Original Article

Bangladesh Journal of Agriculture and Life Science
Faculty of Agriculture, University of Rajshahi
Rajshahi-6205, Bangladesh
Vol. 03 (1): 29-39, 2022
http://csa.ru.ac.bd/bjals/

Growth and Yield Response of Summer Onion Seed (*Allium cepa* L.) Influenced by Plant Spacing and Nitrogen Levels

Mst. Sabina Begum[1], Md. Abdul Alim[1], Md. Abdur Rahim[2] and Md. Arifur Rahman[1]*

[1] *Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi-6205, Bangladesh.*
[2] *Department of Horticulture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.*

ARTICLE INFO

Article History
Received: January 28, 2024
Accepted: January 30, 2025
Online: April 25, 2025

Keywords
Spacing
Nitrogen
Growth
Seed yield
Onion

ABSTRACT

The experiment was carried out to find out the effect of spacing and levels of nitrogen on the growth, yield contributing characters, yield and quality of onion seed. The trial was investigated with plant spacing (*viz*.25 cm x 10 cm, 20 cm x 15 cm, 25 cm x 15 cm and 25 cm x 20 cm) and nitrogen levels (*viz*., 0 Kg ha^{-1}, 100 Kg ha^{-1}, 150 Kg ha^{-1} and 200 Kg ha^{-1}). Results revealed that planting with closest spacing gave the highest seed yield (501.43 kg ha^{-1}) whereas widest spacing produced the highest seed weight per plant (1.43g). The vegetative growth along with seed production ability of the plants was increased gradually with the increase of nitrogen level. The highest seed yield ha^{-1}(490.13 kg) and yield contributing characters were found with the application of highest dose of nitrogen (200 Kg ha^{-1}) but the lowest values were obtained from 0 Kg ha^{-1}. Due to the combined effect, seed yield was increased with reduced in spacing and increase of nitrogen level but the superior quality seed was produced from the combination of wider spacing with highest doses of nitrogen in the experiment.

Introduction

Onion (*Allium cepa* L.) belonging to the family Alliaceae, is one of the most important and popular vegetable and spice crops cultivated worldwide (Mishra et al., 2013). It is originated in Iran and Northern mountains regions of Pakistan (Purseglove, 1972). The major onion producing countries of the world are China, India, USA, Iran, Russia, Turkey, Pakistan, Egypt, Brazil, Mexico, Japan, Netherland, Spain etc. (FAO, 2016). Onion is famous for its characteristics flavour and it is widely used to increase the taste of foods like gravies, soups, stew stuffing, fried fish and meat (Rashid et al., 2016). Among the alliaceous crops, onion contributes significant nutritional value to the human diet and have medicinal properties and are primarily consumed for their unique flavor or for their ability to enhance the flavor of other foods (Randle, 2000). It is important constituent of our daily diet and its demand remains same round the year. So, it is called the queen of the kitchen (Selvaraj, 1976). The onion is preferred mainly because of its green leaves, immature and mature bulbs are either eaten raw or cooked as a vegetable. Mild flavored or colorful bulbs are

***Address of correspondence**
Dept. of Agronomy and Agricultural Extension
University of Rajshahi, Rajshahi-6205, Bangladesh.
Email: arifur_ru@ru.ac.bd (Md. Arifur Rahman)

often chosen for salads. Onion grows well in Bangladesh in winter seasons with very low yield of 5.36 t/ha, whereas world's productivity being 17.45 t/ha (FAO,2015). It is not possible to meet our increasing demand. So, fulfillment of our demand needs to produce onion in summer seasons.

Spacing is very important consideration for any crop growth, seed yield and its quality standard for proper utilization of solar radiation and soil nutrient. Normally more Light interception and nutrient uses efficiency occur in closer spacing than wider spacing, yielding in more production, but actually the quality may not be improved in this way. So, optimum spacing measurement is very important aspect for our farmers. Mirshekari and Mobasher (2006) reported the significance of plant spacing in onion seed production and Asaduzzaman et *al*., (2012) also reported the same findings.

Judicious application of fertilizers is important for onion production. Among the nutrients, nitrogen is the most limiting nutrient in crop production. It increases the vegetative growth and produces adequate quality of foliage and promotes carbohydrate synthesis (Rai, 1981) which might help to produce high yield and quality onion seed. Optimum nitrogen application helps growth of onion seed crop rapidly and bolts earlier, which results in early maturation of seed. Reports indicated that, both yield and quality of onion seed can be improved to a great extent by using nitrogenous fertilizers (Bokshi et al. 1989; Pandey et al. 1992; Rahim et al. 1997). Optimum nitrogen fertilized onion seed crop grows rapidly and bolts earlier, which results in early maturation of seed. With a view to considering all these points, the present investigation was under taken to determine the appropriate spacing and the optimum level of nitrogen to be adopted for satisfactory yield of quality summer onion seed.

Materials and methods

Experimental site and soil

The experiment was carried out at the Pakuria village under the Bagha Upazilla of Rajshahi district during the period from December,2019 to May,2020 to find out the effect of spacing and levels of nitrogen on the growth, yield contributing characters, yield and quality of onion seed. The experiment was comprised of two factors, namely, plant spacing with 25 cm x 10 cm, 20 cm x 15 cm, 25 cm x 15 cm and 25 cm x 20 cm, and nitrogen levels with 0 Kg ha^{-1}, 100 Kg ha^{-1}, 150 Kg ha^{-1} and 200 Kg ha^{-1}. Geographically the experimental field is located at 24^{0}17'- 24^{0}3l' N latitude and 88^{0}28'-88^{0}43' E longitude at an elevation of 20 m above the sea level belonging to the High Ganges River Floodplain (AEZ-11). The land was medium high, flat, well drained and above flood level. The soil p^{H} is 8.5.

Experimental design and treatment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total number of unit plots in the entire experimental plot was 48 (4×4×3). The unit plot size was 2 m×2 m=4m^{2}. The plot to plot distance was 0.5m and the block to block distance was 1.0m.

Plant material

The summer onion variety Binapiaz-1 developed by Bangladesh Institute of Nuclear Agriculture (BINA) was used as test crop in the study. It can produce seed in same year. It requires 200-210 days from seed to seed, 100-110 from seed to bulb and 110-120 from seedling to bulb. Number of leaves 8-11 per plant and individual bulb weight is 15 -20 gram. Plant height is 39-42 cm. Planting time and season: Mid-February to 1st week of December for bulb production, last week of October to 2nd week of November for seed production. Yield is 8.21 t/ha (bulb) and 635 kg/ha (Seed) approximately.

Crop husbandry and data collection

The land was prepared by ploughing and cross ploughing with a power tiller and subsequently leveled by laddering. Forty days old seedlings were used in this study. Intercultural operations were done as and when necessary. Staking was provided in each plot using bamboo sticks and ropes to keep the plants and flower stalk erect as well as protecting the plants from influenced by storm and strong wind. The matured seed umbels were harvested in three times when 15-20 % of the capsules were splitted and exposed their black seeds (Vander Meer and Van Bennecom, 1968). Umbels were harvested with a small portion of flower stalks in the morning to shattering of seed. Harvested onion umbels were dried in open sunlight on brown papers for 4-5 days. Threshing was done manually. Seed were cleaned and dried again until the required moisture content (9-10%). Seeds were then kept in polythene bag. The experimental plots were observed frequently to record changes in plant characters at different stages of growth. Ten sample plants were selected randomly from each plot and data were recorded and their mean values were calculated for each of the following characters.

Statistical analysis

The collected data were analyzed statistically using the analysis of variance technique and the mean differences were adjudged by New Duncan's Multiple Range Test (Gomez and Gomez, 1984) with the help of MSTAT-C software programme.

Results

Effect of spacing and nitrogen levels on growth, seed yield and yield contributing characters of summer onion

The results of the influence of different plant spacing on growth, seed yield and yield producing characters were found significant and shown in Table 1 & 2. The longest plant (36.93cm) was found in the widest plant spacing of (25 x 20) cm^2 but the shortest plant (33.45cm) was obtained from the closest spacing (25 x 10) cm^2. The longest plant height (39.46 cm) was obtained from the plants which received 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (37.28 cm), while the shortest plant height (27.24 cm) was obtained from 0 kg N ha^{-1}(Table 1 & 2).

The differences in the production of tillers $plant^{-1}$ caused by different plant spacing found to be statistically significant. Maximum number of tillers $plant^{-1}$ (2.86) was produced by the plants having the widest spacing of 25 x 20 cm^2 significantly followed by the second widest spacing of 25 x 15 cm^2 and significantly the lowest number of tillers $plant^{-1}$ (2.32) was recorded from the plants with the closest spacing of 25x 10 cm^2 (Table 1). The effect of nitrogen levels on number of tillers per plant was found to be statistically significant. The maximum number of tillers (3.10) was observed in the plants of plots that received 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (2.83) and the minimum number of tillers $plant^{-1}$ (2.00) was found from 0 kg N/ha (Table 2).

The higher length of scape (44.58 cm) was recorded in respect of the widest plant spacing 25 x 20 cm^2 but closest spacing 25x 10 cm^2 produced the lower length of scape (39.83 cm) which was statistically identical to result of the spacing 20x 15 cm^2 (Table 1). The effect of nitrogen levels on the length of scape was found to be statistically significant. The maximum length of scape (47.60 cm) was observed at the highest dose of nitrogen (200 N ha^{-1}), followed by 150 kg N ha^{-1} (43.85 cm) and the minimum length of stalk (36.25 cm) was found from the 0 kg N ha^{-1} (Table 2).

Plant spacing showed significant result in respect of number of umbels $plant^{-1}$. The maximum number of umbels $plant^{-1}$(3.22) was produced from bulbs spaced at the widest spacing 25 x 20 cm^2 and the number of umbels $plant^{-1}$ was reduced with the decrease in plant spacing. Significantly the lowest number of umbels $plant^{-1}$(2.71) was recorded from the bulbs having the closest spacing 25 x 10 cm^2 (Table 1). Different levels of nitrogen showed significant variations in the number of umbels per plant. Number of umbels $plant^{-1}$ was increased with the increased levels of nitrogen. The number of umbels $plant^{-1}$ was found to be the highest (3.36) with the application of 200 kg N ha^{-1} which was statistically identical (3.27) with 150 kg N ha^{-1} and the lowest number of umbels (2.33) $plant^{-1}$ was recorded from the control treatment (0 kg N ha^{-1}) (Table 2).

Number of flowers $umbel^{-1}$ differed significantly at 1% level of significance due to different plant spacing. The highest number of flowers (234.23) was recorded from the plant spacing 25 x 20 cm^2 and the lowest number of flowers (210.00) was recorded from the plant spacing 25 x 10 cm^2. The plant spacing 20 x 15 cm^2 and 25 x 15 cm^2 gave about same result (Table 1). The effect of nitrogen levels on number of flowers $umbel^{-1}$ was found to be statistically significant. The maximum number of flowers $umbel^{-1}$ (243.71) was observed in the plants that received 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (234.14), and the minimum number of flowers $umbel^{-1}$ (197.72) was found from 0 kg N ha^{-1} (Table 2).

The number of seeded fruits $umbel^{-1}$ was significantly affected at 1% level by different plant spacing. Maximum number of seeded fruits per umbel (145.77) was recorded from wider spacing

25 x 20 cm^2 and the number of seeded fruits decreased gradually with close spacing (Fig. 5). The minimum number of seeded fruits $umbel^{-1}$ (119.15) was in the closest spacing 20 x 10 cm^2 (Table 1). The variation in number of seeded fruits $umbel^{-1}$ due to nitrogen levels was found to be significant. The number of seeded fruits $umbel^{-1}$ was found to be the highest (152.77) with the application of 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (143.54) and the lowest number of seeded fruits $umbel^{-1}$ was recorded from the control treatment (105.17) (Table 2).

The widest spacing 25 x 20 cm^2 produced the highest percentage of fruit set (61.80) whereas the closest spacing 25 x 10 cm^2 gave the lowest values (56.45) (Table 1). The highest fruit set (62.50 %) was observed at the highest dose of nitrogen (200 kg ha^{-1}), followed by 150 kg N ha^{-1} (61.15 %), arid the minimum fruit set (53.10%) was found from 0 kg N ha^{-1} (Table 2).

Table 1. Effect of spacing on the yield contributing characters of onion seed crop

Spacing	Plant height (cm)	No. of tillers $plant^{-1}$	Length of scape (cm)	No. of umbels $plant^{-1}$	No. of flowers $umbel^{-1}$	No. of seeded fruits $umbel^{-1}$	% fruit set
25 cm x 10 cm(S_1)	33.45 d	2.32 d	39.83 c	2.71 d	210.00d	119.15 d	56.45 d
20 cm x 15 cm(S_2)	34.07 c	2.54 c	40.94 c	2.84 c	220.25c	126.39 c	57.05 c
25 cm x 15 cm(S_3)	35.18 b	2.69 b	42.80 b	3.10 b	229.18b	136.32 b	59.07 b
25 cm x 20 cm(S_4)	36.93 a	2.86 a	44.58 a	3.22 a	234.23a	145.77 a	61.80 a
LS	*	*	**	*	**	**	*
CV(%)	5.41	6.80	5.73	4.64	8.77	7.34	7.21

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS = Levels of significance; CV=Co-efficient of variation.

Table 2. Effect of nitrogen level on the yield components of onion seed crop

Nitrogen levels (Kg ha^{-1})	Plant height (cm)	No. of tillers $plant^{-1}$	Length of scape(cm)	No. of umbels $plant^{-1}$	No. of flowers $umbel^{-1}$	No. of seeded fruits $umbel^{-1}$	% fruit set
0 (N_0)	27.24 d	2.00 d	36.25 d	2.33 c	197.72 d	105.17 d	53.10 c
100 (N_1)	35.65 c	2.52 c	40.47 c	2.95 b	218.10 c	126.00 c	57.55 b
150 (N_2)	37.29 b	2.83 b	43.85 b	3.27 a	234.14 ab	143.55 b	61.15 a
200 (N_3)	39.46 a	3.10 a	47.60 a	3.36 a	243.71 a	152.77 a	62.50 a
LS	**	**	**	**	**	**	**
CV(%)	0.249	6.80	5.73	4.64	8.77	7.34	7.21

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS = Levels of significance, CV=Co-efficient of variation

Out of four spacing, the widest spacing of 25 x 20 cm^2 gave the highest weight of seeds $umbel^{-1}$ (0.60g) which was markedly superior to the seed weight per umbel under other spacing (Table 6). The lowest seed weight (0.36g) was obtained from the bulbs spaced at the closest spacing of 25 x 10 cm^2 (Table 3). The weight of seeds $umbel^{-1}$ was highest (0.58 g) in the plants of the plots which received 200 Kg N ha^{-1}, followed by 150 Kg N ha^{-1} (0.53 g). The lowest weight of seeds $umbel^{-1}$ (0.37 g) was recorded from the plot received 0 Kg N ha^{-1}(Table 4).

Table 3. Effect of spacing on the seed yield and quality of onion seed crop

Spacing	Seed weight $umbel^{-1}$ (g)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1} (Kg)	Thousand seed weight (g)	Germination % of seed
25 cm x 10 cm(S_1)	0.37 d	1.24 d	501.43 a	3.29 a	73.54 bc
20 cm x 15 cm(S_2)	0.44 c	1.31 c	435.54 b	3.17 b	73.52 c
25 cm x 15 cm(S_3)	0.53 b	1.38 b	364.21 c	3.09 c	73.66 b
25 cm x 20 cm(S_4)	0.60 a	1.43 a	281.05 d	2.96 d	76.17 a
LS	**	*	**	**	**
CV(%)	7.68	5.37	6.03	7.53	10.04

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS = Levels of significance, CV=Co-efficient of variation.

Table 4. Effect of nitrogen level on the seed yield and quality of onion

Nitrogen levels (Kg ha^{-1})	Seed weight $umbel^{-1}$ (g)	Seed yield $plant^{-1}$ (g)	Seed yield ha^{-1}(Kg)	Thousand seed weight (g)	Germination % of seed
0 (N_0)	0.36 d	0.71 d	213.53 d	2.70 d	66.19 c
100 (N_1)	0.47 c	1.38 c	409.28 c	3.04 c	74.78 b
150 (N_2)	0.53 b	1.57 b	466.97 b	3.27 b	76.95 a
200 (N_3)	0.58 a	1.68 a	490.13 a	3.40 a	77.32 a
LS	**	**	**	**	**
CV(%)	7.68	5.37	6.03	7.53	10.04

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS = Levels of significance, CV=Co-efficient of variation

A significant gradual increase in seed yield plant^{-1} was recorded with the increase in plant spacing. The highest seed yield plant^{-1} (1.43g) was produced by the bulbs spaced at the widest spacing of 25 x 20 cm^2 significantly followed by the widest spacing 25 x 15 cm^2 and significantly the lowest seed yield plant^{-1}(1.24) was obtained from the bulbs having the closest spacing of 25 x 10 cm^2(Table 3). The effect of nitrogen levels on seed yield per plant was found to be statistically significant. The highest seed yield plant^{-1}(1.68 g) was observed at the highest dose of nitrogen (200 kg ha^{-1}), followed by 150 kg N ha^{-1} (1.57 g), and the lowest seed yield plant^{-1} (0.71 g) was found from 0 kg N ha^{-1} (Table 4).

The estimated effective seed yield ha^{-1} was also higher in closer spacing than that of wider spacing. The bulbs having the closest spacing of 25 x 10 cm^2 showed the highest seed yield ha^{-1} (501.43 kg) followed by the spacing of 20 x 15 cm^2 (435.54 kg) while the lowest seed yield ha^{-1} (281.05 kg) was recorded from the bulbs with the widest spacing 25 x 20 cm^2 (Table 3). Nitrogen level had highly significant influence on seed yield per hectare. When the yield per plot was converted into yield ha^{-1}, the highest seed yield (490.13kg) was also obtained from the application of 200 kg N ha^{-1}, followed by 150 kg N ha^{-1} (466.97 kg) and the lowest seed yield ha^{-1} (213.53 kg) was found from 0 kg N ha^{-1} (Table 4).

Different plant spacing had significant effect on 1000-seed weight. Thousand-seed weight was the highest (3.29 g) for the bulbs planted at closest spacing 25 x 10 cm^2 followed (3.17 g) by the spacing of 20 x 15 cm^2 whereas the lowest 1000-seed weight (2.96 g) was recorded for the bulbs planted at the widest spacing of 25 x 20 cm^2 (Table 3). The effect of nitrogen levels on thousand seed weight was found to be significant. Seed weight was increased gradually with the increased level of nitrogen application. The highest thousand seed weight (3.40 g) was observed at the highest dose of nitrogen (200 Kg ha^{-1}), followed by 150 kg N ha^{-1} (3.27 g) and the lowest thousand seed weight (2.70 g) was found from the control treatment (0 kg N ha^{-1}) (Table 4).

Higher germination percentage (76.17%) was counted in plant spacing 25 x 20 cm^2 but the lowest (73.52%) was recorded in plant spacing 20 x 15 cm^2 which was statistically identical to the germination percentage (73.54%) obtained from spacing 25 x 10 cm^2 (Table 3). The percentage of germination of seed was gradually increased with the increase in the level of nitrogen. The highest germination (77.32%) of seeds was observed from the highest dose of nitrogen (200 Kg ha^{-1}) which was statistically identical to 150 kg N ha^{-1} (76.95%) and the minimum germination (66.19%) was found from 0 Kg N ha^{-1} (Table 4).

Combined effect of spacing and nitrogen level on the yield contributing characters, seed yield and quality of onion seed

The combined effect of plant spacing and nitrogen levels significantly varied in respect of all the yield contributing characters, seed yield and quality of onion seed.

It was observed that the treatment combination of widest plant spacing 25 x 20 cm^2 and the highest doses of nitrogen (200 kg N ha^{-1}) ($S_4 \times N_3$) produced the tallest plant (42.02 cm), maximum number of tillers plant^{-1} (3.40), tallest scape (50.56 cm), maximum number of umbels plant^{-1} (3.60), maximum number of flowers umbel^{-1} (251.87), maximum number of seeded fruits umbel^{-1} (166.87), the highest percentage of fruit set (65.83), highest seed weight umbel^{-1} (0.70 g), the highest seed yield plant^{-1} (1.80 g) and maximum seed yield ha^{-1}(619.24 kg). However, the highest value (3.52g) for 1000-seed weight was found from the treatment combination of the closest spacing 25 x 10 cm^2 with highest doses of nitrogen (200 kg N ha^{-1}) but the highest germination (79.12%) was recorded with the seeds produced from plant spacing of 25 x 20 cm^2 with highest doses of nitrogen (200 kg N ha^{-1}) ($S_4 \times N_2$). Minimum number of tillers plant^{-1} (1.75), scape (44.92 cm), lowest number of umbels plant^{-1} (2.12), minimum number of flowers umbel^{-1} (183.86), the lowest number of seeded fruits umbel^{-1} (95.23), the lowest fruit set (52.17), lowest values of seed weight umbel^{-1} (0.30 g), The lowest number of seed yield plant^{-1} (0.69 g), The lowest seed yield ha^{-1} (154.87 kg), The lowest 1000-seed weight (2.61 g) was recorded from the treatment combination of widest plant spacing 25 x 20 cm^2 with control treatment ($S_4 \times N_0$) (Table 5 and 6).

Table 5. Combined effect of spacing and nitrogen level on the yield components of onion

Spacing × Nitrogen level	Plant height (cm)	No. of tillers plant^{-1}	Length of scape (cm)	No. of umbels plant^{-1}	No. of flowers umbel^{-1}	No. of seeded fruits umbel^{-1}	% fruit set
$S_1×N_0$	26.07 j	1.75 g	34.92	2.12 l	183.86 l	95.23 k	52.17 hi
$S_1×N_1$	34.05 g	2.27 ef	38.54	2.69 h	204.21 j	113.35 h	55.53 g
$S_1×N_2$	35.43 f	2.55 de	41.47	3.00 f	219.94 h	131.19 f	59.44 e
$S_1×N_3$	38.34 c	2.77 cd	44.45	3.08 e	231.76 f	135.78 e	58.49 e
$S_2×N_0$	26.92 i	2.00 fg	35.48	2.26 k	192.63 k	98.93 j	51.39 i
$S_2×N_1$	34.60 g	2.53 de	39.28	2.80 g	212.80 i	120.17 g	56.38 g
$S_2×N_2$	36.36 e	2.70 cd	42.72	3.11 e	233.73 ef	136.97 e	58.61 e
$S_2×N_3$	38.41 c	2.96 bc	46.36	3.21 d	241.79 cd	149.44 c	61.76 cd
$S_3×N_0$	27.34 i	2.10 f	36.38	2.46 j	203.72 j	107.07 i	52.54 h
$S_3×N_1$	36.01 ef	2.63 cd	41.63	3.07 e	225.66 g	130.13 f	57.46 f
$S_3×N_2$	37.51 d	2.86 b-d	44.26	3.36 c	238.58d e	149.37 c	62.38 c
$S_3×N_3$	39.78 b	3.18 ab	48.94	3.48 b	248.76 ab	158.64 b	63.85 b
$S_4×N_0$	28.69 h	2.22 f	38.30	2.53 i	210.49 i	118.85 g	56.40 g
$S_4×N_1$	37.91 cd	2.62 d	42.40	3.21 d	229.68 fg	140.32 d	60.90 d
$S_4×N_2$	39.81 b	3.14 ab	46.90	3.47 b	244.23 bc	156.63 b	63.92 b
$S_4×N_3$	42.02 a	3.40 a	50.56	3.60 a	251.87 a	166.87 a	65.83 a
LS	**	*	NS	**	*	*	**
CV(%)	5.41	6.80	5.73	4.64	8.77	7.34	7.21

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS= Level of Significance, CV=Co-efficient of variation

Table 6. Combined effect of spacing and nitrogen level on the seed yield and quality of onion

Spacing × Nitrogen level	Seed weight umbel^{-1} (g)	Seed yield plant^{-1} (g)	Seed yield ha^{-1} (Kg)	Thousand seed weight (g)	Germination % of seed
$S_1×N_0$	0.30n	0.69j	278.67j	2.87h	64.56ef
$S_1×N_1$	0.37l	1.30h	520.00d	3.25de	76.82ab
$S_1×N_2$	0.42j	1.47e	589.56b	3.41b	76.75ab
$S_1×N_3$	0.47h	1.54d	619.24a	3.52a	76.98ab
$S_2×N_0$	0.34m	0.71j	236.73k	2.82hi	65.43e
$S_2×N_1$	0.43j	1.36g	452.20e	3.16f	73.04c
$S_2×N_2$	0.48h	1.55d	516.60d	3.32c	75.83ab
$S_2×N_3$	0.54f	1.61c	536.60c	3.39b	76.12ab
$S_3×N_0$	0.40k	0.74j	195.38l	2.72j	66.88g
$S_3×N_1$	0.51g	1.43f	378.70g	3.09g	74.42b
$S_3×N_2$	0.57e	1.62c	431.17f	3.19ef	77.89a
$S_3×N_3$	0.62c	1.69b	451.63e	3.33c	77.66a
$S_4×N_0$	0.45i	0.78i	154.87m	2.61k	67.96d
$S_4×N_1$	0.59d	1.44ef	286.44j	2.80i	76.76ab
$S_4×N_2$	0.64b	1.65c	330.44i	3.18f	78.89a
$S_4×N_3$	0.70a	1.80a	352.00h	3.26d	79.12a
LS	*	**	**	*	*
CV(%)	7.68	5.37	6.03	7.53	10.04

In each column, figures having similar letters or without letters do not differ significantly, whereas figures bearing dissimilar letters differ significantly as per DMRT. *= significant at 5% level of probability; ** = Significant at 1% level of probability; NS = Not significant; LS= Level of Significance, CV=Co-efficient of variation

Discussion

Results revealed that the tallest plants were obtained from the wider spacing. Plant height increased with the increase of plant spacing. Plants raised with the widest spacing produced the tallest plant while the closest spacing significantly produced the shortest plant. It is might be due to the effect of wider spacing in which plant can grow freely with proper utilization of nutrients and water from the soil. The higher levels of nitrogen increased the vegetative growth of onion plant, which might be the cause of higher plant height. The increased plant height at the highest level of nitrogen was probably due to the availability of more nutrients, which helped, in maximum vegetative growth of onion plant. Results were in conformity with Abuga (2014), Ahmed *et al*., (2017), Gebretsadik and Dechassa (2016), Ghoname *et al*., (2007) reported maximum plant height in wider row spacing with nitrogenous fertilizers. This result is also in agreement with the results of Ali (2009), Banset *et al*. (2015), Bhardwaj *et al*. (1991), Chanu *et al*. (2022), who noticed taller plants from higher dose of nitrogen. Maximum number of tillers per plant was produced by the plants having the widest spacing. Decreasing number of tillers per plants was found from the plants having decreasing plant spacing. This might be due to comparatively more competition of plants for nutrient, light and moisture at higher plant density. Results were in conformity with Abuga (2014), Ghoname *et al*., (2007), Naik and Hosamani (2004). Due to the higher dose of nitrogen, the vegetative growth of onion plant was increased which helped to increase the number of tillers per plant. Higher number of tillers per plant were obtained from the plant receiving higher nitrogen (Ali 2009; Banset et al. 2015; Chanu et al. 2022 and Rahim et al. 1997).

The result indicated that the higher length of flowering stalk was recorded in respect of the widest plant spacing but the closest spacing produced the lower length of flowering stalk. This might be due to availability of more space, nutrient, water and light. The length of flowering stalk was increased with the increasing nitrogen levels. Reports from several authors also recorded longer flower stalk with higher nitrogen (Ali 2009; Banset et al. 2015 and Bhatia and Pandey 1991).

The maximum number of umbels per plant was produced by bulbs spaced at the widest spacing and the number of umbels per plant was reduced with the decrease in plant spacing. Significantly the lowest number of umbels per plant was recorded from the bulbs having the closest spacing. Decreasing number of umbels per plant with the decrease in plant spacing was also observed by previous workers (Bosu, 1999). This might be due to non-availability of more space and resources such as nutrients, moisture, and light. Number of umbels per plant was increased with the increased rate of nitrogen. As the higher dose of nitrogen improved the development process of onion which led to higher number of umbels per plant. These observations are in agreement with findings of Asaduzzaman et al. (2012), Banset et al. (2015), Bokshi et al. (1989) and Rahim et al. (1997).

The highest number of flowers was recorded from the plant wider spacing and the lowest number of flowers was recorded from the plant closest spacing. Results showed that the maximum number of flowers per umbel was observed in the plants that received highest doses of nitrogen and the minimum number of flowers per umbel was found from control treatment. The increased levels of nitrogen enhanced the growth and uniform development of onion plants that might have influenced on the production of the higher number of flowers per umbel. Ali (2009), Banset *et al*. (2015), Bokshi *et al*. (1989) and Rahim *et al*. (1997) also reported similar results.

The results revealed that maximum number of seeded fruits per umbel was recorded from wider spacing and the number of seeded fruits decreased gradually with close spacing. The minimum number of seeded fruits per umbel was in the closest spacing. It is might be due to the effect of wider spacing in which plant can develop freely with proper utilization of nutrients and water from the soil as well as with nitrogenous fertilizer responsible for vegetative growth. In several experiments, other authors observed that the widest spacing produced the highest percentage of fruit set whereas the closest spacing gave the lowest values (Ali 2009; Asaduzzaman et al. 2012 and Rahim et al. 1997).

Weight of seed per umbel increased with the increase in plant spacing. This is attributed to decreased competition for nutrients and moisture at wider spacing. Similar inference was drawn by Singh et al. (1990) who observed higher seed weight per umbel from wider spacing. The weight of seeds per umbel was highest in the plants of the plots which received higher doses of nitrogen, and the lowest weight of seeds per umbel was recorded from the control plot. Higher dose of nitrogen increased the vegetative growth of onion plant, which helped to increase the number of tillers per plant, number of seeds per umbel and thousand seed weight which might be the cause of higher weight of seeds per umbel. Asaduzzaman et al. (2012), Ali (2009), Bhardwaj et al. (1991) and Bhatia and Pandey (1991) also noticed similar results.

A significant gradual increase in seed yield per plant was recorded with the increase in plant spacing. The highest seed yield per plant was produced by the bulbs spaced at the widest spacing and significantly the lowest seed yield per plant was obtained from the bulbs having the closest spacing. Increasing yield might be due to availability of more space, moisture, nutrient and light at wider plant spacing. Several authors (Bhardwaj 1991; Kanwar et al. 2000; Raijadhav et al. 1992; Singh et al. 1998; Singh and Sachan 1999[a]; and Singh and Sachan 1999[b]) also published a supportive result. The highest seed yield per plant was observed at the highest dose of nitrogen and the lowest seed yield per plant was found from 0 kg N/ha. The higher dose of nitrogen increased the vegetative growth of onion plant which might have helped to increase the number of tillers per plant, number flowers per umbel, number of seeded fruits per umbel and thousand seed weight that resulted higher seed yield per hill. These results are in agreement with the findings of Asaduzzaman et al. (2012), Ali (2009), Banset et al. (2015), Chanu et al. (2022) and Rahim et al. (1997).

The seed yield per plot in closer spacing was maximum in spite of minimum seed yield per plant due to maximum number of plant population. The highest seed yield per plot was obtained from the bulbs with the closest spacing but the lowest from the bulbs having the wider spacing. The highest seed yield per unit area was associated with the closest spacing due to accommodation of maximum number of plants. This result supports the findings of others (Ali et al. 1998; Bhardwaj, 1991; Kanwar et al. 2000; Pandey et al. 1992; Singh and Sachan 1999a and Singh and Sachan 1999).

Since the seed yield per hectare was calculated on the basis of per plot yield. The estimated effective seed yield per hectare was also higher in closer spacing than that of wider spacing. The bulbs having the closest spacing showed the highest seed yield per hectare while the lowest seed yield per hectare was recorded from the bulbs with the widest spacing. The highest seed yield per hectare was directly related to the highest plant population per hectare. Although the seed yield per plant was maximum in wider spacing, larger number of plant population compensated this yield. This result is similar to the findings of others (Ali et al. 1998; Kanwar et al. 2000; Pandey et al. 1992; Singh and Sachan l999a and Singh and Sachan 1999[b]). This result was almost similar to the findings of other authors (Banset et al. 2015, Bokshi et al. 1989; Chanu et al. 2022 and Rahim et al. 1997). Bhatia and Pandey (1991) and Pandey *et al.* (1992) also observed that the higher dose of nitrogen increased the vegetative growth of onion plant which might have facilitated to increase the number of tillers per plant, number of flowers per umbel, number of seeded fruits per umbel and thousand seed weight that resulted higher seed yield per hectare.

Thousand-seed weight was the highest for the seedlings planted at closest spacing whereas the lowest was recorded for the seedlings planted at the widest spacing. The trend of 1000-seed weight was about same for all the plant spacing. This might be due to lower availability of nutrient and water for the plants of all plant spacing. The results support the reports made by Banset et al. (2015). Seed weight was increased gradually with the increased level of nitrogen application. The highest thousand seed weight was observed at the highest dose of nitrogen and the lowest one was found from the control treatment. Increasing levels of nitrogen increased the thousand seed weight of onion was also reported by Bhatia and Pandey (1991).

Higher germination percentage was counted in plant closest spacing and the lowest was recorded in plant widest spacing. Similar result was reported by Singh and Sachan, (1999a). They reported that there was no significant effect on germination percentage by the plant spacing. The percentage of germination of seed was gradually increased with the increase in the level of nitrogen. The highest germination of seeds was observed from the highest dose of nitrogen and the minimum germination was found from the control treatment. Higher doses of nitrogen gave the higher germination percentage. Banset et al. (2015), Bhatia and Pandey (1991) and Bokshi et al. (1989) also found similar observations in their findings.

Conclusion

Plants grown in closer spacing produced the highest seed yield per unit area whereas the seedling grown with wider spacing produced the vigorous seeds with highest weight per plot. Overall performance of spacing it can be concluded that closer spacing produced higher seed yield (501.43 kg /ha) comparing other spacing, So, closer spacing may be recommended for practicing of onion seed production in Rajshahi region of Bangladesh and further investigation may be carried out up to 2-3 years for more precision of the experimental results. On the other hand, higher levels of nitrogen gave higher growth and seed yield (490.13 kg/ha). The highest quantity of seeds (619.24 Kg ha^{-1}) was found in the treatment combination of the closest spacing of 25 x 10 cm^2 with highest doses of nitrogen (200 kg N ha^{-1}) but the superior quality seed was produced from the combination of wider plant spacing of 25 x 20 cm^2 with highest doses of nitrogen (200 kg N ha^{-1}.

Acknowledgment

The work was supported in part by grant from the Ministry of Science and Technology, Government of the People's Republic of Bangladesh (Grant No.3249/2019 to Mst. Sabina Begum).

Authors' Contribution

Conceptualization, MSB, MAA and MAR; Methodology, MSB, MAR and MAR; Investigation, MSB and MAR; Data collection and analysis, MSB and MAA; Draft preparation, MSB and MAA; Review and editing, MAR and MAA. All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interests.

References

Abuga I (2014). The effect of inorganic fertilizer on onion production. International Journal of Biological Sciences 1:21-29.

Ahmed I, Khan MA, Khan N, Ahmed N, Waheed A, Saleem FY, Khan S and Aslam S (2017). Impact of plant spacing on garlic rust (*Puccinia allii*), bulb yield and yield component of garlic (*Allium sativum* L.). Pakistan Journal of Agricultural Research 30: 380-385.

Ali MK (2009). Studies on quality seed production of onion (*Allium cepa* L.) through nitrogen level and application time. Journal of Bangladesh Society of Agricultural Science and Technology 6:141-150.

Ali N, Baloch MA, Hussan SA and Ali N (1998). Study on the effect of planting space and bulb size on the seed production of onion crop. Sarad Journal of Agriculture 14: 563-568.

Asaduzzaman M, Hasan MM, Hasan MM and Moniruzzaman M (2012). Quality seed production of onion (*Allium Cepa* L.): An integrated approach of bulb size and plant spacing. Journal of Agricultural Research 50: 119-28.

Ashagrie **T,** Belew D, Alamerew S **and** Getachew **Y (**2014). Effects of Planting Time and Mother Bulb Size on Onion (*Allium cepa* L.) Seed Yield and Quality at Kobo Woreda,

Northern Ethiopia International Journal Agricultural Research 9: 231-241.

Basnet M, Shakya SM, Shrestha SM and Mishra K (2015). Effect of Nitrogen and off season bulb size on onion seed production. Journal of Institute of Agriculture and Animal Science 33-34: 41-46.

BBS. (2017). Yearbook of Agricultural Statistics- 2017. Bangladesh Bureau of Statistics. Statistics Division. Ministry of Planning. Govt. of the Peoples's Republic of Bangladesh. Dhaka, Bangladesh. Pp. 377.

BBS. (2021). Monthly (February) Statistical Bulletin of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. Pp. 43.

Begum, MS (2015). Effect of planting date, spacing and nitrogen level on growth, yield and quality seed production of onion (*Allium Cepa* L.). M. Phill Thesis, Dept. of Agronomy and Agricultural Extension, University of Rajshahi, Bangladesh. Pp. 114.

Bhardwaj, ML, Rattan RS and Kohli UK (1991). Effect of nitrogen, phosphorus and depth of bulb planting on seed production in onion. Indian Journal of Horticulture 48: 264-268.

Bhatia AK and Pandey UC (1991). Response of planting methods, fertility levels and spacings on seed production of kharif onions. Haryana Agricultural University Journal of Research 19: 352-154.

Bokshi, AI, Mondal MF and Pramanik MHR (1989). Effect of nitrogen and phosphorus nutrition on the yield and quality of onion seeds. Bangladesh Horticulture 17: 30-35.

Boshu GK (1999). Effects of growing in polythene tunnel, spacing and date of planting on the yield and quality of onion seeds. MS Thesis, Department of Horticulture, Bangladesh Agricultural University, Mymensingh, Bangladesh. Pp. 77.

Chanu KI, Devi AKB, Singh UC, Devi, NS and Singh SNG (2022). Effect of different levels of nitrogen and spacing on growth and yield of common onion (*Allium cepa* L.) cv. Prema 178 under Manipur condition. The Pharma Innovation Journal 11: 1268-1274.

Dhaliwal MS (2017). Bulbous Vegetables. In: Handbook of Vegetable Crops. Edn 3, Kalyani Publishers, New Delhi, India. Pp:177-192.

FAO (Food and Agriculture Organization) (2016). Production Yearbook. Food and Agriculture Organization of the United Nations, Rome, Italy. Pp. 153.

FAO (Food and Agriculture Organization) (2015). Food and Agriculture Organization Statistical Year Book, Food and Agriculture Organization of the United Nations, Rome, Italy. Pp. 28.

Farag, IA and Korriem SO. (1996). Influences of size and cutting mother bulb on yield and quality of onion seeds. Assuit Journal of Agricultural Science 27: 97-106.

Gebretsadik K and Dechassa N (2016). Effect of Nitrogen Fertilizer Rates and Intra Row Spacing on Bulb Yield of Onion (*Allium cepa* L.) at Shire, Northern Ethiopia. International Journal of Science and Research 5:1769-1772.

Ghoname A, El-Bassiony AM, Riad GS and Abd El-Baky MMH (2007). Reducing onion bulbs flaking and increasing bulb yield and quality by potassium and calcium application. Australian Journal of Basic and Applied Sciences 1: 610-618.

Gomez KA and Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nd Edn. John Willey and Sons, New York. Pp. 97-411.

Hassan MS (1978). Effect of plant population densities on yield of onion in the Sudan Gezira. Acta. Hort. No.84 p 85-90. HRDP. 1995. Traininig Mannual: Winter vegetable and Spices Production. Horticulture Research and Development Project (FAO/UNDP/AsBD Project. BGD/87/025 and BADC, Dhaka. Pp.284.

Kanwar JS, Gill BS and Bal SS (2000). Response of planting time and density to onion seed yield and quality. Seed Research 28:212-214.

Kokobe W, Derbew B and Adugna D (2013). Effect of farmyard manure and nitrogen fertilizer rates on growth, yield and components of onion (*Allium cepa* L) at Jimma, South West Ethiopia. Asian Journal of Plant Science 12(6-8):228-234.

Mirshekari B and Mobasher M (2006). Effect of sowing date, plant density and onion size on seed yield of Azashahr Red onion variety in Tabriz. Journal of Agricultural Science 12: 397-405.

Mishra HP, Sarkar C, Viswajith KP, Dhekale BS and Sahu PK (2013). Instability and forecasting using ARIMA model in aua, Production and productivity of onion in India. Journal of Crop and Weed 9: 96-101.

Mohanty BK (2001). Effect of planting time on the performance of onion cultivars. Vegetables Science 140-142.

Moses M and Tuarira M (2014). Effects of mulching and fertilizer sources on growth and yield of onion. Journal Glob Innovation Agricultural Society of Science 2: 102-106.

Naik BH and Hosamani RM (2003). Effect of spacing and nitrogen levels on growth and yield of Kharif onion. Karnataka Journal of Agriculture Science 16: 98-102.

Pandey UB, Panwar DS and Sharma VP (1992). Effect of spacing and levels of nitrogen on growth and seed yield of kharif onion. Seed Research 20: 147-148.

Purseglove JW (1972). Tropical Crops (Monocotyledons-1). Longman Group Ltd., London. Pp. 32-50.

Rahim MA, Hakim MA and Rahman MM (1997). Effects of nitrogen and potash on the yield of onion seed. Bangladesh Journal Science and Industrial Research 32: 322-325.

Rai MM (1981). Principles of Soil Sciences. Macmilan India ltd..Calcutta. Pp. 179-182.

Raijadhav SB, Supe VS and Kale PN (1992). Effects of different levels of spacings and cuts to bulbs on seed yield of onion. Journal of Maharashtra Agricultural University 17: 278-279.

Randle WM (2000). Increasing nitrogen concentration in hydrophonic solution affects onion flavor and bulb quality. Journal of Horticultural Science 125: 254-259.

Rashid MHA, Massiah AJ and Thomas B (2016). Genetic regulation of day length adaptation and bulb formation in onion (*Allium cepa* L.). Acta Horticulturae 1143:7-14.

Rashid MHA (2010). Effect of sulphur and GA3 on the growth and yield of onion. Progressive Agriculture 21: 57-63.

Selvaraj S (1976). Onion is queen of kitchen. Kishan World. 3: 32-34.

Singh B, Kumar Y, Sharma RS, Singh B and Kumar Y (1998). Effect of bulb spacing and nitrogen levels on growth and seed yield of onion (*Allium cepa* L.). Seed Research. 26: 180-182.

Singh SR and Sachan BP (1999[a]). Evaluation of different bulb size, spacing and varieties for higher seed yield and yield attributing traits on onion (*Allium cepa* L.). Crop Research, Hissar 17: 351-355.

Singh SR and Sachan BP (1998). Response of different bulb sizes and varieties of onion (*AlIlum cepa* L.). Crop Research, Hisar 15: 57-60.

Singh Daljeet DS, Singh Hari HS, Gill SS and Chadha ML (1990). Effect of plant density on onion seed yield. Ann. Bio. Ludhiana, India 6: 171-172.

Singh SR and Sachan BP (1999[b]). Interaction of bulb size and spacing on seed yield and yield attributing trait of onion (*Allium cepa* L.) cv. Kalyanpur Round Red. Scientific Horticulture 6:125-128.

Vander Meer QP and Van Bennekom JL (1968). Some experiences with growing onion for seed. Zaadbelangen, 22: 291

.