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Growth and Yield of Onion (Bari Piaz4) as Influenced by Row Spacing and Organic and Inorganic Nitrogen with Micro Bio Fertilizer

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Abstract

This study was conducted to evaluate the impact of different row spacings and nitrogen fertilizer levels on the growth and yield of BARI Piaz4 onions. The experiment, carried out from October 2021 to January 2022 at the Agronomy Field Laboratory, University of Rajshahi, employed a Randomized Complete Block Design (RCBD) with three replications. Two factors were tested: nitrogen fertilizer types (N1: 100% Chemical Nitrogen + MBF, N2: 100% Organic Nitrogen + MBF, N3: 50% Organic Nitrogen + 50% Chemical Nitrogen + MBF) and row spacings (S1: 10 cm x 5 cm, S2: 12 cm x 8 cm). Results indicated that the N3 treatment (50% Organic Nitrogen + 50% Chemical Nitrogen + MBF) yielded the highest values for plant height (72.58 cm), leaf number (8.56), leaf length (56.19 cm), bulb length (6.72 cm), bulb diameter (4.68 cm), fresh weight (46.31 g), dry weight (26.94 g), and yield (12.56 t ha^{-1}). In contrast, N1 produced the highest neck diameter (2.47 cm). The wider row spacing (S2) showed superior growth parameters except for yield, where S1 resulted in the highest yield (12.56 t ha^{-1}). Significant interaction effects were noted, with the combination of N3 and S2 achieving the highest values across all growth and yield parameters, including plant height (78.89 cm), leaf number (9.28), bulb length (7.43 cm), bulb diameter (5.11 cm), and yield (13.27 t ha^{-1}). The study concludes that a combination of 50% Organic Nitrogen + 50% Chemical Nitrogen + MBF and a 12 cm x 8 cm spacing is optimal for onion cultivation and recommends further research to validate these findings.

Keywords: Onion yield; Nitrogen fertilizer; Organic nitrogen; Chemical nitrogen; Micro bio-fertilizer (MBF); Row spacing

Abbreviations: MBF: Micro Bio-Fertilizer; RCBD: Randomized Complete Block Design; DMRT: Duncan's Multiple Range Test; AEZ: Agro Ecological Zone

Introduction

Onion (*Allium cepa* L.), popularly referred to as "Queen of Kitchen." is an important herbaceous bulb and spice crop in the world which belongs to the family Alliaceae. It is also considered as the most important vegetable crops commercially grown in the world. Onion is mainly used as spices but it is also used as condiments for flavoring food and also as delicious vegetables and salad crop. Onion is liked for its flavor and pungency which is due to the presence of a volatile oil 'allyl propyl disulphide'-organic compound rich in sulphur. Onion has got good medicinal value. Recently onion is being used by processing industry to greater extent for preparing dehydrated forms like powder and flakes. Currently, Bangladesh ranks seventh in the production of onion and similar spices (BBS, 2023). It is groom in almost all the districts of Bangladesh, but it is commercially cultivated in the greater districts of Faridpur, Rajshahi, Mymensingh, Comilla, Jessore, Rangpur and Pabna [1]. Onion production in Bangladesh during the fiscal year of 2021-2022 was 2.27 million tonnes which is 45 percent more than that of six years ago (BBS, 2023). Onions are the most susceptible crop plants in extracting nutrients, especially the immobile types, because of their shallow and unbranched root system; hence they require and often respond well to addition of fertilizers [2].

Therefore, optimum fertilizer application and cultivation of suitable varieties with appropriate agronomic practices in specific environment are necessary for obtaining good yield of onion. Nitrogen (N) and phosphorus (P) are often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and the large quantities taken up from the soil relative to other essential nutrients [3]. Nitrogen plays an important role for optimum yield of onion and is found to be essential to increase the bulb size and yield. Increasing nitrogen application rates significantly enhances plant height, number of green leaves per plant and weight of bulb, marketable yield and also total soluble solids [4].

In addition to nitrogen, plant spacing is an important factor determining onion yield and quality. A crop canopy development from essential aspect of any crop production system is commonly managed by manipulating row spacing and plant population; as plant density increases, yield per unit area increases and will approach an upper limit, the plateau. Then, the yield per unit area declines since yield per plant tends to decrease with further increase in the plant density because of competition for growth factors between adjacent plants [5]. Planting density greatly influences quality, texture, taste and yield of onion even within a particular variety [6]. Yield responses to plant population need to be known for practical purposes, as planting density is a major management variable used in matching crop requirements to the resources by the environment [7]. Coleo et al. [8] reported that the highest commercial bulb yield was recorded at a higher planting density, but the highest proportion of large bulbs and average bulb weight at lower planting density. To optimize onion productivity a specific package of recommendation of nitrogen fertilizer and plant spacing is required.

Material and Methods

The experiment was conducted at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the period from October 2020 to January 2021 to study the influence of row spacing and nitrogen fertilizers level on the growth and yield of BARI Piaz4. The experimental field was situated at the western side of Agronomy and Agricultural Extension Department. Geographically the experimental field was located at 24022’36’’ N latitude and 88038’ 36’’E longitude at an elevation of 20m above the sea level belonging to the agro ecological zone (AEZ-11). The land of the experimental field was flat, well drained and above flood level (Medium high land). The soil was sandy loam textured having pH value of 8.1 composite soil sample was collected from 0-15 cm depth of the experimental plot before applying any fertilizer and was analyzed for physical and chemical properties. The experimental field was under subtropical climate characterized by moderately high temperature and heavy rainfall during the Boro season (October to Mar) and scantly rainfall with moderately low temperature during the rabi season (October to March).

Planting Material used for the Experiment

Seeds of onion cultivar namely “BARI Piaz1” was used for the experiment. The seeds were collected from Khorkhori bazar, Rajshahi. The experiment consists of two factors which are - Factor A: Nitrogen i.e. 1. N_1 =100% Chemical Nitrogen + MBF, 2. N_2 =100% Organic Nitrogen + MBF and 3. N_3 = 50%Organic Nitrogen +50% Chemical Nitrogen + MBF and Factor B: Spacing i.e. 1. S_1 =Row to Row 10cm and Plant to plant 5cm; 2. S_2 =Row to Row 12 cm and Plant to plant 8cm. The two-factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Details of the Field Operations

The selected land for raising seedlings was fine textured and well drained. The land was opened and drying for 10 days. Seedbed was made on 10 October, 2020 for raising seedlings and the size of the seedbed was 3 m with a height of about 20 cm. For making seedbed, the soil was prepared by ploughing and cross ploughing along with removal of weeds, stubbles and other impurities. Cowdung @9 t/ha was applied to the prepared seedbed. Applying Furadan 3G @ 20 kg/ha was covered by polythene for two days. Onion seeds were soaked overnight (12 hours) in water and allowed to sprout in a piece of moist cloth keeping in the sun shade for one day. Seeds were treated by Vitavax-200 @ 5g/1kg seeds to protect some seed borne diseases. The date of the seed sowing was 20 October, 2020. Seeds were sown on in the seedbed to get 35 days old seedlings. Seeds was sown at a depth of 0.6 cm and covered with a fine layer of soil followed by light watering by water can. Shade was given over the seedbed to retain soil moisture and to save the seedlings from direct sun and rain. Light watering and weeding were done several times. No chemical fertilizers were applied for rising of seedlings. When the seedlings of the seedbeds attained a height of about 10 cm, thinning operation was done. Healthy and 35 days old seedlings were transplanted into the main field on 25 November, 2020. Besides, some other cultural operations like final land preparation and application of manures and fertilizers on it, transplanting of seedlings, irrigation, harvesting and storage also done consecutively. Some intercultural operations i.e., weeding, thinning, mulching, earthing up and most importantly staking are notable around the whole cultivation and production period.

Collection of Data

Data were collected on the following parameters -

- Growth parameters: Plant height (cm), Leaf length (cm), Leaf number, Leaf diameter (cm)
- Yield contributing parameters: Neck (pseudostem) diameter (cm), Bulb length (cm), Bulb diameter (cm), Fresh weight (g), Dry weight (g)
- Yield parameters i.e., Yield ha^{-1} (t)

Statistical Analysis

The data recorded were compiled and tabulated for statically analysis. The collected data were analyzed statistically using

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the statistical package "STATVIEW" (Apple, 1985). The mean differences were adjudged by Duncan's multiple range test (DMRT).

Results

Data obtained from the experiment with respect to growth, yield and yield-contributing characteristics of onion influenced by intra-row spacing and nitrogen fertilizer levels were statistically analyzed and the results have been presented in tables 1 to 4. The growth parameters of onion variety under the nitrogen fertilizers level and spacing as well as their interactions were discussed in this section.

Plant Height (cm)

Significant differences in plant height of onion were observed under different types of nitrogen sources at all observations (35, 65 and 95 days after transplanting) (Table 1). At 35 DAT, the tallest plant (57.68 cm) was observed in N_1 due to the application of 100% Chemical Nitrogen along with MBF which is statistically similar with N_3 and shortest plant (54.99 cm) was recorded from N_2. At 65 DAT, the highest plant height (66.58 cm) was found in N_3 showing non-significant results with N1 and lowest plant height (58.6 cm) was recorded from N_2. At 95 DAT, the plant height was highest (72.58 cm) in N_3 and lowest (64.60 cm) in was observed in N_2. Significant difference in plant height was observed at all growth stages (35, 65 and 95 DAT) due to different spacing (Table 1). At 35 DAT, the plant height (61.34 cm) observed in S_2 using spacing of 12cm × 8cm was higher than that of S_1 (54.56 cm) i.e. by maintaining 10cm × 5cm spacing. At 65 DAT, the tallest plant (68.35 cm) was recorded form S_2 and the shortest plant (56.86 cm) was found in S_1. At 95 DAT, highest plant height (74.35 cm) was recorded from S_2 and lowest plant height (62.86 cm) was found from S_1. Plant height was statistically significant due to interaction between nitrogen fertilizers level and spacing at all observations (35, 65 and 95 days after transplanting) (Table 1). At 35 DAT, the highest plant height (65.16 cm) was examined in combination of N_3 with S_2 and lowest plant height (51.33 cm) was recorded from N_2S_1. At 65 DAT, the tallest plant (69.4 cm) was observed from combination of N_3 with S_2 and shortest plant (53.19 cm) was found in combination of N_2 with S_1. At 95 DAT, the highest value for plant height (78.89 cm) was given by N_3S_2 interactions meanwhile corresponding lowest value for plant height (59.19 cm) was found in combination of N_2 with S_1.

Table 1: Varietal differences, nitrogen fertilizations and their interactions in growth parameters of Onion.

Nitrogen	Plant height(cm)			Leaf number		
	35 DAT	65 DAT	95 DAT	35 DAT	65 DAT	95 DAT
N_1	57.68±1.76ab	62.63±3.15ab	68.63±2.94ab	6.28 ± .28ab	6.67 ± .15ab	8.17 ± .33a
N_2	54.99±2.32b	58.6±3.09b	64.6±2.88ab	5.78 ± .33b	6.28 ± .20b	7.78 ± .42a
N_3	61.18±2.17a	66.58±3.54a	72.58±3.33a	6.89 ± .38a	7.06 ± .38a	8.56 ± .40a
Spacing						
S_1	54.56±1.50b	56.86±1.85b	62.86±1.61b	5.81 ± .24b	6.19 ± .08b	7.69 ± .26b
S_2	61.34±1.41a	68.35±2.08a	74.35±1.86a	6.81 ± .26a	7.15 ± .22a	8.65 ± .29a
Nitrogen × Spacing						
N_1S_1	55.14±.2.06bc	57.12±3.32cd	63.12±2.74cd	5.89 ± .39bc	6.33 ± 0.00bc	7.83 ± .46ab
N_1S_2	60.22±2.18ab	68.15±2.84ab	74.15±2.27ab	6.67 ± .29ab	7.00 ± .00b	8.5 ± .46ab
N_2S_1	51.33±3.09c	53.19±2.85d	59.19±2.27d	5.22 ± .39c	5.89 ± .11c	7.39 ± .56b
N_2S_2	58.64±1.99abc	64±3.22abc	70±2.64bc	6.33 ± .29abc	6.67 ± .19b	8.17 ± .65ab
N_3S_1	57.21±2.04bc	60.27±3.03bcd	66.27±2.45bcd	6.33 ± .29abc	6.33 ± 0.00bc	7.83 ± .46ab
N_3S_2	65.16±1.91a	6.4±3.69a	78.89±3.12a	7.44 ± .58a	7.78 ± .44a	9.28 ± .24a
LS	0.05	0.05	0.05	0.05	0.05	0.05
CV (%)	6.72	8.77	6.56	10.55	5.2	10.39

Mean values in a column having a different letter (s) differed significantly, CV= Co-efficient of variation, LS= Level of significance, N_1 =100% CN + MBF, N_2 =100% ON + MBF, N_3 =50%ON +50% CN+ MBF, S_1=10cm × 5cm and S_2 = 12cm × 8cm.

Leaf Number

This section summarizes the findings about significant differences in leaf number of onion that was observed under different types of nitrogen sources at all observations (35, 65 and 95 days after transplanting) (Table 1). At 35 DAT, the highest leaf number (6.89) was observed in N_3 and lowest number of leaf (5.78) was recorded from N_2. At 65 DAT, the highest leaf number (7.06) was observed in N_3 showing non-significant results with N_1 and lowest leaf number (6.28) was recorded from N_2. At 95 DAT,

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leaf number was non-significant. In that case, the leaf number was highest (8.56) in N_3 and lowest (7.78) in N_2. Significant difference in leaf number was observed at all growth stages (35, 65 and 95 days after transplanting) due to different spacing (Table 1). At 35 DAT, the highest leaf number (6.81) was observed in S_2 using spacing of 12cm × 8cm and lowest value for leaf number (5.81) was found in S_1 i.e. by maintaining 10cm × 5cm spacing. At 65 DAT, the maximum leaf number (7.15) was recorded form S_2 and minimum leaf number (6.19) was found in S_1. At 95 DAT, highest leaf number (8.65) was recorded from S_2 and lowest leaf number (7.69) was found from S_1. Statistically significant differences in leaf number of onion were observed at all growth stages (35, 65 and 95 days after transplanting) due to interaction between nitrogen fertilizers level and different spacing (Table 1). At 35 DAT, the highest leaf number (7.44) was observed in combination of N_3 with S_2 and lowest leaf number (5.22) was found in N_2S_1. At 65 DAT, the highest no of leaf (7.78) was recorded form N_3 with S_2 and lowest no of leaf (5.89) was found in N_2S_1. At 95 DAT, highest leaf no (9.28) was recorded from the combination of N_3 with S_2 and lowest number of leaf (7.39) was found from N_2S_1.

Leaf Length (cm)

The present study confirmed the findings about significant differences in leaf length of onion which was observed under different types of nitrogen sources at all observations (35, 65 and 95 days after transplanting) (Table 2). At 35 DAT, the highest leaf length (49.95 cm) was observed in N_3 and lowest length of leaf (45.61 cm) was recorded from N_2. At 65 DAT, the highest leaf length (52.19 cm) was observed in N3 showing non-significant results with N_1 and lowest leaf length (74.74 cm) was recorded from N_2. At 95 DAT, leaf length was significant. In that case, The leaf length was highest (56.19 cm) in N_3 and lowest (51.47 cm) was in N_2. Significant difference in leaf length was observed due to different spacing (Table 2). At 35 DAT, the highest leaf length (49.93 cm) was observed in S_2 and lowest value for leaf length (45.47 cm) was found in S_1. At 65 DAT, the highest leaf length (53.96 cm) was recorded form S_2 and lowest leaf length (45.97 cm) was found in S_1. At 95 DAT, highest leaf length (57.96 cm) was recorded from S_2 and lowest leaf length (49.97 cm) was found from S_1. Statistically significant differences in leaf length of onion were observed due to interaction between nitrogen fertilizers level and different spacing (Table 2). At 35 DAT, the highest leaf length (52.40 cm) was observed in combination of N_3 with S_2 and lowest leaf length (43.02 cm) was found in N_2S_1. At 65 DAT, the highest leaf length (56.12 cm) was recorded form N_3 with S_2 and lowest leaf length (43.63 cm) was found in N_2S_1. At 95 DAT, highest leaf length (60.12 cm) was recorded from the combination of N_3 with S_2 and lowest leaf length (47.63 cm) was found from N_2S_1.

Table 2: Varietal differences, nitrogen fertilizations and their interactions in growth parameters of Onion.

Nitrogen	Leaf length(cm)			Leaf diameter(cm)		
	35 DAT	65 DAT	95 DAT	35 DAT	65 DAT	95 DAT
N_1	47.55 ± 1.15ab	50.23 ± 2.38ab	54.23 ± 2.38ab	.78 ± .05a	.90± .04ab	1.03 ± .03ab
N_2	45.61 ± 1.62b	47.47 ± 2.22b	51.47 ± 2.22b	.71 ± .06a	.81± .05b	.94 ± .04b
N_3	49.95 ± 1.68a	52.19 ± 2.04a	56.19 ± 2.04a	.81 ± .04a	1.04 ± .10a	1.17 ± .10a
Spacing						
S_1	45.47 ± 1.06b	45.97 ± 1.29b	49.97 ± 1.29b	.70 ± .04b	.80 ± .03b	.93 ± .02b
S_2	49.93 ± 1.11a	53.96 ± 1.18a	57.96 ± 1.18a	.84 ± .03a	1.03 ± .06a	1.16 ± .06a
Nitrogen × Spacing						
N_1S_1	45.89 ± 1.33bc	46.01 ± 2.44cd	50.01 ± 2.44cd	.73 ± .06ab	.82 ± .05bc	.95 ± .02bc
N_1S_2	49.21 ± 1.46ab	54.46 ± 2.11ab	58.46 ± 2.11ab	.83 ± .06a	.97 ± .04b	1.10 ± .01b
N_2S_1	43.02 ± 2.16c	43.63 ± 1.89d	47.63 ± 1.89d	.62 ± .05b	.72 ± .04c	.85 ± .01c
N_2S_2	48.19 ± 1.31abc	51.31 ± 2.51abc	55.31 ± 2.51abc	.81 ± .06a	.90 ± .03bc	1.03 ± .01bc
N_3S_1	47.50 ± 1.39abc	48.26 ± 2.28bcd	52.26 ± 2.28bcd	.76 ± .05ab	.87 ± .02bc	1 ± .02bc
N_3S_2	52.40 ± 2.48a	56.12 ± .34a	60.12 ± .34a	.87 ± .04a	1.22 ± .14a	1.35 ± .15a
LS	0.05	0.05	0.05	0.05	0.05	0.05
CV (%)	6.35	7.16	6.63	12.32	12.9	10.46

Mean values in a column having a different letter (s) differed significantly, CV= Co-efficient of variation, LS= Level of significance, N_1 =100% CN + MBF, N_2 =100% ON + MBF, N3 =50%ON +50% CN+ MBF, S_1=10cm × 5cm and S_2 = 12cm × 8cm.

Leaf Diameter (cm)

Leaf diameter were statistically significant under different types of nitrogen sources except 35 DAT (Table 2). At 35 DAT, the highest leaf diameter (0.81 cm) was observed in N_3 and lowest diameter of leaf (0.71 cm) was recorded from N_2. At 65 DAT, the highest leaf diameter (1.04 cm) was observed in N_3 showing non-significant results with N_1 and lowest leaf diameter (0.81 cm) was

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recorded from N_2. At 95 DAT, The leaf diameter was highest (1.17 cm) in N_3 and lowest (1.03 cm) was in N_2. Statistically significant difference in leaf diameter was observed due to different spacing (Table 2). At 35 DAT, the highest leaf diameter (0.84 cm) was observed in S_2 and lowest value for leaf diameter (0.70 cm) was found in S_1. At 65 DAT, the highest leaf diameter (1.03 cm) was recorded form S_2 and lowest leaf diameter (0.80 cm) was found in S_1. At 95 DAT, highest leaf diameter (1.16 cm) was recorded from S_2 and lowest leaf diameter (0.93 cm) was found from S_1. Significant differences in leaf diameter of onion were observed due to interaction between nitrogen fertilizers level and different spacing (Table 2). At 35 DAT, the highest leaf diameter (0.87 cm) was observed in combination of N_3 with S_2 and lowest leaf diameter (0.62 cm) was found in N_2S_1. At 65 DAT, the highest leaf diameter (1.22 cm) was recorded form N_3 with S_2 and lowest leaf diameter (0.72 cm) was found in N_2S_1. At 95 DAT, highest leaf diameter (1.35 cm) was recorded from the combination of N_3 with S_2 and lowest leaf diameter (0.85 cm) was found from N_2S_1.

Bulb Diameter (cm)

Bulb diameter were statistically significant under different types of nitrogen sources at all observations except at 65 DAT (Table 3). At 35 DAT, the highest bulb diameter (2.34 cm) was observed in N_3 and lowest diameter of bulb (2.02 cm) was recorded from N_2. At 65 DAT, the highest bulb diameter (2.88cm) was observed in N_3 showing non-significant differences with N_1 and N_2 and lowest bulb diameter (2.35 cm) was recorded from N_2. At 95 DAT, the bulb diameter was highest (4.68 cm) in N_3 and lowest (4.15 cm) was in N_2. Statistically significant difference in bulb diameter of onion was observed due to different spacing (Table 3). At 35 DAT, the highest bulb diameter (2.41 cm) was observed in S_2 and lowest value for bulb diameter (1.95 cm) was found in S_1. At 65 DAT, the highest bulb diameter (2.98 cm) was recorded form S_2 and lowest bulb diameter (2.25 cm) was found in S_1. At 95 DAT, highest bulb diameter (4.78 cm) was recorded from S_2 and lowest bulb diameter (4.05 cm) was found from S_1. Significant differences in bulb diameter of onion were observed due to interaction between nitrogen fertilizers level and different spacing (Table 3). At 35 DAT, the highest bulb diameter (2.65 cm) was observed in combination of N_3 with S_2 and lowest bulb diameter (1.87 cm) was found in N_2S_1. At 65 DAT, bulb diameter was non-significant. In that case, the highest bulb diameter (3.31 cm) was recorded form N_3 with S_2 and lowest bulb diameter (2.00 cm) was found in N_2S_1. At 95 DAT, highest bulb diameter (5.11 cm) was recorded from the combination of N_3 with S_2 and lowest bulb diameter (3.80 cm) was found from N_2S_1.

Table 3: Varietal differences, nitrogen fertilizations and their interactions in yield contributing parameters of onion.

Nitro-gen	Bulb diameter (cm)			Bulb length (cm)			Neck diameter (cm)		
	35 DAT	65 DAT	95 DAT	35 DAT	65 DAT	95 DAT	35 DAT	65 DAT	95 DAT
N_1	2.18 ± .10ab	2.61 ± .14c	4.41 ± .20ab	3.61 ±.18ab	4.60±.26b	6.10±.27b	1.08 ± .04b	1.35 ± .03ab	2.47 ± .03ab
N_2	2.02 ± .07b	2.35 ± .16b	4.15 ± .22b	3.36 ±.20b	4.19±.28b	5.69±.29b	1.02 ± .05b	1.24 ± .06b	2.36 ±.06b
N_3	2.34 ± .18a	2.88 ± .20a	4.68 ± .23a	3.84 ±.20a	5.22±.37a	6.72±.33a	1.25 ± .11a	1.51 ± .11a	2.36 ± .11a
Spacing									
S_1	1.95 ± .02b	2.25 ± .07b	4.05 ± .13b	3.29 ±.12b	4.09±.18b	5.59±.18b	1.00 ± .03b	1.24 ± .04b	2.36 ±.04b
S_2	2.41 ± .10a	2.98 ± .10a	4.78 ± .14a	3.91 ±.13a	5.26±.21a	6.76±.19a	1.24 ± .07a	1.49 ± .07a	2.61 ±.07a
Nitrogen × Spacing									
N_1S_1	1.96 ± .01c	2.30 ± .02c	4.10 ± .19bc	3.34±.21bc	4.14±.32cd	5.64±.34cd	.99 ± .01b	1.30 ± .01bc	2.42 ±.01c
N_1S_2	2.40 ± .06ab	2.92 ± .09b	4.72 ± .26ab	3.87±.20ab	5.06±.18b	6.56±.20b	1.16 ± 00b	1.41 ± .01b	2.53 ±.01b
N_2S_1	1.87 ± .04c	2.00 ± .09d	3.80 ± .26c	3.06±.22c	3.61±.19d	5.11±.21d	.91 ± .01b	1.10 ± .02c	2.22 ±.02c
N_2S_2	2.17 ± .05bc	2.70.05b	4.50 ± .22abc	3.66±.23abc	4.78±.17bc	6.28±.20bc	1.13 ± 0.1b	1.37 ± .01b	2.5 ±00b
N_3S_1	2.03 ± .02c	2.45 ± .07c	4.25 ± .24bc	3.47±.20bc	4.52±.19bc	6.02±.21bc	1.09 ± .02b	1.34 ± .03bc	2.46 ±.02bc
N_3S_2	2.65 ± .26a	3.31 ± .10a	5.11 ± .10a	4.22±.14a	5.93±.38a	7.43±.10a	1.42 ± .19a	1.00 ± 1.8a	2.80 ±.18a

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LS	0.05	NS	0.05	0.05	0.05	0.05	NS	0.05	0.05
CV (%)	8.93	4.99	8.6	9.82	9.33	6.19	12.34	9.55	5.25

Mean values in a column having a different letter (s) differed significantly, CV= Co-efficient of variation, LS= Level of significance, N_1 =100% CN + MBF, N_2 =100% ON + MBF, N_3 =50%ON +50% CN+ MBF, S_1=10cm × 5cm and S_2 = 12cm × 8cm.

Bulb Length (cm)

Significant differences in bulb length of onion were observed at 35 DAT whereas 65 and 95 DAT showed non-significant values under different types of nitrogen sources (Table 3). At 35 DAT, the highest bulb length (3.84 cm) was observed in N_3 and lowest length of bulb (3.36 cm) was recorded from N_2. At 65 DAT, the highest bulb length (5.22 cm) was observed in N_3 showing significant results with N_1 and lowest bulb length (4.19 cm) was recorded from N_2. At 95 DAT, bulb length was highest (6.72 cm) in N_3 and lowest (5.69 cm) was in N_2. Significant difference in bulb length was observed for maintaining different spacing (Table 3). At 35 DAT, the highest bulb length (3.91 cm) was observed in S_2 and lowest value for bulb length (3.29 cm) was found in S_1. At 65 DAT, the highest bulb length (5.26 cm) was recorded form S_2 and lowest bulb length (4.09 cm) was found in S_1. At 95 DAT, highest bulb length (6.76 cm) was recorded from $S_2$and lowest bulb length (5.59cm) was found from S_1. Statistically significant differences in bulb length of onion were observed due to interaction between nitrogen fertilizers level and different spacing (Table 3). At 35 DAT, the highest bulb length (4.22 cm) was observed in combination of N_3 with S_2 and lowest bulb length (3.06 cm) was found in N_2S_1. At 65 DAT, the highest bulb length (5.93 cm) was recorded form N_3 with S_2 and lowest bulb length (3.61 cm) was found in N_2S_1. At 95 DAT, highest bulb length (7.43 cm) was recorded from the combination of N_3 with S_2 and lowest bulb length (5.11 cm) was found from N_2S_1.

Neck Diameter (cm)

Neck diameter were statistically significant under different types of nitrogen sources at all observations except 35 DAT (Table 3). At 35 DAT, the highest neck diameter (1.25 cm) was observed in N_3 and lowest diameter of neck (1.02 cm) was recorded from N_2. At 65 DAT, the highest neck diameter (1.51cm) was observed in N_3 showing non-significant differences with N_1 and N_2 and lowest neck diameter (1.24 cm) was recorded from N_2. At 95 DAT, the neck diameter was highest (2.47 cm) in N_1 and lowest (2.36 cm) were both in N_2 and N_3. Statistically significant difference in bulb diameter of onion was observed due to different spacing (Table 3). At 35 DAT, the highest neck diameter (1.24 cm) was observed in S_2 and lowest value for neck diameter (1.00 cm) was found in S_1. At 65 DAT, the highest neck diameter (1.49 cm) was recorded form S_2 and lowest neck diameter (1.24 cm) was found in S_1. At 95 DAT, highest neck diameter (2.61 cm) was recorded from $S_2$and lowest neck diameter (2.36 cm) was found from S_1. Significant differences in neck diameter of onion were observed due to interaction between nitrogen fertilizers level and different spacing (Table 3). At 35 DAT, neck diameter was non-significant. In that case, the highest neck diameter (1.42 cm) was observed in combination of N_3 with S_2 and lowest neck diameter (0.91 cm) was found in N_2S_1. At 65 DAT, the highest neck diameter (1.37 cm) was recorded form N_2 with S_2 and lowest neck diameter (1.00 cm) was found in N_3S_2. At 95 DAT, highest neck diameter (2.80 cm) was recorded from the combination of N_3 with S_2 and lowest neck diameter (2.22 cm) was found from N_2S_1.

Fresh Weight (g)

Fresh weight showed statistically non-significant differences under various types of nitrogen sources at all observations (Table 4). At 35 DAT, the highest fresh weight (14.31 g) was observed in N_3 and lowest fresh weight (10.37 g) was recorded from N_2. At 65 DAT, the highest fresh weight (34.31 g) was observed in N_3 and lowest fresh weight (30.37 g) was recorded from N_2. At 95 DAT, the highest fresh weight was observed (46.31) in N_3 which reduce only 8.50 % and 4.08% in N_2 and N_1, respectively. Statistically significant difference in fresh weight of onion was observed due to different spacing (Table 4). At 35 DAT, the highest fresh weight (15.32 g) was observed in S_2 which is 38.57% higher than S_1. At 65 DAT, the highest fresh weight (35.32 g) was recorded form S_2 and lowest fresh weight (29.41 g) was found in S_1. At 95 DAT, highest fresh weight (47.32g) was recorded from S_2 which is 14.27% higher than S_1. Fresh weight of onion showed significant differences due to interaction between nitrogen fertilizers level and different spacing (Table 4). At 35 DAT, the highest fresh weight (18.30 g) was observed in combination of N_3 with S_2 and lowest fresh weight (8.45 g) was found in N_2S_1. At 65 DAT, the highest fresh weight (38.30 g) was recorded form N_3 with S_2 and lowest fresh weight (28.45 g) was found in N_2S_1. At 95 DAT, highest fresh weight (50.30 g) was recorded from the combination of N_3 with S_2 and lowest fresh weight (40.45 g) was found from N_2S_1 which is 24.35 % lower than N_3S_2.

Dry Weight (g)

Dry weight showed statistically significant differences under various types of nitrogen sources at all observations (Table 4). At 35 DAT, the highest dry weight (3.94 g) was observed in N_3 and lowest dry weight (2.82 g) was recorded from N_2. At 65 DAT, the highest dry weight (11.94 g) was observed in N_3 and lowest dry weight (10.18 g) was recorded from N_2. At 95 DAT, the highest dry weight was observed (26.94 g) in N_3 which reduce only 6.53 % and 4.15% in N_2 and N_1, respectively. Statistically significant difference in dry weight of onion was observed due to different spacing (Table 4). At 35 DAT, the highest dry weight (4.05 g) was observed in S_2 which is 112% higher than S_1. At 65 DAT, the highest

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dry weight (12.05 g) was recorded form S_2 and lowest dry weight (9.91 g) was found in S_1. At 95 DAT, highest dry weight (27.05g) was recorded from S_2 which is 8.60% higher than S_1. Dry weight of onion showed significant differences due to interaction between nitrogen fertilizers level and different spacing (Table 4). At 35 DAT, the highest dry weight (5.18 g) was observed in combination of N_3 with S_2 and lowest dry weight (1.25 g) was found in N_2S_1. At 65 DAT, the highest dry weight (13.18 g) was recorded form N_3 with S_2 and lowest dry weight (9.25 g) was found in N_3S_2. At 95 DAT, highest dry weight (28.18 g) was recorded from the combination of N_3 with S_2 and lowest dry weight (24.25 g) was found from N_2S_1 which is 13.94 % lower than N_3S_2.

Table 4: Varietal differences, nitrogen fertilizations and their interactions in yield contributing parameters of onion.

Nitrogen	Fresh weight (g)			Dry weight (g)			Yield (t ha-1)
	35DAT	65DAT	95DAT	35DAT	65DAT	95DAT	
N_1	12.42 ±1.35b	32.42 ±1.75a	44.42 ±1.75a	2.82 ±.48b	10.82 ± .54b	25.82 ± 1.01a	12.13 ± .44a
N_2	10.37 ±.91c	30.37 ±1.48a	42.37 ±1.48a	2.18 ±.42c	10.18 ± .47b	25.18 ± .93a	11.64 ± .40a
N_3	14.31 ±1.79a	34.31 ±2.08a	46.31 ±2.08a	3.94 ±.59a	11.94 ± .62a	26.94 ± 1.11a	12.56± .46a
Spacing							
S_1	9.41 ±.29b	29.41 ±.87b	41.41 ±.87b	1.91 ±.22b	9.91 ± .28b	24.91 ± .71b	12.56 ± .46b
S_2	15.32 ±.90a	35.32 ±1.30a	47.32 ±1.30a	4.05 ±.34a	12.05 ± .37a	27.05 ± .80a	11.50 ± .28a
Nitrogen × Spacing							
N_1S_1	9.45 ±.18de	29.45 ± 1.65bc	41.45 ±1.65bc	1.78 ± .13d	9.78 ± .40d	24.78 ± 1.37a	12.71 ± .32ab
N_1S_2	15.38 ±.51b	35.38 ±1.97ab	47.38 ±1.97ab	3.87 ± .21b	11.87 ± .48b	26.87 ± 1.44a	11.52 ± .50ab
N_2S_1	8.45 ±.25e	28.45 ±1.71c	40.45 ±1.79c	1.25 ± .09d	9.25 ± .36d	24.25 ± 1.33a	12.73 ± .61b
N_2S_2	12.29 ±.61c	32.29 ±2.08bc	44.29 ±.08bc	3.12 ± .07c	11.12 ± .34b	26.12 ± 1.31a	11.13 ± .52ab
N_3S_1	10.32 ±.12d	30.32 ±1.58bc	42.32 ±1.58bc	2.70 ± .10c	10.70 ± .37bc	25.70 ± 1.34a	12.14 ± .52ab
N_3S_2	18.30 ±.32a	38.30 ±1.78a	50.30 ± 1.78a	5.18 ± .47a	13.18 ± .47a	28.18 ± 1.68a	13.27 ± .55a
LS	0.05	0.05	0.05	NS	0.05	NS	0.05
CV (%)	5.24	9.66	7.05	12.99	6.44	9.46	7.66

Mean values in a column having a different letter (s) differed significantly, CV= Co-efficient of variation, LS= Level of significance, N_1 =100% CN + MBF, N_2 =100% ON + MBF, N_3 =50%ON +50% CN+ MBF, S_1=10cm × 5cm and S_2 = 12cm × 8cm.

Yield (t ha^{-1})

The yield of onion showed non-significant difference due to various nitrogen fertilizers application (Table 4). The highest yield (12.56 t ha^{-1}) was calculated from N3 which reduced only by 7.32% and 3.42% in N_2 and N_1, respectively. Significant differences in case of onion yield was observed due to various spacing. The highest yield (12.56 t ha^{-1}) was found in S_1 which reduced significantly by 8.44% in S_2 (Table 4). Interaction effect between nitrogen fertilizers level and spacing exhibited significant differences in case of onion yield. The highest yield (13.27 t ha^{-1}) was recorded from the combination of N_3 with S_2 which reduced significantly by 16.12% in N_2S_2 (Table 4).

Discussion

This study evaluated the growth and yield responses of onion (BARI Piaz-4) to different row spacing and nitrogen fertilizer levels. The findings underscore the critical role of nitrogen in enhancing various physiological processes in plants, including chlorophyll synthesis, protein formation, and energy metabolism [9,10]. Adequate nitrogen availability was shown to significantly increase plant height, leaf number, leaf length, and overall vigor. These effects can be attributed to the increased photosynthetic capacity resulting from higher chlorophyll content, which promotes growth and biomass accumulation [11,12]. Higher nitrogen levels lead to the development of larger and thicker leaves, as well as increased bulb size. Nitrogen's role in promoting vegetative growth and supporting the development of structural components like leaves and bulbs [13,14] was evident. This is in line with findings by Tilahun et al., [15] and Attaya et al., [13], who reported that sufficient nitrogen enhances both the fresh and dry weight of plants by supporting cell division and expansion, thereby leading to higher biomass production and overall plant productivity.

Conversely, nitrogen deficiency restricted growth and development, resulting in lower yields. This emphasizes the importance of maintaining optimal nitrogen levels for maximizing onion yield. Regarding spacing, the research results corroborate previous studies indicating that different spacing arrangements significantly impact the competition for light, water, and nutrients among plants. Wider spacing reduced competition, thereby enhancing access to these resources [12,16]. This led to improved growth parameters, including increased plant height, leaf number, and leaf length. Adequate spacing also ensured better light penetration, promoting photosynthesis and healthy growth [17], which manifested in larger and thicker leaves and better-developed bulbs. Furthermore, wider spacing facilitated more extensive root systems [12], allowing plants to access more nutrients and water, supporting better overall growth. This resulted in increased leaf diameter, bulb diameter, and neck diameter. Proper spacing minimized plant stress by reducing competition and improving air circulation, which in turn led to higher fresh and dry weights as plants could allocate resources more effectively. The research findings are in agreement with Elouattassi et al. [18] and Gelaye et al. [16], who reported that optimal spacing maximizes yield by ensuring each plant has sufficient resources for growth and development. In contrast, crowded conditions increased competition and stress, ultimately leading to lower yields.

Conclusion

The application of 50% Organic Nitrogen + 50% Chemical Nitrogen + MBF (N_3) yielded superior results for most growth and yield parameters of BARI Piaz4 onions compared to other nitrogen treatments. This combination resulted in the highest values for plant height, leaf number, leaf length, bulb length, bulb diameter, fresh weight, dry weight, and yield (12.56 t ha^{-1}). Optimal row spacing (S_2: 12 cm x 8 cm) also significantly influenced these parameters, except yield, which was highest with closer spacing (S_1). The interaction of N_3 and S_2 produced the most favorable outcomes across all measured metrics, including the highest yield (13.27 t ha^{-1}). Consequently, the combination of 50% Organic Nitrogen + 50% Chemical Nitrogen + MBF with a 12 cm x 8 cm spacing is recommended for optimal onion cultivation. Further research is suggested to validate and expand upon these finding [19-58].

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