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Optimizing Spacing and Nutrient Sources for Enhanced Yield and Quality of Summer Onion (*Allium cepa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Authors NI and TM planned the experiment and lead the research. Authors FA and TM designed and carried out the research. Author FA performed the statistical analysis. Authors FA and TM carried out the research on the field. Authors FA collected the data and wrote the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript. Author MHR interpreted the results and revised the manuscript. All authors read and approved the final manuscript

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ABSTRACT

Onion (*Allium cepa* L.) is a crucial crop in Bangladesh, but current winter-only cultivation fails to meet national demand. This study aims to optimize summer onion production through proper plant spacing and nutrient management. The field experiment was conducted during the period from

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March to June 2016 in the Horticultural Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to find out the effect of spacing and nutrient sources on yield of summer onion. The experiment consisted of two factors: Factor A: Three levels of spacing. Viz., S_1: 10 cm x 15 cm, S_2: 15 cm x 15 cm, and S_3: 20 cm x 15 cm. Factor B: Four levels of nutrient sources. viz., F_0: (control); F_1: Vermicompost (7 t/ha); F_2: Mustard oil cake (6 t/ha) and F_3: Inorganic fertilizer (N-110 + P-50 + K-125 Kg/ha). There were 12 treatment combinations. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Results indicated that 15x15 cm spacing significantly enhanced plant height, bulb diameter, and yield, achieving 22.03 t/ha. Vermicompost (7 t/ha) yielded the highest plant height, bulb size, and overall yield (20.61 t/ha). Combined treatment of 15x15 cm spacing with vermicompost resulted in the highest yield (24.06 t/ha). These findings suggest that optimized spacing and organic nutrient application can significantly improve summer onion production, potentially reducing dependency on imports and enhancing food security in Bangladesh.

Keywords: Onion; spacing; nutrient sources; variety; yield.

1. INTRODUCTION

Onion (*Allium cepa* L.) is an important herbaceous bulb and spice crop in the world which belongs to the family Alliaceae. It is grown in almost all areas of Bangladesh, but commercial cultivation is found to be concentrated only in the greater division of Dhaka, Rajshahi, Khulna and Rangpur [1]. At present total production of onion was about 2547 metric tons from 503 acres of land in Bangladesh with an average yield of nearly 22.7 t ha^{-1} in the year 2022- 2023 [1]. Onions are grown only in winter season; this production of onions cannot fulfill our national demand. Every year Bangladesh imports huge amount of onion from the neighboring countries and expand crore taka [2,3]. But introducing heat and summer tolerant varieties with proper culture technique, it has now been cultivated in summer season also. Summer onion production is greatly influenced by agronomic practices [4,5,6,7]. The optimum level of any agronomic practice like plant spacing, plant population, planting date, harvesting time can bring desired result. Spacing determines the plant density and is generally dependent upon the expected growth of a particular crop plant variety in a given agro-climatic region [8,9]. Successful bulb production in onion depends on the plant spacing. Spacing influences the plant growth, size of bulbs, yields as well as the quality of the onion bulb [10,11,12]. The balanced fertilization from different nutrient sources plays an important role for enhancing yield and quality in onion. The physical and chemical characteristics of soil are improved by organic fertilizers such cow dung, chicken manure, compost, mustard oilcake, vermicompost, and bio-slurry. These attributes are crucial for onion plant growth, yield, and quality [13,5]. Considering the above facts, the experiment was carried out to maximize summer onion yield and quality by optimizing spacing and nutrient sources.

2. MATERIALS AND METHODS

2.1 Experimental Location and Duration

The experiment was conducted at the Horticultural farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from March 2016 to June 2016.

2.2 Climate and Soil of the Experimental Area

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year. The soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5 (Haider, 1991). The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka.

2.3 Variety

"KSP-30" a high yielding variety was considered for this study as a test material. This is an exotic Indian Onion variety. It has originated from India in 2015. The seed was collected from a

renowned seed company named 'Bejo Sheetal Seeds Pvt. Company Limited'. The days to maturity for this variety is 110-120days after transplanting. The average weight of an individual bulb is 90-100gm. The bulbs are dark red in color with round shape. Seed sowing round the year and the bulbs have long shelf life. The average yield of the bulb is about 35-40 t/hac.

2.4 Treatment and Layout of the Experiment

The experiment consisted of two factors as follows:

Factor A: Three levels of spacing: S_1=10 cm x 15 cm, S_2= 15 cm x 15 cm, S_3= 20 cm x 15 cm **Factor B**: Four levels of nutrient sources: F_0= Control (No organic + No inorganic), F_1= Vermicompost (3.5 t/ha), F_2= Mustard oil cake (4.5 t/ha), F_3= Inorganic fertilizer (N-60 kg + P-25 kg + K 55 kg/ha). Organic fertilizer vermicompost contains 1.76% N, 3.03% P, 1.06% K and mustard oil cake contains 6.4% N, 2.9% P_2O_5 & 2.2% K_2O. Inorganic fertilizer like N-110kg, P-50kg, K-125 kg were applied in the form of Urea 240 kg, TSP 220kg & MP 250kg/ha.

2.5 Experimental Design

The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors with three replications. An area of 20.90 m x 5.10 m was divided into three equal blocks. Each block was consisting of 12 plots where 12 treatments were allotted randomly. There were 36-unit plots in the experiment. The size of each plot was 1.2 m x 0.70 m. The distance between two blocks and two plots were kept 0.75 m and 0.5 m respectively.

2.6 Cultivation Procedure

2.6.1 Land preparation

The land of the experimental field was ploughed with a power tiller on 15 April 2016. Later on, the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded, and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was made ready. The field layout and design was followed after land preparation on 20 April 2016.

2.6.2 Raising of seedlings

The seeds were soaked in water for 15 hours before sowing for a good germination and kept in a piece of cloth for sprouting. Sprouted seeds were sown in a well prepared 3 m x 1 m size seed bed at the rate of two hundred and fifty (250) grams of seeds on each of the two seedbeds on 14 March 2016. After sowing, seeds were covered with light soil. The emergence of the seedlings took place within 7 to 8 days after sowing.

2.6.3 Fertilizer application

Different amounts of manures and fertilizers were applied as per treatment. Manures were applied as the basal dose and inorganic fertilizers like urea (N), TSP (P) and MOP (K) were applied as the split dose per requirement.

2.6.4 Transplanting of seedlings

Healthy and uniform 35 days old seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots on 26 April 2016 maintaining spacing as per treatment between the rows and plants, respectively. Seedlings were also planted around the border area of the experimental plots for gap filling.

2.6.5 Intercultural operations

After transplanting the seedlings, various kinds of intercultural operations were accomplished for better growth and development of the plants. A few gaps filling was done by healthy seedlings of the same stock where initial planted seedling failed to survive. Numbers of weeding were accomplished as and whenever necessary to keep the crop free from weeds and to conserve soil moisture. The first irrigation was given immediate after the transplantation whereas other were applied when and when required depending upon the condition of soil.

Preventive measures were taken against soil born insects. For the prevention of cut worm (*Agrotis ipsilon*) soil treatment was done with Furadan 5G at the rate of 20 kg per hectare. Purple blotch caused by *Alternaria pori* was found to attack many plants in the experimental field. It was controlled by spraying Ridomil and Rovral at the rate of 2g/L of water.

2.7 Data Collection

Eight plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Plant height (cm), Number of leaves plant^{-1}, Length of leaf (cm) were recorded at 15, 30 and 45 days after transplanting (DAT). The plant height (cm) was taken from the neck of the onion bulb to the tip of the longest leaf. The leaf length(cm) was measured from the pseudo stem to the tip of the leaf and the number of leaves from each plant. Yield component data- Length of bulb (cm), Diameter of bulb (cm), Weight of single bulb (g), Yield of bulb plot^{-1} (kg), Yield hectare^{-1} (ton) were collected.

2.8 Statistical Analysis

The recorded data on various parameters were statistically analyzed using MSTAT-C statistical package program developed by Russel (1986). The mean for all the treatments was calculated and analysis of variance (ANOVA) for all the characters were performed by F-Difference between treatment means were determined by Least Significance Difference (LSD) according to Gomez and Gomez, (1984) at 5% level of significance.

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Attributes Influenced by Spacing

Spacing had significant influence on different parameters of summer onion, such as plant height, number of leaves per plant, length of bulb, diameter of bulb, weight of single bulb, yield of bulb per plot (Table 1). The longest plant (51.12 cm), the highest leaves plant^{-1} (10.90), length of bulb (3.83 cm), diameter of bulb (3.92 cm) was recorded from S_2 (15 cm x 15 cm) treatment while the shortest plant (43.78 cm), lowest leaves plant^{-1} (7.40), length of bulb (2.88 cm), diameter of bulb (2.95 cm) was found from S_3 (20 cm x 15 cm) treatment. The maximum weight of single bulb (66.64 g) was observed from S_3 (20 cm x 15 cm) treatment, while the minimum result (22.76 g) was found from S_1 (15 cm x 15 cm) treatment. Successful bulb production in onion depends on the plant spacing. Optimum spacing is one of the important factors to achieve the optimum plant growth, size of bulbs, economically viable yield as well as the quality of the onion bulb [12]. The highest yield of bulb plot^{-1} (1.85 kg), yield hectare^{-1} (22.03 ton) was recorded from S_2 (15 cm x 15 cm) treatment, while the lowest yield of bulb plot^{-1} (1.27 kg), yield hectare^{-1} (15.17 ton) was found from S_1 (10 cm x 15 cm). Wider spacing allowed the plant to have enough room for its natural resources. It might be averting intense rivalry between plants for resources like light, water, and nutrients. [14]. also observed that the wider spacing of 20 cm x 10 cm produced maximum equatorial number of marketable bulbs and total bulb yield [15]. Significant effect of all the growth and yield components of onion and larger percentage of small and medium bulbs were obtained in the narrowest spacing [12].

3.2 Yield and Yield Attributes Influenced by Nutrient Sources

Nutrient sources had significant variations for plant height, number of leaves, bulb length and bulb diameter, bulb weight and estimated yield per hectare. The longest plant (52.00 cm), highest leaves plant^{-1} (10.48), length of bulb (3.54 cm), diameter of bulb (3.75 cm), weight of single bulb (54.28 g), yield of bulb plot^{-1} (1.73 kg), yield hectare^{-1} (20.61 ton) was recorded from F_1 (Vermicompost 7 t/ha) while the shortest plant (45.67 cm), lowest leaves plant^{-1} (7.81), length of bulb (3.54 cm), diameter of bulb (2.26 cm), lowest weight of single bulb (45.97 g), yield of bulb plot^{-1} (1.47 kg) , yield hectare^{-1} (17.60 ton) was found from F_0 (Control) treatment which is statically similar to F_3 treatment. Maximum leaf length, plant height, bulb length and yield ha^{-1} were recorded due to using organic nutrient sources [16]. Organic material such as farmyard manure, mustard oil cake, vermicompost, poultry manure and bio-slurry improve soil physical and chemical properties that might be important for plant growth. Many researchers have found that addition of animal manure resulted in higher onion yield and nutrient uptake compared to NPK fertilizer [17,18]. The height bulb diameter was recorded with the application of FYM +vermicompost in onion [4]. The application of vermicompost alone has produced significantly higher bulb yield and fresh weight of bulb [19,14,20].

Table 1. Effect of spacing on plant height, number of leave per plant, length of bulb, diameter of bulb, weight of single bulb, yield of bulb per plot, yield per hectare of summer onion

Treatment	Plant height (cm)	No. of leave/plant	Length of bulb (cm)	Diameter of bulb (cm)	Weight of single bulb (g)	Yield of bulb /plot (kg)	Yield (t/ha)
S_1	47.37 b	8.23 b	3.45 b	3.53 b	22.76 c	1.27 c	15.17 c
S_2	51.12 a	10.9 a	3.83 a	3.92 a	57.84 b	1.85 a	22.03 a
S_3	43.78 c	7.4 c	2.88 c	2.95 c	66.64 a	1.59 b	19.04 b
LSD (0.05)	0.81	0.31	**0.14**	**0.11**	**0.31**	**15.52**	**0.10**
CV (%)	2.07	4.29	**5.27**	**4.27**	**8.29**	**7.58**	**5.63**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. S_1: 10 cm × 15 cm, S_2: 15 cm × 15 cm, S_3: 20 cm × 15 cm

Table 2. Effect of nutrient sources on plant height, number of leave per plant, length of bulb, diameter of bulb, weight of single bulb, yield of bulb per plot, yield per hectare of summer onion

Treatment	Plant height (cm)	No. of leave/plant	Length of bulb (cm)	Diameter of bulb (cm)	Weight of single bulb (g)	Yield of bulb /plot (kg)	Yield (t/ha)
F_0	45.67 c	7.81 d	3.24 b	3.26 c	45.97 c	1.47 c	17.60 c
F_1	52.00 a	10.48 a	3.54 a	3.75 a	54.28 a	1.73 a	20.61 a
F_2	47.89 b	9.26 b	3.39 ab	3.48 b	49.90 b	1.60 b	19.07 b
F_3	47.12 b	8.15 c	3.37 b	3.37 bc	46.18 c	1.48 c	17.72 c
LSD (0.05)	0.93	0.35	**0.16**	**0.13**	**0.36**	**17.92**	**0.12**
CV (%)	2.07	4.29	**5.27**	**4.27**	**8.29**	**7.58**	**5.63**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. F_0: Control (No nutrients), F_1: Vermicompost (7 t/ha), F_2: Mustard oil cake (6 t/ha), F_3: Inorganic fertilizer (N-110 kg, P-50 kg, K-125 kg/ha)

3.3 Combined Effects of Spacing and Nutrient Sources on Yield and Yield Attributes of Summer Onion

The combined effects of spacing and nutrients showed significant difference on yield and yield attributes of summer onion. The longest plant (53.78 cm) and leaves plant^{-1} (9.15) was recorded from S_2F_1 (15 cm x 15 cm + Vermicompost 7 t/ha) treatment combination which is statically identical to S_2F_2 treatment combination while the shortest (42.12 cm) plant and leaves plant^{-1} (6.81) was observed in S_3F_0 (20 cm x 15 cm + Control) treatment combination. However, the highest length of bulb (4.03 cm) was recorded from S_2F_1 (15 cm x 15 cm + Vermicompost 7 t/ha) treatment combination which is statically similar to S_2F_3 and S_2F_2 treatment combination and the lowest length of bulb (2.69 cm) was found from S_3F_0 (20 cm x 15 cm + Control) treatment combination which is statically identical to S_3F_1 treatment combination. The highest diameter of bulb (4.40 cm) was observed from S_2F_1 (15 cm x 15 cm + Vermicompost 7 t/ha) treatment combination and the lowest diameter of bulb (2.73 cm) was found from S_3F_0 (20 cm x 15 cm + Control) treatment combination which is statically identical to S_3F_1 treatment combination. On the other hand, the maximum weight of single bulb (75.32 g) was recorded from S_3F_1 (20 cm x 15 cm + Vermicompost 7 t/ha) treatment combination and the lowest weight of single bulb (20.98 g) was found from S_1F_0 (10 cm x 15 cm + Control) treatment combination. Whereas the highest yield of bulb plot^{-1} (2.02 kg) and yield hectare^{-1} (24.06 ton) was recorded from S_2F_1 (15 cm x 15 cm + Vermicompost 7 t/ha) treatment combination and the lowest yield of bulb plot^{-1} (1.17 kg), and yield hectare^{-1} (13.98 ton) was found from S_1F_0 (10 cm x 15 cm + Control) treatment combination (Table 3). That the growth of onion parameters was significantly influenced by the application of soil and foliar application of nutrients with proper spacing [16]. Significantly higher plant height in onion with application of vermicompost was reported [21]. This might be vermicompost has an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and

Table 3. Combined effect of spacing and nutrient sources on plant height, number of leave per plant, length of bulb, diameter of bulb, weight of single bulb, yield of bulb per plot, yield per hectare of summer onion

Treatment	Plant height (cm)	No. of leave/plant	Length of bulb (cm)	Diameter of bulb (cm)	Weight of single bulb (g)	Yield of bulb /plot (kg)	Yield (t/ha)
S_1F_0	46.78de	8.15 cd	3.46 d	3.46 e	20.98 k	1.17 k	13.98 k
S_1F_1	47.78.cd	8.15 cd	3.53 cd	3.53 de	24.38 h	1.37 h	16.25 h
S_1F_2	45.78 ef	7.81 de	3.16 e	3.40 e	23.18 i	1.30 i	15.45 i
S_1F_3	49.12 bc	8.81 ab	3.66 bcd	3.73 bcd	22.53 j	1.26 j	15.02 j
S_2F_0	48.12 cd	8.48 bc	3.56 cd	3.60 cde	56.81 f	1.82 c	21.64 c
S_2F_1	53.78 a	9.15 a	4.03 a	4.40 a	63.16 c	2.02 a	24.06 a
S_2F_2	52.78 a	9.15 a	3.93 ab	3.90 b	58.91 e	1.88 b	22.44 b
S_2F_3	49.78 b	8.81 ab	3.79 abc	3.80 bc	52.50 g	1.68 d	20.00 d
S_3F_0	42.12 h	6.81 f	2.69 f	2.73 g	60.12 d	1.44 g	17.17 g
S_3F_1	43.78 g	7.48 e	2.79 f	2.80 g	75.32 a	1.81 c	21.52 c
S_3F_2	45.12 fg	7.81 de	3.09 e	3.16 f	67.62 b	1.62 e	19.32 e
S_3F_3	44.12 g	7.48 e	2.93 ef	3.13 f	63.52 c	1.52 f	18.15 f
LSD (0.05)	**1.62**	**0.58**	**0.28**	**0.22**	**0.62**	**0.031**	**0.21**
CV (%)	**7.14**	**8.31**	**5.27**	**4.27**	**13.51**	**7.58**	**5.63**

In a column, means with similar letter (s) are not significantly different by LSD at 5% level of significance. S_1: 10 cm × 15 cm, S_2: 15 cm × 15 cm, S_3: 20 cm × 15 cm; F_0: Control (No nutrients), F_1: Vermicompost (7 t/ha), F_2: Mustard oil cake (6 t/ha), F_3: Inorganic fertilizer (N-110 kg, P-50 kg, K-125 kg/ha)

populations, improving the moisture-holding capacity of soil, increasing the soil cation exchange capacity (CEC) and increasing crop yield [14].

4. CONCLUSIONS

The current study demonstrated that both spacing and nutrient sources significantly influenced the yield and yield attributes of summer onions. The optimal results were observed with a spacing of 15 cm x 15 cm and the application of vermicompost at 7 t/ha. This combination yielded the highest plant height, number of leaves, bulb size, and overall yield per hectare. Therefore, adopting this spacing and nutrient management practice can substantially enhance summer onion production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1.ChatGPT, GRT-3.5, large language model and Open AI, Microsoft
2. Quillbot, windows word version 16.0.1162 & word online, formal model and writing tool that uses generative AI to do a variety of tasks related to writing.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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