stalk in the morning to prevent shattering of seeds. The harvesting continued upto to 10 April, 2018.

3.7. Threshing, Cleaning, Drying and Storage

Harvested onion umbels were dried on the cemented floor of under sunlight. Umbels were ready for threshing when the capsules and small stems were brittle and broke quickly while rubbed between the hands. The seeds were threshed b) beating the umbels with son and small stick. Seeds were then cleaned by winnowing manually and dried by spreading in the open sunlight on brown paper until they reached safe moisture content (6-9%). After putting the seeds in airtight polythene bags, these were kept in dry and cool place at room temperature for storing.

3.8. Weighing

The seeds thus collected were dried in the sun for reducing the moisture in the seeds to a constant level. The dried seeds and straw were cleaned and weighed.

3.9. Seed Quality

Seeds obtained from the field experiment were taken separately. These seeds were used for taking quality determination experiments in the laboratory. For this purpose standard germination test was conducted and other different quality attributes data were taken.

3.10. Data Collection

The data were recorded on the following parameters:

A. Morphological characters

a) Plant height (cm)
b) Number of leaflets plant^{-1}

B. Yield contributing characters

a) Number of seeds umbel^{-1} plant
b) Umbel diameter (cm)
c) Number of Seeds umbel^{-1}
d) 1000 seed weight (g)
e) Length of flowering stalk (cm)

C. Yield parameter

a) Seed yield plant^{-1} (g)
b) Seed yield plot^{-1} (g)
c) Seed yield ha^{-1} (kg)

D. Seed quality parameter

a) Total germination (TG %)
b) Vigor index (VI)
c) Shoot length (cm)
d) Root length (cm)

3.11. Procedure of Recording Data

3.11.1. Plant Height (cm)

The height of the 10 randomly selected plant was measured from the ground level to the tip of the largest leaf at 30 DAP, 45 DAP, 60 DAP and at harvest.Mean highest was them calculated.

3.11.2 Number of Leaves Plant^{-1}

Total number of leaves was counted from the 10 randomly selected plants at 30 DAP, 45 DAP, 60 DAP and at harvest and the mean of total number of leaves was then taken.

3.11.3. Number of Umbels Plant^{-1}

Number of umbel plant^{-1} was counted from the 10 randomly selected plant sample and then the average umbel number was calculated.

3.11.3. Umbel Diameter (cm)

Umbel diameter was measured by a meter scale from 10 randomly selected umbels of plants and then the average umbel diameter was calculated.

3.11.4. Number of Seeds Umbel^{-1}

Number of seeds per umbel was counted from 10 randomly selected umbels of plants and then the average seed number was calculated.

3.11.5. Weight of 1000 Seeds (g)

1000 seeds were counted, which were taken from the seeds sample of each plot separately, then weighed in an electrical balance and data were recorded.

3.11.6. Seed Yield

3.11.6.1. Yield of Seeds Plant^{-1} (g)

The 10 plants selected at random from the inner rows of each plot were harvest to take seed yield per plant. The seed were threshed, cleaned, weighed and then averaged the seed yield in g plant^{-1}.

3.11.6.2. Yield of Seeds Plot^{-1} (g)

All plots were harvested individually and the average yield of seeds plot^{-1} was recorded.

3.11.6.3. Yield of Seeds ha^{-1} (kg).

The yield of seed in g per plot was adjusted at 12% moisture content of seed and then it was converted to kg per hectare.

3.11.7. Total Germination (TG %)

Total germination (TG) was calculated as the number of seeds which was germinated within 15 days as a proportion of number of seeds set for germination test in each treatment.

$$\text{TG (\%)} = \frac{Number\ of\ germinated\ seeds}{Total\ number\ of\ seeds\ set\ for\ germination} \text{ x } 100.$$

3.11.8. Vigor Index (VI)

Vigor index (VI) was calculated as following formula

$$\text{Vigor index} = \left(\frac{No.of\ germinating\ seeds}{Days\ of\ first\ count}\right) + \ldots\ldots\ldots + \left(\frac{No.of\ germinating\ seeds}{Days\ of\ final\ count}\right)$$

3.11.9. Shoot Length (cm)

Randomly selected 10 seedlings from each treatment were collected and cotyledons were removed from them and the shoots were measured with a ruler.

3.11.10. Root Length (cm)

Randomly selected 10 seedlings from each treatment were collected and cotyledons were removed from them and the root length was measured with a ruler.

3.12. Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments by using the Statistix-10 computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Different Test (LSD) at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted with different doses of GA_3 and frequency of spacing to study their effects on onion. The results regarding the effect of GA_3 and spacing on different yield attributes and yield of onion are presented in this chapter.

4.1. Plant height (cm)

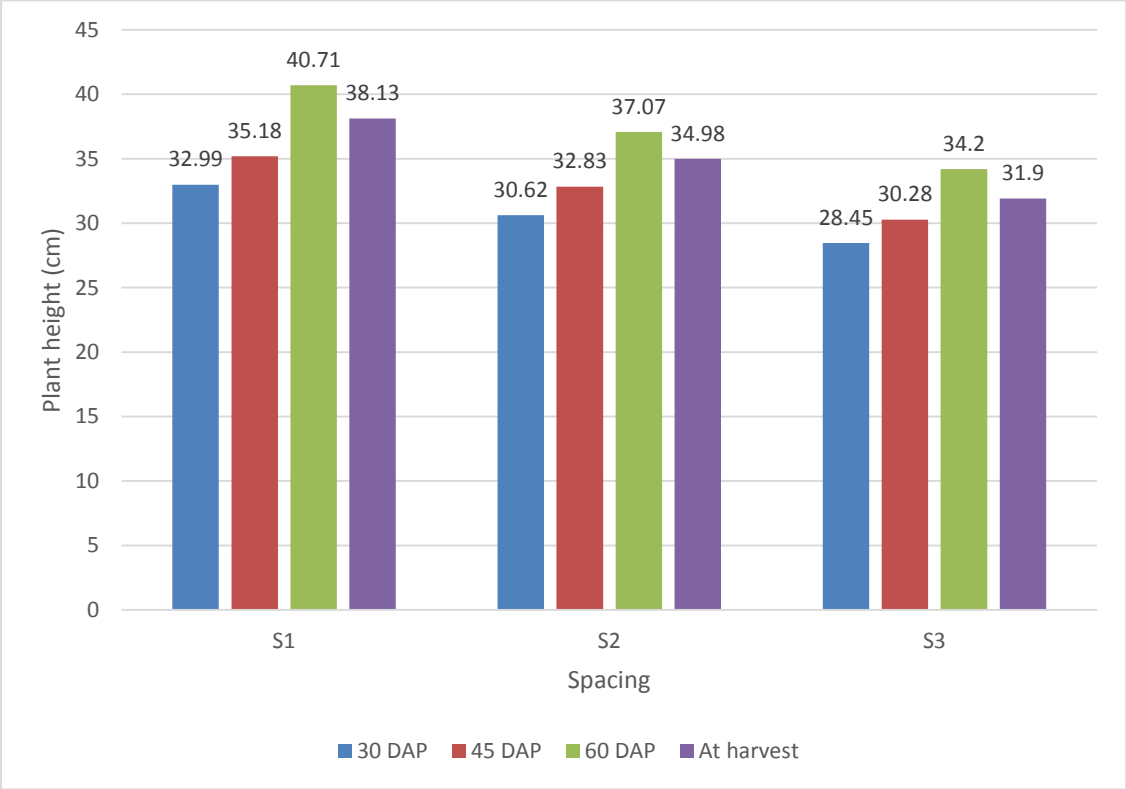
The result showed significant differences on plant height with the different GA_3 application. GA_3 combination significantly increased the plant height throughout the growth period. At 60 DAP, the maximum plant height (46.39 cm) was obtained from G_3 (120 ppm) treatment and the minimum plant height (26.38 cm) was noted from G_0 (Control) treatment (Table 1). Rasid (2010) observed the effect of GA_3 on plant height. It was revealed that GA_3 probably influenced cell division or cell elongation of onion plants, thus the plant height was increased.

Table 1.Effect of GA_3 on Plant height (after 30 DAP, 45 DAP, 60 DAP and at harvest)

Treatment	Plant height			
	30 DAP	**45 DAP**	**60 DAP**	**At harvest**
G_0	18.14 d	20.50 d	26.38 d	22.40 d
G_1	27.04 c	28.42 c	34.14 c	33.40 c
G_2	36.38 b	38.31 b	42.40 b	40.50 b
G_3	41.24 a	43.83 a	46.39 a	43.91 a
LSD	**2.44**	**1.80**	**2.90**	**2.92**
CV %	**8.14**	**5.63**	**7.95**	**8.53**

G_0: Control; G_1: 80 ppm; G_2: 100 ppm; G_3: 120 ppm

Plant height at 30, 45, 60 and at harvest was significantly affected by plant spacing. In this experiment, plant height was increased up to 60 DAP and then decreased up to drying of leaves. At 60 DAP, maximum plant height (40.71 cm) was obtained from S_1 (30 cm x 10 cm) treatment and the minimum plant height (34.20 cm) was noted from S_3 (30 cm x 10 cm) treatment (Fig 1). Khan *et al.* (2003) was found the similar nature of result on plant spacing.



S_1: 30×10 cm S_2: 30×15 cm S_3: 30×20 cm

Fig.1. Effect of spacing on Plant height (after 30 DAP, 45 DAP, 60 DAP and at harvest) of onion (LSD $_{0.05}$ 2.11, 1.56, 2.51,2.52)

Combined effect of GA_3 and plant spacing was significantly influenced by plant height. At 60 DAP, the tallest plant height (50.95 cm) obtained from G_3S_1 (120 ppm with 30 cm x 10 cm) treatment combination. On the other hand the shortest plant height (22.91 cm) was recorded from G_0S_3 (Control with 30 cm x20 cm) treatment combination (Table 2). This result showed that plant height was increased by the increase in GA_3 on the other hand plant height was increased by the higher combination of plant spacing.

Table 2. Combined Effect of GA_3 and spacing on plant height (after 30 DAP, 45 DAP, 60 DAP and at harvest)

Treatments	Plant height (cm)			
	30 DAP	45 DAP	60 DAP	At harvest
G_0S_1	20.45 f	22.36 f	29.47 fg	24.91 f
G_0S_2	17.80 fg	20.35 fg	26.78 gh	22.79 fg
G_0S_3	16.19 g	18.78 g	22.91 h	18.92 g
G_1S_1	28.20 e	30.52 d	37.33 de	35.96 cd
G_1S_2	27.52 e	28.51 de	33.99 ef	33.99 de
G_1S_3	25.40 e	26.24 e	31.09 fg	30.25 e
G_2S_1	38.76 bc	40.48 b	45.10 b	42.85 b
G_2S_2	35.99 cd	38.14 bc	42.10 b-d	40.37 bc
G_2S_3	34.40 d	36.33 c	40.02 cd	38.29 b-d
G_3S_1	44.57 a	47.38 a	50.95 a	48.80 a
G_3S_2	41.34 ab	44.33 a	45.42 b	42.79 b
G_3S_3	37.80 b-d	39.77 b	42.79 bc	40.15 bc
LSD	**4.23**	**3.12**	**5.02**	**5.05**
CV (%)	**8.14**	**5.63**	**7.95**	**8.53**

G_0: Control
G_1: 80 ppm
G_2: 100 ppm
G_3: 120 ppm

S_1: 30×10 cm
S_2: 30×15 cm
S_3: 30×20 cm

4.2 Number of leaves per plant

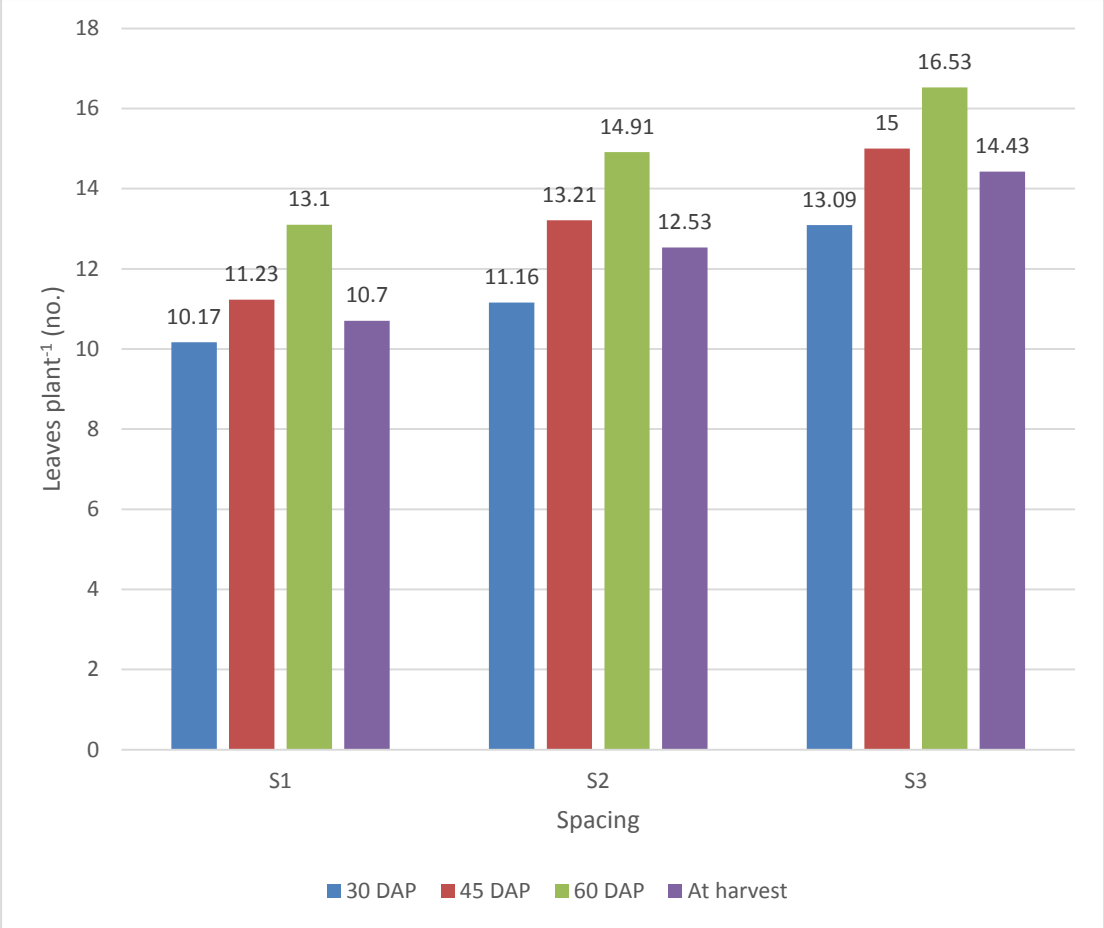
The result showed significant differences on plant height with the application of different GA_3 application. At 60 DAP, the maximum leaves per plant (16.92) was observed from G_2 (100 ppm) treatment which was statistically similar to G_3 and the minimum leaves per plant (11.69) was noted from G_0 (Control). (Table 3)

Table 3.Effect of GA_3 on leaves per plant (after 30 DAP, 45 DAP, 60 DAP and at harvest)

Treatment	Number of leaves			
	30 DAP	**45 DAP**	**60 DAP**	**At harvest**
G_0	8.05 c	9.51 c	11.69 c	8.74 c
G_1	11.39 b	12.74 b	14.89 b	12.10 b
G_2	13.39 a	15.33 a	16.92 a	14.75 a
G_3	13.06 a	15.02 a	15.88 ab	14.66 a
LSD	**0.82**	**1.30**	**1.56**	**0.80**
CV %	**7.36**	**10.36**	**10.78**	**6.57**

G_0: Control; G_1: 80 ppm; G_2: 100 ppm; G_3: 120 ppm

The result showed significant differences on plant height with the different plant spacing. Leaves of plant at 30, 45, 60 DAP and at harvest was significantly affected by plant spacing. In this experiment, Leaves of plant was increased up to 60 DAP and then decreased up to drying of leaves. At 60 DAP, maximum leaves of plant (16.53) was obtained from S_1 (30 cm x 10 cm) treatment and the minimum leaves of plant (13.1) was noted from S_3 (30 cm x 10 cm) treatment (Fig 2). Sikder *et al.* (2010) was discovered the similar nature of result on plant spacing.



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Fig 2. Effect of spacing on leaves per plant (LSD $_{0.05}$ 0.71, 1.13, 1.35, 0.70)

Combined effect of GA_3 and plant spacing was significantly impact by leaves per plant. At 60 DAP, the maximum number of leaves per plant 19.36) obtained from G_2S_3 (100 ppm with 30 cm x 10 cm) treatment combination. On the other hand the minimum leaves per plant (22.91 cm) was recorded from G_0S_3 (Control with 30 cm x20 cm) treatment combination which was statistically similar to G_1S_1 (Table 4).

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Table 4. Combined Effect of GA_3 and spacing on plant height (after 30 DAP, 45 DAP, 60 DAP and at harvest)

Treatments	Number of leaves			
	30 DAP	45 DAP	60 DAP	At harvest
G_0S_1	6.50 g	7.06 f	8.90 e	5.93 g
G_0S_2	8.04 f	10.31 e	12,57 d	9.00 f
G_0S_3	9.62 e	11.14 de	13.61 cd	11.30 e
G_1S_1	10.87 de	11.47 c-e	13.73 cd	11.44 de
G_1S_2	11.28 cd	13.00 b-d	15.10 b-d	12.42 c-e
G_1S_3	12.02 b-d	13.76 bc	15.84 bc	12.71 cd
G_2S_1	11.98 b-d	13.69 bc	15.42 bc	12.58 c-e
G_2S_2	12.54 bc	14.66 b	15.99 bc	14.43 b
G_2S_3	15.65 a	17.65 a	19.36 a	17.25 a
G_3S_1	11.36 b-d	12.71 b-d	14.33 cd	13.22 bc
G_3S_2	12.77 b	14.89 b	16.00 bc	14.29 b
G_3S_3	15.06 a	17.45 a	17.33 ab	16.48 a
LSD	**1.43**	**2.30**	**2.71**	**1.40**
CV (%)	**7.36**	**10.36**	**10.78**	**6.57**

G_0: Control
G_1: 80 ppm
G_2: 100 ppm
G_3: 120 ppm

S_1: 30×10 cm
S_2: 30×15 cm
S_3: 30×20 cm

4.3 Number of umbel per plant

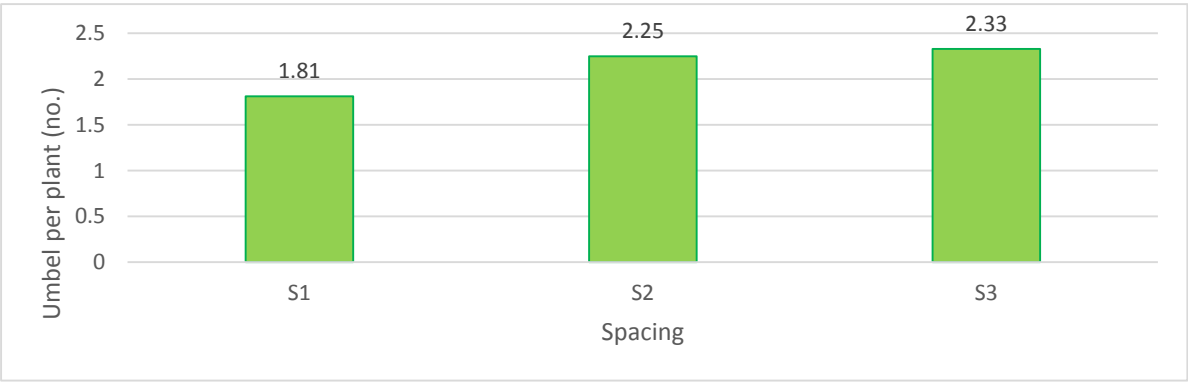
Number of umbel per plant is very important for seed yield. GA_3 has pragmatic impact on the number of umbel per plant. The maximum number of umbel per plant (2.80) was obtained from G_2 (100 ppm) treatment and the minimum umbel per plant (1.35) was noted from G_0 (Control). (Table 5)

Table 5. Effect of GA_3 on umbel per plant, umbel diameter, seeds per umbel and length of flowering stalk of onion

Treatments	Number of umbel per plant	Umbel diameter (cm)	Number of seeds per umbel	Length of flowering stalk (cm)
G_0	1.35 d	3.36 c	481.80 c	59.93 c
G_1	1.90 c	3.88 b	545.49 ab	70.01 b
G_2	2.80 a	4.47 a	561.53 a	74.83 b
G_3	2.46 b	3.91 b	534.52 b	81.86 a
LSD	**0.13**	**0.40**	**16.76**	**5.67**
CV (%)	**7.62**	**10.78**	**3.23**	**8.10**

G_0: Control; G_1: 80 ppm; G_2: 100 ppm; G_3: 120 ppm

The number of umbels per plant was significantly depended on spacing. The maximum umbel per plant (2.33) was showed from S_3 (30 cm x 20 cm) treatment which was statistically identical to S_2 and the minimum umbel per plant (1.81) was obtained from S_1 treatment. (Fig. 3)



S_1: 30×10 cm S_2: 30×15 cm S_3: 30×20 cm

Fig 3.Effect of spacing on umbel per per plant (LSD $_{0.05}$ 0.13)

Combined effect of GA_3 and plant spacing was significantly influenced by umbel per plant. The highest umbel per plant (3.21) obtained from G_3S_1 (120 ppm with 30 cm x 10 cm) treatment combination which was statistically identical to G_2S_3 treatment combination. On the other hand minimum umbel per plant (1.20) was recorded from G_0S_1 (Control with 30 cm x10 cm) treatment combination. (Table 6)

Table 6. Combined effect of GA_3 on umbel plant^{-1}, umbel diameter, seed umbel^{-1} and length of flowering stalk of onion

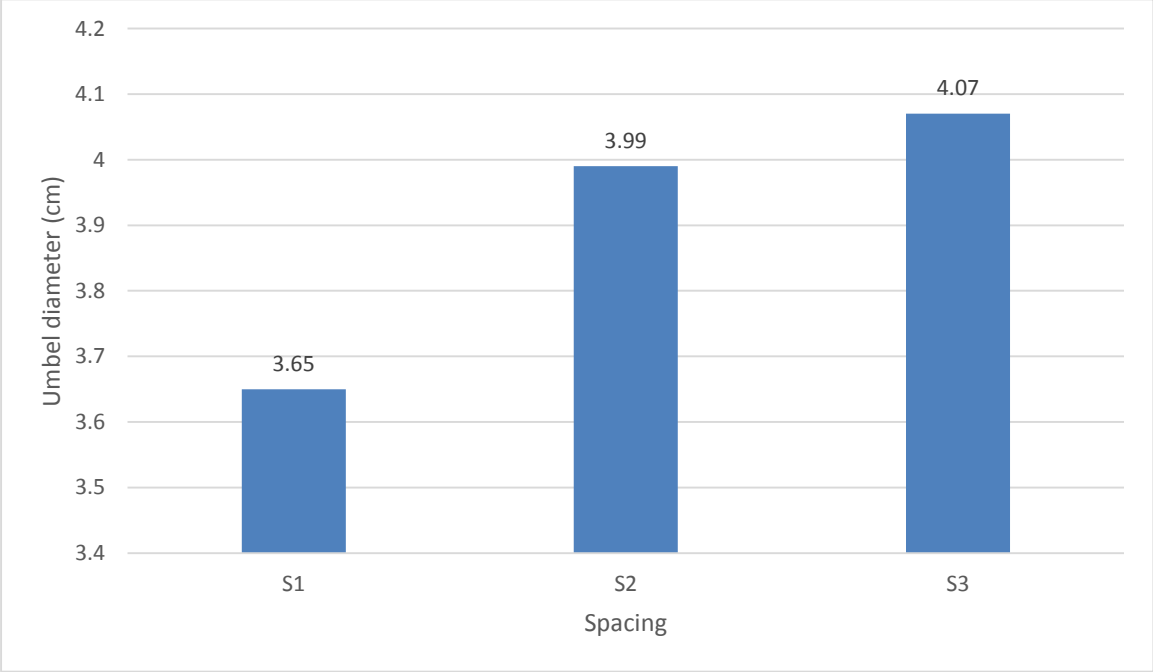
Treatment	Number of umbel per plant	Umbel diameter (cm)	Number of seeds per umbel	Length of flowering stalk (cm)
G_0S_1	1.20 f	3.21 d	460.63 g	63.83 e-g
G_0S_2	1.33 ef	3.37 cd	484.04 fg	60.50 fg
G_0S_3	1.51 e	3.51 cd	500.74 ef	55.46 g
G_1S_1	1.56 e	3.68 cd	517.12 de	73.96 b-d
G_1S_2	2.04 d	3.93 c	549.46 bc	69.22 b-f
G_1S_3	2.11 cd	4.02 bc	569.88 ab	66.85 d-f
G_2S_1	2.09 d	3.96 bc	533.57 cd	79.23 a-c
G_2S_2	3.21 a	4.67 ab	597.34 a	74.48 b-d
G_2S_3	3.10 a	4.74 a	553.69 bc	70.78 c-e
G_3S_1	2.37 bc	3.76 cd	528.81 c-e	87.26 a
G_3S_2	2.43 b	3.97 bc	534.07 cd	82.63 ab
G_3S_3	2.60 b	3.99 bc	540.67 cd	75.70 b-d
LSD	**0.27**	**0.71**	**29.04**	**9.82**
CV (%)	**7.62**	**10.78**	**3.23**	**8.10**

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm, S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

4.4 Umbel diameter (cm)

GA_3 showed positive impact on umbel diameter. The result showed significant differences on umbel diameter with the different GA_3 application. The maximum umbel diameter (4.47 cm) was noted from G_2 (100 ppm) treatment and the minimum umbel per plant (3.36) was noted from G_0 (Control). (Table 5)

The result showed significant differences on umbel diameter with the different spacing. The maximum umbel per plant (4.07) was obtained from S_3 (30 cm x 20 cm) treatment which was statistically similar to S_2 and the minimum umbel diameter (3.65) was obtained from S_1 treatment. (Fig. 4)



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

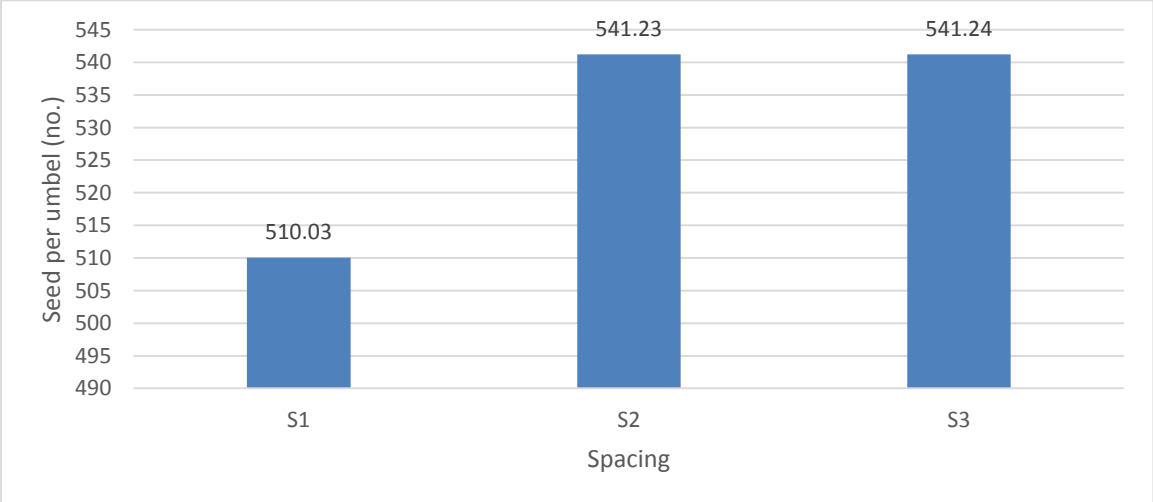
Fig 4. Effect of spacing on umbel diameter (LSD $_{0.05}$ 0.35)

Combined effect of GA_3 and plant spacing was significantly affected by umbel diameter. The maximum umbel diameter (4.74 cm) noted from G_2S_3 (100 ppm with 30 cm x 20 cm) treatment combination which was statistically identical to G_2S_2 treatment combination. On the other hand minimum umbel diameter (3.21) was recorded from G_0S_1 (Control with 30 cm x10 cm) treatment combination. (Table 6)

4.5 Seeds per umbel

The result showed significant differences on seed per umbel with the different GA_3 application. The maximum seed per umbel (561.53) was obtained from G_2 (100 ppm) treatment and the minimum seed per umbel (481.80) was noted from G_0 (Control). (Table 5)

The result showed has pragmatic impact on the on seed per umbel with the different plant spacing. The maximum seed per umbel (541.24) was obtained from S_3 (30 cm x 20 cm) treatment which was statistically identical to S_2 and the minimum seed per umbel (510.03) was obtained from S_1 treatment. (Fig. 5)



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

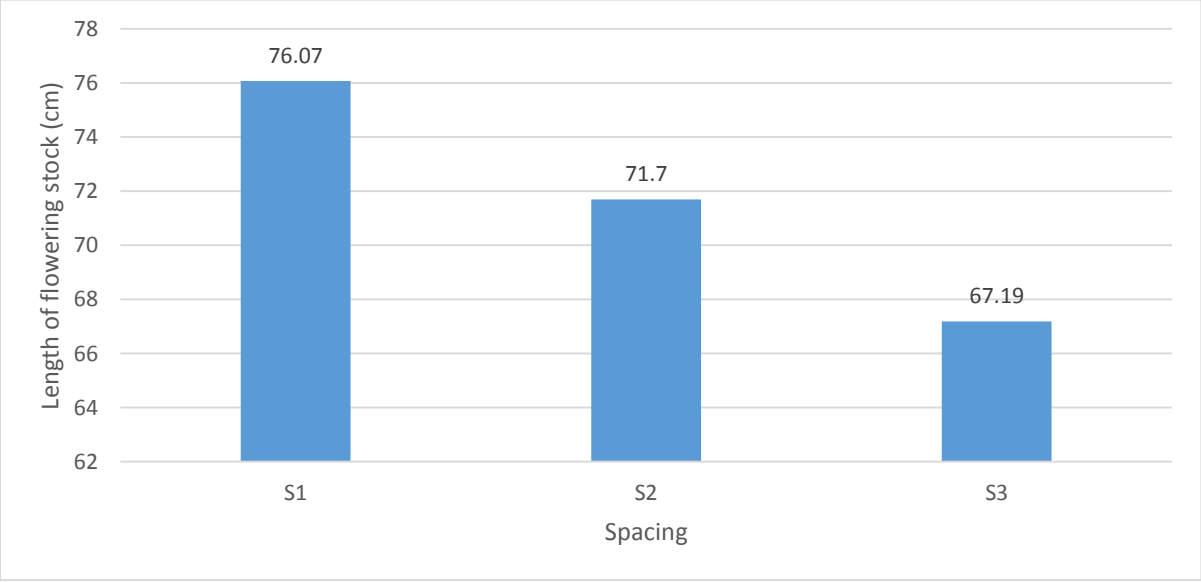
Fig 5. Effect of spacing on seed per umbel (LSD $_{0.05}$ 14.52)

Combined effect of GA_3 and plant spacing was significantly affected by seeds per umbel. The maximum seeds per umbel (597.94) obtained from G_2S_2 (100 ppm with 30 cm x 15 cm) treatment combination which was statistically similar to G_1S_3 treatment combination. On the other hand minimum seed per umbel (460.63) was recorded from G_0S_1 (Control with 30 cm x10 cm) treatment combination. (Table 6)

4.6 Length of flowering stalk

Length of flowering stalk was greatly influenced by GA_3 application. Excessive growth of flowering stalk is not good for a seed production of onion. The maximum flowering stalk (81.86 cm) was obtained from G_3 (120 ppm) treatment and the minimum flowering stalk (59.93 cm) was noted from G_0 (Control). (Table 5)

Different plant spacing showed significant differences on length of flowering stalk. The highest flower stalk (76.07 cm) was obtained from S_1 (30 cm x 10 cm) treatment which was statistically identical to S_2 and the flower stalk 67.19) was obtained from S_1 treatment. (Fig. 6)



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Fig 6. Effect of spacing on length of flowering stalk (LSD $_{0.05}$ 4.91)

Combined effect of GA_3 and plant spacing was significantly affected on length of flowering stalk. The maximum length of flowering stalk (87.26) obtained from G_3S_1 (100 ppm with 30 cm x 10 cm) treatment combination which was statistically similar to G_3S_2 treatment combination. On the other hand minimum length of flowering stalk (55.46) was recorded from G_0S_3 (Control with 30 cm x20 cm) treatment combination. (Table 6)

4.7 Seed yield per plant (g)

The effect of GA_3 on seed weight per plant was significant. The result showed significant differences on seed yield per plant with the different GA_3 application. The maximum seed yield per plant (2.61 g) was obtained from G_2 (100 ppm) treatment and the minimum seed yield per plant (1.11 g) was noted from G_0 (Control) treatment. (Table 7)

Table 7. Effect of GA_3 on seed yield per plant, seed yield plot^{-1}, seed yield ha^{-1} and 1000 seed weight of onion

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per ha (Kg)	1000 seed weight (g)
G_0	1.11 c	35.73 c	248.17 c	3.26 b
G_1	1.56 b	49.15 b	341.37 b	3.33 ab
G_2	2.61 a	80.73 a	560.63	3.47 a
G_3	1.48 b	46.68 b	324.21 b	3.39 ab
LSD	**0.13**	**3.96**	**20.28**	**0.15**
CV (%)	**7.86**	**7.12**	**5.63**	**4.74**

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

Plant spacing has significant influence on the seed yield per plant. The highest seed yield per plant (2.20 g) was obtained from S_3 (30 cm x 20 cm) treatment and followed by S_2 and the lowest seed yield per plant (0.89 g) was noted from S_1 (30 cm x 10 cm) treatment. (Table 8)

Table 8. Effect of spacing on seed yield plant^{-1}, seed yield plot^{-1}, seed yield ha^{-1} and 1000 seed weight of onion

Treatments	Seed yield per plant (g)	Seed yield per plot (g)	Seed yield per ha (Kg)	1000 seed weight (g)
S_1	0.89 c	42.85 c	297.64 c	3.35
S_2	1.97 b	63.35 a	439.98 a	3.36
S_3	2.20 a	53.01 b	368.17 b	3.39
LSD	**0.11**	**3.42**	**21.94**	**0.13**
CV (%)	**7.86**	**7.63**	**5.63**	**4.74**

S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Combined effect of GA_3 and plant spacing was significantly impacted on seed yield per plant. The maximum seed yield per plant (3.37 g) obtained from G_2S_2 (100 ppm with 30 cm x 15 cm) treatment combination which was statistically identical to G_2S_3 treatment combination. On the other hand minimum seed yield per plant (0.72) was recorded from G_0S_1 (Control with 30 cm x10 cm) treatment combination. (Table 9)

4.8 Seed yield per plot (g)

The seed yield per plot was greatly influenced due to different combination of GA_3. The result showed significant differences on seed yield per plot with the different GA_3 application. The maximum seed yield per plot (80.73 g) was obtained from G_2 (100 ppm) treatment and the minimum seed yield per plot (35.73 g) was noted from G_0 (Control) treatment. (Table 7)

The result showed significant differences on seed yield per plot with the different spacing. The maximum seed yield per plot (63.35 g) was obtained from S_2 (30 cm x 20 cm) treatment and the minimum seed yield per plot (42.85 g) was noted from S_1 (30 cm x 10 cm) treatment. (Table 8)

Combined effect of GA_3 and plant spacing combination on the seed yield per plot was highly significant. The maximum seed yield per plot (108.08g) obtained from G_2S_2 (100 ppm with 30 cm x 15 cm) treatment combination. On the other hand minimum seed yield per plot (33.91 g) was recorded from G_0S_3 (Control with 30 cm x10 cm) treatment combination. (Table 9)

4.9 Seed yield per hectare (kg ha^{-1})

Different application of GA_3 showed significant differences on seed yield per hectare. The maximum seed yield per hectare (560.63 kg) was obtained from G_2 (100 ppm) treatment and the minimum seed yield per hectare (248.17 kg) was noted from G_0 (Control) treatment. (Table 7)

The result showed significant differences on seed yield per hectare with the different plant spacing. The highest seed yield per hectare (439.98 kg) was obtained from S_2 (30 cm x 20 cm) treatment and the minimum seed yield per hectare (297.64 kg) was noted from S_1 (30 cm x 10 cm) treatment. (Table 8)

Table 9. Combined effect of GA_3 and spacing on seed yield per plant, seed yield per plot, seed yield per ha and 1000 seed weight of onion

Treatments	Seed yield per plant(g)	Seed yield per plot (g)	Seed yield per ha (Kg)	1000 seed weight (g)
G_0S_1	0.72 g	34.62 g	240.40 g	3.25
G_0S_2	1.20 ef	38.67 fg	268.59 fg	3.27
G_0S_3	1.41 de	33.91 g	235.51 g	3.28
G_1S_1	0.84 g	40.38 fg	280.41 f	3.31
G_1S_2	1.83 c	58.66 c	407.34 c	3.32
G_1S_3	2.01 bc	48.44 de	336.36 e	3.37
G_2S_1	1.12 f	53.89 cd	374.24 cd	3.40
G_2S_2	3.37 a	108.08 a	750.54 a	3.50
G_2S_3	3.34 a	80.22 b	557.10 b	3.50
G_3S_1	0.88 g	42.55 ef	295.50 f	3.46
G_3S_2	1.50 d	48.01 de	333.43 e	3.32
G_3S_3	2.06 b	49.49 d	343.70 de	3.40
LSD	**0.22**	**6.85**	**35.13**	**0.27**
CV (%)	**7.86**	**7.63**	**5.63**	**4.74**

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm, S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Combined effect of GA_3 and plant spacing is greatly impact on seed yield per hectare. The highest seed yield per hectare (750.54 kg) obtained from G_2S_2 (100 ppm with 30 cm x 15 cm) treatment combination. On the other hand lowest seed yield per hectare (235.51 kg) was recorded from G_0S_3 (Control with 30 cm x 20 cm) treatment combination. (Table 9)

4.10 1000 seed weight (g)

Application of GA_3 is more significant effect on 1000 seed weight than control.G_2 (3.47 g) treatment was the highest which was statistically identical to G_1 and G_3 .The lowest 1000 seed weight (3.26) was G_0(Control). (Table 7)

Plant spacing on 1000 seed weight was non significant. (Table 8)

Combined application of GA_3 and plant spacing showed non significant of 1000 seed weight of onion. (Table 9)

4.11 Germination (%)

The effect of GA_3 was found non-significant influence on the weight of 1000 seeds.(Table 10)

The effect of spacing was found non-significant influence on the weight of 1000

seeds (Table 11)

Combined effect of GA_3 and plant spacing was found non-significant influence on the weight of 1000 seeds.(Table 12)

Table 10. Effect of GA_3 on germination (%), germination index (%), shoot length and root length

Treatment	Germination (%)	Seed vigor index (%)	Shoot length (cm)	Root length (cm)
G_0	82.15	12.21	8 c	3.98 c
G_1	82.31	12.25	8.56 bc	4.09 bc
G_2	82.37	12.29	9.44 ab	4.37 ab
G_3	82.72	12.37	9.56 a	4.44 a
LSD	**1.12**	**0.27**	**0.88**	**0.28**
CV (%)	**1.40**	**2.29**	**10.12**	7

G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

4.12 Seed vigor index

The effect of GA_3 was found non-significant influence on seed vigor index of onion seeds. (Table 10)

The effect of spacing was found non-significant influence on the seed vigor

Index of onion seeds. (Table 11)

Combined effect of GA_3 and plant spacing was found non-significant influence on the seed vigor index of onion seeds. (Table 12).

Table 11. Effect of spacing on germination (%) and seed germination index, of onion

Treatments	Germination (%)	Seed vigor index
S_1	82.02	12.25
S_2	82.46	12.29
S_3	82.68	12.30
LSD	**0.97**	**0.23**
CV (%)	**1.40**	**2.29**

S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Table 12. Combined of GA_3 and spacing on germination (%), germination index (%), shoot length and root length

Treatment	Germination (%)	Seed vigor index	Shoot length (cm)	Root length (cm)
G_0S_1	81.23	12.2	7.46 c	3.83 c
G_0S_2	82.05	12.21	8.08 bc	4.06 a-c
G_0S_3	82.40	12.22	8.46 a-c	4.04 a-c
G_1S_1	82.01	12.24	7.91 bc	3.85 bc
G_1S_2	82.66	12.26	8.76 a-c	4.09 a-c
G_1S_3	83.03	12.27	9.03 ab	4.33 ab
G_2S_1	82.20	12.29	8.81 a-c	4.10 a-c
G_2S_2	83.00	12.42	9.82 a	4.51 a
G_2S_3	82.96	12.39	9.71 a	4.50 a
G_3S_1	82.66	12.26	9.24 ab	4.33 ab
G_3S_2	82.13	12.28	9.71 a	4.49 a
G_3S_3	82.33	12.33	9.72 a	4.50 a
LSD	**1.95**	**0.47**	**1.52**	**0.50**
CV (%)	**1.40**	**2.29**	**10.12**	**7**

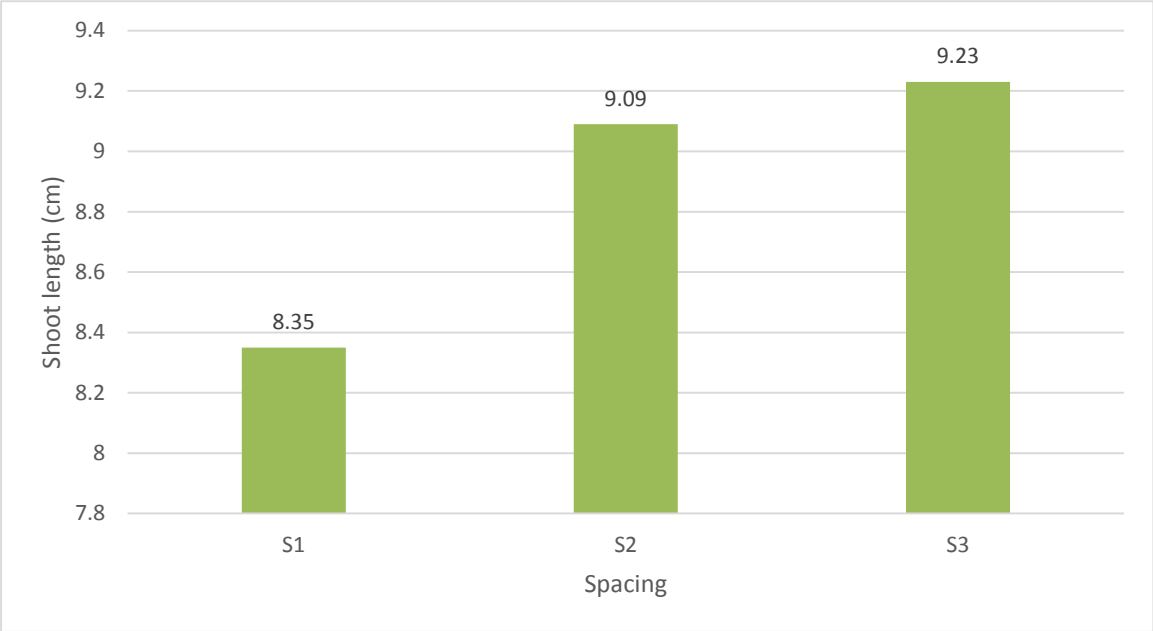
G_0: Control, G_1: 80 ppm, G_2: 100 ppm, G_3: 120 ppm

S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

4.13 Shoot length (cm)

The application of GA_3 showed significant impact on shoot length (Table 10). The maximum shoot length (9.56 cm) was recorded in G_3 (120ppm) which was statistically similar to G_2 and the lowest shoot length (8 cm) was G_0 (Control) treatment. (Table 10)

Spacing of plant significant effect on shoot length of onion (Figure 10). The maximum shoot length (9.23 cm) was recorded in S_3 (30x20) treatment which was statistically similar to S_2 and the lowest shoot length (8.35 cm) was S_1 (30x10) treatment. (Fig 7)



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

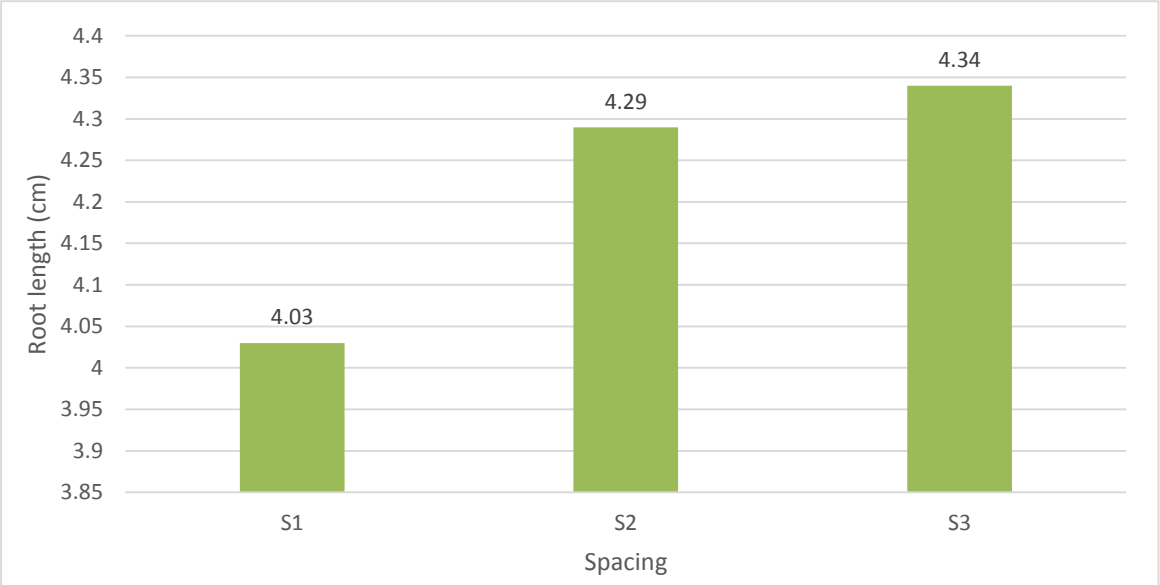
Fig 7. Effect of spacing on shoot length(LSD $_{0.05}$ 0.76)

The application of GA_3 and spacing showed significant on shoot length of onion. The maximum shoot length (9.72 cm) was recorded in G_3S_3 (120 ppm with 30 cm x 20 cm) treatment combination which was statistically identical to G_2S_2, G_2S_3, G_3S_2 treatment combination and statistically similar to G_0S_3, G_1S_2 , G_1S_3 , G_2S_1 treatment combination. Among these treatment G_0S_1 (7.46 cm) treatment combination was the lowest. (Table 12)

4.14 Root length (cm)

The application of GA_3 showed significant impact on root length (Table 10). The maximum root length (4.44 cm) was recorded in G_3 which was statistically similar to G_2 and the lowest (3.98 cm) treatment was G_0 (Control). (Table 10)

Spacing of plant significant effect on root length of onion.The highest root length (4.34 cm) was in S_3 treatment which was statistically similar to S_2 treatment and S_1 (4.03 cm) was the lowest. (Fig. 8)



S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm

Fig 8. Effect of spacing on root length (LSD $_{0.05}$ 0.25)

Combined effect of GA_3 and plant spacing is slightly impact on root length of onion (Table 6.). The maximum root length (4.51 cm) was recorded in G_2S_2 (10 ppm with 30 cm x 15 cm) treatment combination which was statistically identical to G_2S_3, G_3S_2, G_3S_3 treatment combination and statistically similar to G_0S_2, G_0S_3, G_1S_2 ,G_1S_3, G_2S_1, G_3S_1 treatment combination,. Among those the lowest (3.83 cm) treatment was G_0S_1 treatment combination (Table 12).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during Rabi (November to March, 2017) to study the effect of gibberellic acid (GA_3) and spacing on the morphological characters, yield and seed quality of onion. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Different concentration of GA_3 (4 levels); G_0: Control, G_1:80 ppm, G_2:100 ppm, G_3:120 ppm and factor B: Plant spacing (3 levels); S_1: 30×10 cm, S_2: 30×15 cm, S_3: 30×20 cm. The variety, Taherpuri was used in this experiment as the test crop. There were 12 treatment combinations. The total numbers of unit plots were 36. Urea, T.S.P., M.P and zypsum were applied as per treatment variables and other fertilizers were applied as per BARI recommendation. Data on different yield contributing characters and yield were recorded to find out the optimum levels of GA_3 and spacing for higher yield of onion seed.

The experiment was laid out in RCBD with three replications. The size of unit plot was 1.44 m^2 (1.2 m × 1.2 m) and plants were accommodated in each unit according to spacing. Spacing 30 cm × 10 cm (S_1) was accommodated in 48 plants and spacing 30 cm × 15 cm (S_2) was accommodated in 32 plants and spacing 30 cm × 20 cm (S_3) was accommodated in 24 plants. Seed crop was harvested at maturity between 28 March to 10 April, 2018. Data were collected from 10 randomly selected plants and seed yield was recorded from all plants of unit plots. Observations were made on plant height, number of leaves, number of umbels per plant, umbel diameter, length of flowering stalk, seed yield(g) per plant, seed yield (g) per plot, seed yield (kg) per hectare, number of seeds per umbel, shoot length (cm), root length(cm),1000 seed weight(g), seed germination (%) and speed of seed germination. The collected data were statistically analyzed and the means were compared with LSD values.

Different growth and yield parameters, seed quality were significantly influenced by different levels of GA_3. At 60 DAP, the tallest plant (46.39 cm) was obtained from G_3 while the shortest plant (26.38 cm) was obtained from G_0 treatment., the maximum leaves of plant (16.92) was obtained from G_2 at 60 DAP while the minimum leaves of plant (11.69) was obtained from G_0 treatment. The highest and lowest number of umbel plant^{-1} (2.80 and 1.35), umbel diameter (4.47 cm and 3.36 cm), seeds umbel^{-1} (561.53 and 481.80) was recorded in G_2 and G_0 .The highest and lowest length of flowering stalk (81.86 and 59.93) was recorded in G_3 and G_0.1000 seed weight (3.47 g and 3.26 g) recorded in G_2 and G_0 treatment. The highest and lowest seed yield per plant (2.61 g and 1.11 g), seed yield per plot (80.73 g and 35.73 g), seed yield per hectare (560.63 kg g and 248.17 kg) were record in G_2 and G_0. The highest and lowest number of germination percent (82.72% and 82.15%) was recorded in G_3 and G_0 which was not significant. Vigor index (12.37 % and 12.21 %) was recorded in G_3 and G_0 which was not significant. Shoot length (9.56 cm and 8 cm) was recorded in G_3 and G_0, root length (4.44 cm and 3.98 cm) was found in G_3 and G_0 treatment, respectively.

Different growth and yield parameters, seed quality were significantly influenced by different levels of plant spacing. At 60 DAP the tallest plant (40.71 cm) was obtained from S_1 while the shortest plant (34.2 cm) was obtained from S_0 treatment. At 60 DAP, the maximum leaves of plant (16.53) was obtained from S_3, while the minimum leaves of plant (13.1) was obtained from S_0 treatment. The maximum and minimum leaf per plant (6.75) and (5.90) was obtained from treatment S_3 and S_1 treatment, respectively. The highest and lowest number of umbel per plant (3.11 and 2.66), umbel diameter (4.42 cm and 3.97 cm), seeds per umbel (226.13 and 211.30) was recorded in S_3 and S_1.The highest and lowest length of flowering stalk (80.11 and 73.28) was recorded in S_1 and S_3.The maximum and minimum 1000 seed weight (3.39 g and 3.35 g) recorded in S_3 and S_1 treatment which was not significant. The highest and lowest seed yield per plant (2.20 g and 0.89 g) was found in S_3 and S_1 but seed yield per plot (63.35 g and 42.85 g), seed yield per hectare (439.98 g and 297.64 g) found in S_2 and S_1.The highest and lowest germination percent (82.68% and 82.02%), germination index (17.98 % and 17.72 %) was found in S_3 and S_1 respectively which was not significant. The maximum and

minimum shoot length (9.23 cm and 8.23 cm), root length (4.34 cm and 34.03 cm) was recorded in S_3 and S_1 treatment, respectively.

Different growth and yield parameters, seed quality were significantly influenced by combination of different GA_3 and plant spacing. At 60 DAP, the tallest plant (50.95 cm) was obtained from G_3S_1, while the shortest plant (22.91 cm) was obtained from G_0S_3 treatment combination. At 60 DAP, the maximum leaves per plant (19.36) was obtained from G_2S_3, while the minimum leaves per plant (8.90) was obtained from G_0S_1 treatment. The highest and lowest number of umbel per plant (3.21 and 1.20) recorded in G_2S_2 and G_0S_1. The maximum and minimum umbel diameter (4.74 cm and 3.21 cm) was found in G_2S_2 and G_0S_1. The highest and lowest number of seeds per umbel (597.34 and 460.63) was recorded in G_2S_2 and G_0S_1.The highest and lowest length of flowering stalk (87.26 and 55.46) was recorded in G_3S_1 and G_0S_3. The highest and lowest 1000 seed weight (3.73 g and 3.08 g) recorded in G_2S_2 and G_0S_1 treatment. Yield per plant (3.21 g and 1.20 g) was recorded in G_2S_2 and G_0S_3. The highest and lowest seed yield per plant (3.37 g and 0.72 g), seed yield per plot (108.08 g and 33.91 g) was recorded in G_2S_2 and G_0S_3 and yield per hectare (750.54 kg and 235.51 kg) was recorded in G_2S_2 and G_0S_3. The highest and lowest germination percent (83% and 81.23%) in G_2S_2 and G_0S_1 which was not significant. The highest and lowest seed vigor index (12.42 and 12.2) recorded in G_2S_2 and G_0S_1 treatment which was not significant. The highest and lowest shoot length (9.72 cm and 7.46 cm) was found in G_2S_2 and G_0S_1. Root length (4.51 cm and 3.83 cm), was recorded in G_2S_2 and G_0S_1 treatment respectively.

In conclusion, the results of the present experiment have revealed that recommended combination of 100 ppm GA_3 (G_2) treated plants have highest growth, yield and quality of onion seeds. Plant spacing of 30 cm x 15 cm (S_2) also gave have highest growth, yield and quality of onion seeds. The effect of GA_3 of and spacing had positive effect on morphological characters, yield contributing characters, yield and seed quality in onion. Application of G_2 (100 ppm) with S_2 (30 cm × 15 cm) combination seemed to be more suitable for onion seed production in Sher-e-Bangla Agricultural University research field.

However, this is one year experiment, more researchers on this aspect are necessary to conduct at different agro-ecological zones for arriving at a definite conclusion and recommendations.

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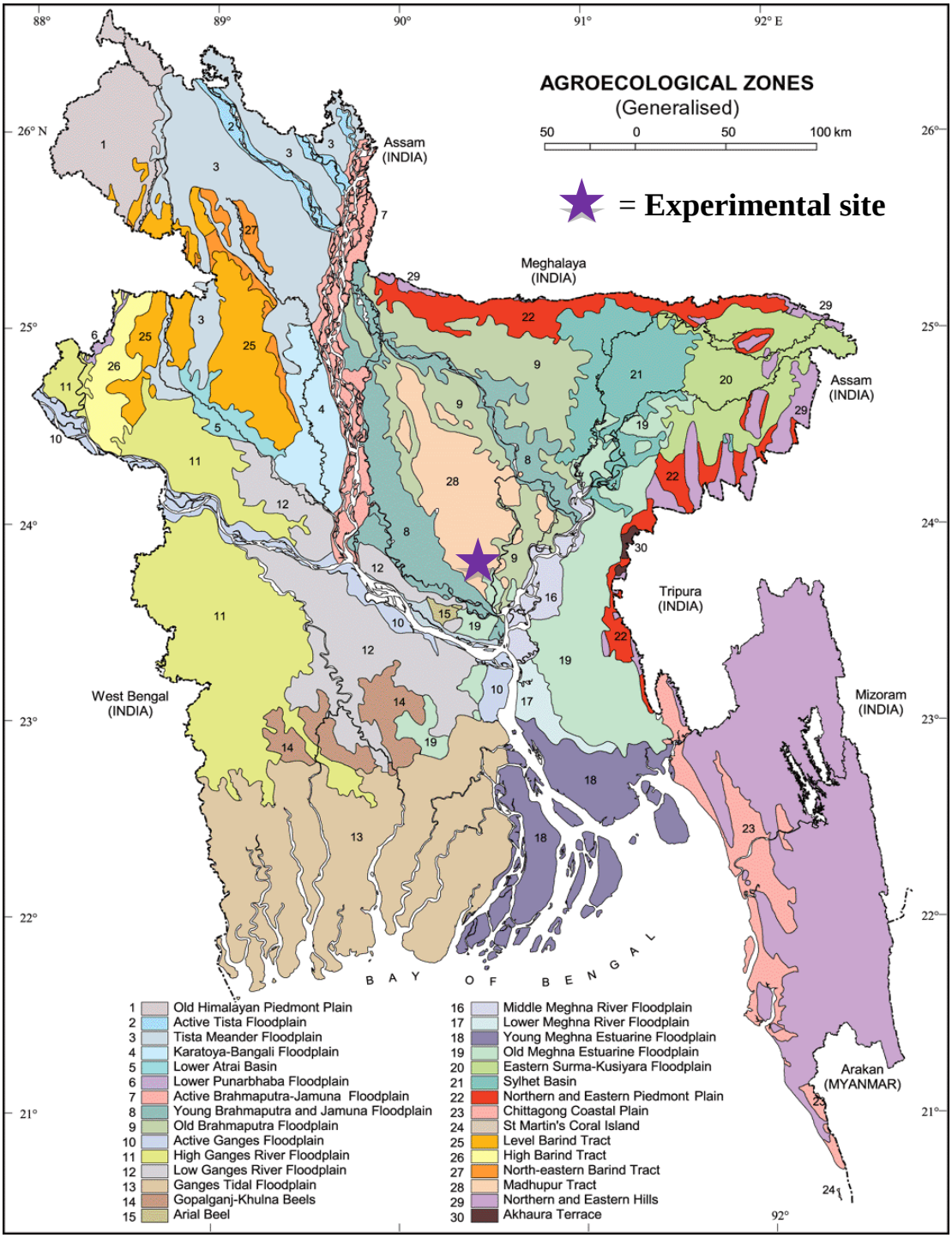
APPENDICES

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



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay
Chemical characteristics	
Soil characters	**Value**
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.05
Available P (ppm)	20.54
Exchangeable K (me/100 g soil)	0.10

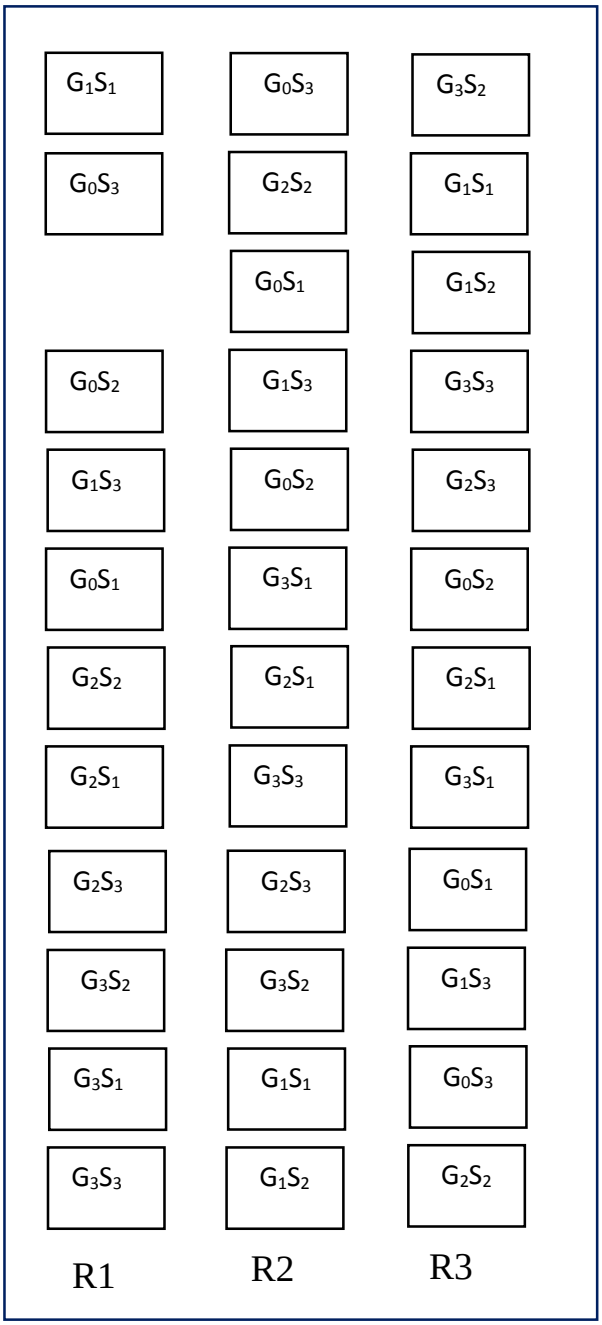
Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

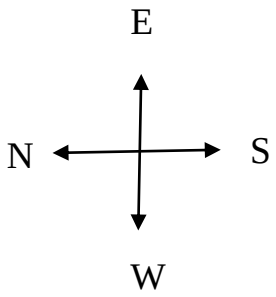
Appendix III. Monthly meteorological information during the period from November, 2017 to March, 2018

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2017	November	28.9	11.2	58	46
	December	25.00	9.5	65.34	0
	January	30.4	15.6	68.4	50
	February	32.30	21.80	74.3	75
	March	33.9	13.6	55.29	102

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout for experimental field.





Treatments:

Factor A: GA_3 (Four levels of GA_3)

i. G_0: Control
ii. G_1 : 80 ppm
iii. G_2 :100 ppm
iv. G_3 : 120 ppm

Factor B: **Plant Spacing (Three levels of spacing)**

i. S_1 : 30 cm ×10 cm
ii. S_2 : 30 cm ×15 cm
iii. S_3 :30 cm ×20 cm

Experimental Layout:

Total number of unit plots: 12 × 3 = 36
Unit plot size: 1.2 m×1.2 m = 1.44 m^2
The main plot and unit plots were separated by 1m and 0.5m, respectively.

Appendix V. Analysis of variance of the data on plant height (cm) after (30 DAP, 45 DAP, 60 DAP and at harvest) of onion as influenced by combined effect of GA_3 and Spacing

Source of variation	df	Mean square value			
		plant height after 30 DAP (cm)	Plant height after 45 DAP (cm)	Plant height after 60 DAP (cm)	Plant height at harvest (cm)
Replication	2	22.07	23.91	23.42	3.70
GA_3 (A)	3	943.17	967.54	713.26	827.98
Spacing (B)	2	62.07	72.19	127.73	116.25
GA_3 (A) X Spacing (B)	6	2.40	2.73	1.91	3.73
Error	22	6.25	3.40	8.80	8.92

Appendix VI. Analysis of variance of the data on no. of leaves plant^{-1} after (30 DAP, 45 DAP, 60 DAP and at harvest) of onion as influenced by combined effect of GA_3 and Spacing

Source of variation	df	Mean square value			
		no. of leaves plant^{-1} after DAP (cm)	no. of leaves plant^{-1} after 45 DAP (cm)	no. of leaves plant^{-1} after 60 DAP (cm)	no. of leaves plant^{-1} at harvest (cm)
Replication	2	2.11	4.62	1.16	0.76
GA_3 (A)	3	53.76	60.05	45.96	71.81
Spacing (B)	2	26.32	42.67	35.47	39.79
GA_3 (A) X Spacing (B)	6	1.39	1.68	2.21	2.71
Error	22	0.71	1.85	2.56	0.68

Appendix VII. Analysis of variance of the data on no. of umbel plant$^{-1,}$ umbel diameter, no. of seed umbel$^{-1,}$ length of flowering stalk of onion influenced by combined effect of GA_3 and Spacing

Source of variation	df	Mean square value			
		No. of umbel plant^{-1}	Umbel diameter	No. of seed umbel^{-1}	Length of flowering stalk
Replication	2	0.13	1.60	1822.2	133.42
GA_3 (A)	3	3.66	1.80	10724.6	763.35
Spacing (B)	2	0.95	0.58	3894.4	236.27
GA_3 (A) X Spacing (B)	6	0.18	0.06	913.5	3.92
Error	22	0.02	0.17	294.2	33.67

Appendix VIII. Analysis of variance of the data on seed yield plant$^{-1,}$ seed yield plot^{-1}, seed yield ha^{-1} and 1000 seed weight of onion influenced by combined effect of GA_3 and Spacing

Source of variation	df	Mean square value			
		yield plant^{-1} (g)	seed yield plot^{-1}(g)	seed yield ha^{-1}(kg)	1000 seed weight
Replication	2	0.12	137.03	4073	0.01
GA_3 (A)	3	3.73	3365.27	162274	0.06
Spacing (B)	2	5.93	1260.31	60782	0.004
GA_3 (A) X Spacing (B)	6	0.56	418.05	20160	0.008
Error	22	0.01	16.41	431	0.02

Appendix IX. Analysis of variance of the data on germination %, germination index, shoot length, root length, as influenced by combined effect GA_3 and Spacing

Source of variation	df	Mean square value			
		Germination %	Germination index	Shoot length cm	Root length cm
Replication	2	0.29	0.17	2.70	0.22
GA_3 (A)	3	0.51	0.04	4.94	0.44
Spacing (B)	2	1.32	0.01	2.66	0.34
GA_3 (A) X Spacing (B)	6	0.78	0.002	0.09	0.02
Error	30	1.32	0.07	0.81	0.08