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Effects of plant and row spacing and nitrogen levels on growth, yield and economics of onion (*Allium cepa* L.) in Khost, Afghanistan

Qasimullah RYAN[1] (✉), Shafigul SHAFIQI[1], Abdul Aziz WAZIRI[2], Ahmad Yar AHMADI[1], Qiamudin ABAD[1]

[1] Department of Agronomy, Faculty of Agriculture, Shaikh Zayed University, Kabul main road, 1200 families, Khost, Afghanistan

[2] Department of Plant Protection, Faculty of Agriculture, Shaikh Zayed University, Kabul main road, 1200 families, Khost, Afghanistan

✉ Corresponding author: qasimullah.ryan@gmail.com

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ABSTRACT

Poor soil fertility management and inappropriate plant and row spacing are the main factors constraining onion production in Khost. Therefore, it was felt necessary to develop a package to recommend nitrogen (N) levels and plant and row spacing in the study area. Hence, this study was initiated to assess the effect of plant and row spacing and N levels on the growth, yield and economics of onion at the Agricultural Research Farm of Shaikh Zayed University (SZU), Khost. A randomized complete block design (RCBD) with three replications was used to set up the experiment, which was a factorial combination of three plant and row spacings (10×10, 15×10, and 20×15 cm) and four levels of nitrogen (0, 50, 100, and 150 kg N/ha). The analysis's findings showed that the growth and yield attributes of onion were significantly influenced by the main and interaction effects of N levels and spacing. Higher growth and yield components were recorded with higher N levels and wider spacing, but significantly higher bulb yield and net returns over the control were obtained with the application of 150 kg N/ha combined with narrow plant and row spacing (10×10 cm). The control group with no nitrogen produced the lowest growth and yield attributes across all spacing treatments. Therefore, 10×10 cm plant and row spacing combined with 150 kg N/ha is recommended for optimum bulb yield and economically attractive benefits in the study area.

Keywords: plant geometry, nitrogen levels, onion performances and profitability

INTRODUCTION

Onion (*Allium cepa* L.) is an important vegetable, grown for its spicy bulbs and belongs to the family of *Amaryllidaceae* (Welbaum, 2015). It is believed to have originated in Asia (Malik, 1999). Except for the seeds, all plant components can be consumed (Rabinowitch, 2002). In addition to meeting human nutritional needs, onions have therapeutic benefits. Onions are famous for their anti-allergenic, anti-bacterial, antiviral, and anti-inflammatory properties, and they are also known to reduce the risk of heart disease, diabetes and cancer (MoARD, 2009). Due to its unique flavor, it enhances the flavor of other foods (Ketter and Randle, 1998). Onions are a rich source of vitamins B1, C and E, and certain trace elements. It contains 5 to 11% carbohydrate (Ranbinowitch, 2002).

The world onion cultivated land during 2021 was about 3,318,119 hectares, from which 99,968,016 tons of onion were produced with an average yield of 23 t/ha. China is the biggest producer of onions followed by India, the UAS, Egypt and Turkey (FAO, 2021). In 2021 in Afghanistan, 352,725 tons of onions were produced from 18,343 hectares of land with a 19 t/ha average yield (FAO, 2021). It indicates that onion productivity in

Afghanistan is significantly lower than the world average. Poor agronomic practices and the unavailability of high-quality seeds are factors that may adversely affect onion production (Agnieszka et al., 2017; Babaji et al., 2012; Fageria, 2014).

It could be challenging to make general suggestions for the various agroecological zones, because crop varieties and the environment determine the optimum rate of fertilizers and plant density (Agnieszka et al., 2017). Therefore, a specific package of information should be developed.

Optimal utilization of natural resources can be achieved through appropriate plant and row spacing and nitrogen levels (Babaji et al., 2012; Fageria, 2014). Optimal plant density and nitrogen levels help mitigate inter and intraspecific weed competition (Freckleton, 1999), and enhance the photosynthetic ability of the crop, thereby increasing productivity. Plant and row spacing determine crop canopy which influences the yield and quality of onions while increasing the number of plants per unit area leads to higher total bulb yield, it often results in a decrease of yield per individual plant, but yield per plant decreases (Gupta and Sharma, 2000).

Optimum spacing varies with the fertility and moisture status of the soil, crop nature and severity of weed infestation (Sing et al., 1997). In addition, Awas et al. (2010) reported that plant spacing controls bulb size, shape and yield of onions. moreover, a higher mean bulb weight was recorded with an intra-row spacing of 10 cm compared to 5 cm and 7.5 cm (Belay et al., 2015).

Due to their shallow and unbranched root systems, onions are highly susceptible to nutrient depletion (Rizk et al., 2012). Nitrogen (N) is a primary macronutrient, which plays an important role in photosynthesis and enhancing onion performance (Nasreen et al., 2007; Al-Fraihat, 2009). Results indicate that optimal plant densities, coupled with adequate nutrient levels, resulted in the highest onion yields. According to Gebretsadik and Dechassa (2018), a spacing of 20×6 cm in combination with 100 kg N/ha recorded the best overall bulb production when compared to 4, 8 and 10 cm. The higher growth parameters of onions were recorded at 15 cm intra-row spacing with 138 kg N/ha and the lowest was obtained at 7.5 cm intra-row spacing without N fertilizer (Gessesew et al., 2015). The results of experiments conducted by Falodun and Ehigiator (2015) showed that the higher onion bulbs were produced at optimum plant density (250,000 plants/ha) with 80 kg/ha NPK 15:15:15, as compared to low (160,000 plants/ha) and high (333,333 plants/ha) densities. Research findings suggest that increasing nitrogen rates and widening intra-row spacing lead to improvements in growth parameters and individual bulb attributes, and vice versa (Gessesew et al., 2015; Renbomo and Biswas 2017). The experiment conducted by Gebretsadik and Dechassa (2018) contains four levels of intra-row spacing (4, 6, 8 and 10 cm) with 20 cm of inter-row spacing. By 20×6 cm, a better marketable bulb yield of 26.72 t/ha was attained. The same trend was found in potatoes, as reported by Arega et al., (2018). Hordofa et al., (2020) reported that 7.5 cm intra-row spacing with the application of 125 kg N/ha produced a higher total and marketable bulb yield with a 35.94% advantage over plants spacing 12.5 cm apart.

The optimal application of N and appropriate plant and row spacing result in high productivity and a low cost of cultivation. The high net returns were obtained by applying 138 kg N/ha with 7.5 cm plant spacing compared to wider plant spacing and lower N rates (Gessesew et al., 2015). Gebretsadik and Dechassa (2018) reported that the economically attractive benefits of onions were obtained with the optimum rate of N and appropriate spacing. The highest economic benefits with less cost of production were obtained with the application of a high rate of N and 15×10 cm plant and row spacing, followed by a low rate of N with wider spacing (Kumar et al., 2018). In the experiment carried out by Sinta and Garo (2021), they found that among four beetroot plant densities (133333, 100000, 80000 and 66666 plant/ha) and four N levels (0, 46, 92 and 138 kg N/ha), the lowest density with 92 kg N//ha recorded with the highest net and marginal rate of returns.

The aforementioned research findings indicate that various onion cultivars perform differently in different environments, influenced by varying plant and row spacing and nitrogen levels. Therefore, it is necessary to develop the best practices for optimal onion production in the study area. This investigation aimed to assess the effects of plant and row spacing and N levels on growth, yield, and economics of onion cultivation under specific conditions in the study area.

MATERIAL AND METHODS

Description of the experimental site

The experiment was conducted at the Agricultural Research Farm of Shaikh Zayed University (SZU), Khost in 2020. The site is located between 33° 34′ N latitude and 69° 86′ E longitude, with an elevation of 1240 m above sea level (Figure 1). The study site is typified as a semi-arid climate with 487 mm of annual rainfall and high temperature (39-42 °C) during summer and low temperatures (-4 °C) during winter (WWO), (Wali et al., 2016).

The soil physio-chemical characteristics, as analyzed by ANASTU lab, are presented in Table 1.

Experimental treatments and materials

The experiment employed a factorial combination of three plant and row space configurations (10×10, 15×10, and 20×15 cm) and four nitrogen (N) levels (0, 50, 100, and 150 kg N/ha) (Table 2).

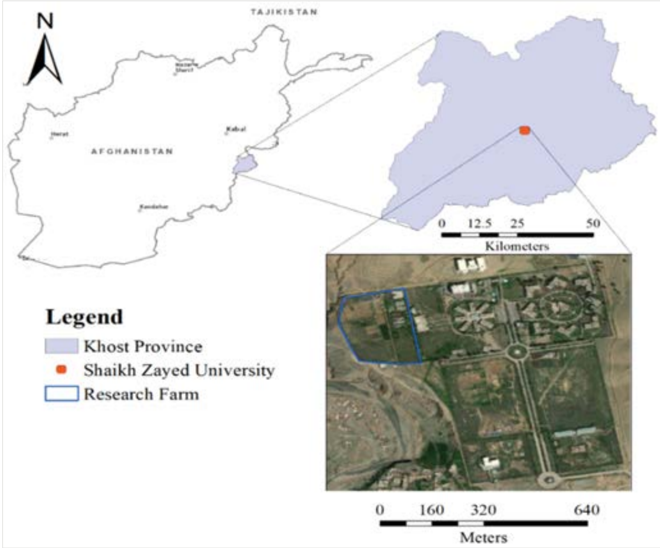

Figure 1. Geographical location of the study area (Agricultural research farm, Khost, Afghanistan)

It was arranged in a randomized complete block design (RCBD) with three replications. Each plot measured 1.5×1.2 m, with a distance of 1.0 m between replications. Within each block, there were 12 plots, resulting in a total of 36 plots. Treatments were randomly assigned to each plot within the block.

Seedlings were raised in well-prepared nursery beds. The test crop for the study was a locally grown variety (Balkhail), which shares characteristics with the bombey red variety. The Balkhail variety is a distinctive cultivar of the common onion that is widely grown in the study area.This medium to large-sized onion variety features a deep reddish-purple to maroon skin color, complemented

Table 1. Physio-chemical properties of soil at the experimental site during the 2020 winter

Chemical properties		Physical properties	
pH	7.6	Sand (%)	58.4
EC (dSm/m)	0.12	Silt (%)	21.8
O.M (%)	1.3	Clay (%)	19.8
O.C (%)	0.75	Textural class	Sandy loam
Total N (kg/ha)	291.65		
Available Phosphorus (kg/ha)	3.06		

EC stands for electrical conductivity; O.M. for organic matter; O.C. for organic carbon; N for nitrogen by a reddish-purple flesh and a slightly flattened, globe-like shape with mild to moderately pungent flavor. The crop thrives in subtropical climates with moderate temperatures ranging from 15 °C to 25 °C and adequate rainfall of around 500-800 mm annually, preferring well-drained, fertile soils with a slightly acidic to neutral pH (Vibhute and Singh, 2019).

Nursery beds were supplied with an adequate amount of manure and urea and managed for about 8 weeks, after which then seedlings were transplanted to the main plots. The main experimental plots were ploughed and levelled by tractor, stubbles and weed residues were collected manually. The experimental plot layout was done according to plan. The carefully uprooted seedlings were transported when they reached about 12-15 cm in height. For the safe uplifting of seedlings, the main experimental plots were irrigated one day before transplanting of seedlings. Healthy and vigorous seedlings were grown in the main plots as per the treatment plan, and within a week gap, filling was done. Marked planting boards were used for plant and row spacing. Phosphorus (P) in the form of DAP (92 kg P_2O_5/ha) was applied to all experimental units equally just before transplanting at 10 cm depth. Nitrogen (N) in the form of urea was applied (0, 50, 100 and 150 Kg N/ha) in two splits (1/2 at the active vegetative stage and ½ at just before bulb initiation). Weeds were manually removed using a hand hoe. The Main plots were irrigated manually through pipes. Irrigation was done based on the moisture status of the soil and plant conditions. Bulbs were harvested and used for yield measurements when 70% of the plants in each plot showed neck fall. Hail frequently fell in the study area during the summer. For physical protection of the crop during hailstorms, a hail net was utilized (Figure 2).

Figure 2. Hail net for physical protection of the crop during hail fall

Data collection

The data on the growth and yield components of onions were recorded from the central rows of each plot. Within these central rows, five pre-tagged plants were randomly selected for observations, and the average mean was calculated for statistical analysis.

Growth parameters

Plant height (cm) for five pre-tagged plants was measured from ground level to the tip of the leaves using a ruler. Likewise, the number of leaves per plant was counted from five pre-tagged plants in each plot. The average mean of the number of leaves per plant was calculated for further analysis.

Yield and yield components

Onion-matured bulb diameters (cm) were measured for five pre-tagged plants using a calliper, considering the widest portion of the bulbs during measurement. Similarly, bulb length (cm) was also measured for five pre-tagged onions with a calliper. Matured bulb lengths of onions were measured as vertical average lengths. Fresh biomass (g/plnatplant) was measured for five pre-tagged plants during harvesting for the whole plant, and then the average mean of fresh biomass (g/plant) was recorded.

Individual bulb weight (gr) was recorded for five plants, harvested from the central rows, using sensitive balance. Then the average mean was calculated. The bulbs that were greater than 3 cm in diameter are considered as marketable yield (Morsy et al., 2012). All produced bulbs were marketable (> 3 cm in diameter) in large, medium, and smaller sizes. Bulb yield (t/ha) was calculated as the net plot yield and converted to hectares.

Table 2. Treatments combination of plant and row spacing and nitrogen levels

Treatments (T)	Symbol	Nitrogen (kg/ha) × Spacing (cm)
T_1	N_1S_1	0 × (10×10)
T_2	N_2S_1	50 × (10×10)
T_3	N_3S_1	100 × (10×10)
T_4	N_4S_1	150 × (10×10)
T_5	N_1S_2	0 × (15×10)
T_6	N_2S_2	50 × (15×10)
T_7	N_3S_2	100 × (15×10)
T_8	N_4S_2	150 × (15×10)
T_9	N_1S_3	0 × (20×15)
T_{10}	N_2S_3	50 × (20×15)
T_{11}	N_3S_3	100 × (20×15)
T_{12}	N_4S_3	150 × (20×15)

where, T stands for treatment, N for nitrogen, and S for spacing

Statistical analysis

The collected data underwent analysis of variance (ANOVA) using SAS version 9.4 software (SAS Institute, Inc., 2004). The data mean separation was carried out with the Least Significant Difference (LSD) at a significance level of 5%.

Economic analysis

The economic analysis was conducted using CIMMYT's methodology (CIMMYT Economics Program, 1988). The prevailing market prices for input and output during sowing and harvesting of the crop were used in the computations. For each treatment, the costs and benefits were determined on an Afghani (AFN) basis for a single hectare. The total cost of cultivation was calculated by summing up the costs of inputs and management practices. Gross return, net return, and benefit-cost ratio (B:C) were calculated using the following formulas.

Gross returns = Market price (AFN/kg) × Seed yield (kg/ha)

Net returns = (Gross return) – (Total cost of cultivation)

Benefit-cost ratio = Gross returns (AFN./ha) / Cost of cultivation (AFN./ha)

RESULTS AND DISCUSSION

Plant height (cm)

The main and interaction effects of plant and row spacing and N levels were both significant ($P < 0.05$) for onion plant height (Table 3). Onion plant height increased with increasing plant and row spacing and nitrogen levels. Compared to S1 spacing, S2 and S3 spacing produced 8.3 and 15% taller plants, respectively. There was no significant difference between S2 and S3 spacing. Likewise, N4 (150 kg N/ha) produced 25.7% taller plants as compared to control (N1). The difference of N4 with N3 and N3 with N2 was not significant. The interaction effects of factors significantly influenced the plant height. The low N rates combined with narrow plant and row spacing (S1N1) produced the shortest plants, while the highest plant height was recorded with wider spacings and high levels of N (S3N4), which was significantly higher compared to other treatments (Table 4). The difference of S1N3 with S3N1 and S1N2 with S2N1 was not statistically significant. The increase in plant height of onions could be due to appropriate spacing and more available nutrients, which are attributed to enhanced cell division and vegetative growth (Marschner, 1995). The results of this study conform with the results of (Gessesew et al., 2015), who showed that wider spacing and a high rate of N produced taller plants as compared to narrow spacing and low N rates.

Number of leaves per plant

The main and interaction effects of plant and row spacing and N levels significantly ($P < 0.05$) increased the number of leaves per plant. The highest number of leaves was obtained in wider spacing with high N levels. S3 and S2 spacing produced significantly more leaves (27.8 and 17.7%) as compared to S1 spacing, respectively. The difference between S3 and S2 spacing was not significant. Similarly, the number of leaves increased with the increase in N level (Table 3). The lowest number of leaves was recorded in control N, whereas the highest rate of N (N4) greatly increased leaf number by around 25.7%. In terms of statistics, N4 did not differ from N3. The increase in the number of leaves due to interaction effects was significant. With an increase in N, the number of leaves increased in each spacing, and at the same level of N, the number of leaves increased as the spacing widened. Statistically, the highest number of leaves (79.6%) was recorded with S3N4, as compared to S1N1. The differences between S3N4, S2N4 and S3N3, and S3N2, S2N3 and S1N4 was not significant (Table 4). It is possible that the presence of sufficient growth factors, which facilitated the leaf buds' rapid growth with less competition, contributed to the rise in the number of leaves at wider spacing and a higher N level. These results are in line with the findings of Jilani (2004) and El-Tantawy and El-Beik. (2009), who reported that with increasing N levels the number of leaves increased. Hordofa et al. (2020) confirmed that the shallot leaves number increased with the widening of spacing with a higher level of N.

Bulb diameter (cm)

With increasing N levels and spacing, the bulb diameter significantly ($P < 0.05$) increased (Table 3). S3 and S2 spacing produced 29.7 and 10.6% wider bulb diameters than S1, respectively. As well, high N levels (N4, N3, and N2) resulted in a significantly wider bulb diameter (39.5, 34.8 and 25.5%) than the control (N1), respectively. The bulb diameter of the plants that received a high rate of N with wider spacing (S3N4) was significantly wider (81.5%) than those that did not receive N with narrow spacing (S1N1), (Table 4).

The differences in bulb diameter between S3N4, S3N3 and S3N2 treatments and S2N4 to S2N3 treatments were not significant. The reason for a wider bulb diameter in plants that were grown wider and received more N could be that these plants were healthier than others. The findings are supported by Gebretsadik and Dechassa (2018) and Islam et al. (2015), who found that bulb diameter increased with higher N levels and wider spacing.

Table 3. Effect of plant and row spacing and N levels on the growth and yield of onions

Plant and row spacing (cm)	Plant height (cm)	Number of leaves (per plant)	Bulb diameter (cm)	Bulb length (cm)
S1 (10×10)	47.7^{b}	7.9^{b}	4.7^{c}	5.1^{b}
S2 (15×10)	51.7^{ab}	9.3^{a}	5.2^{b}	5.4^{b}
S3 (20×15)	55.0^{a}	10.1^{a}	6.1^{a}	5.8^{a}
F-test	*	*	*	*
LSD (0.05)	4.12	0.82	0.42	0.32
		N levels		
N1 (0)	45.1^{c}	7.5^{c}	4.3^{c}	4.7^{c}
N2 (50)	50.9^{b}	8.7^{b}	5.4^{b}	5.4^{b}
N3 (100)	53.3^{ab}	9.7^{a}	5.8^{ab}	5.8^{a}
N4 (150)	56.61^{a}	10.4^{a}	6.0^{a}	5.9^{a}
F-test	*	*	*	*
LSD (0.05)	4.75	0.95	0.49	0.37
CV (%)	9.49	10.76	9.37	6.97

where, CV stands for Coefficient of Variation; * stands for significance at $P < 0.05$. LSD stands for Least Significant Differences; values within columns followed by the same letter are not significant

Bulb length (cm)

The increases in bulb length due to the main and interaction effects of spacing and N levels were significant (Table 3). Higher bulb length (13.7%) was obtained from wider spacing (S3) as compared to narrow spacing (S1). The difference in bulb length obtained from plants grown in wider spacing (S3) with S2 spacing was not significant. Similarly, the length of the bulb increased linearly as N levels increased from 0 to 150 kg N/ha. The highest bulb length (25.5%) as compared to null N was recorded from plants receiving a high rate of N, followed by N3 (100 kg N/ha). At the same spacing, with increasing N levels bulb length increased. As well, at the same level of N, with spacing widening, bulb length increased (Table 4). The widest spacing combined with the highest rate of N (S3N4) produced significantly the highest bulb length (51.3%) compared to the narrowest spacing and null N (S1N1). N enhances root growth and the uptake of other nutrients (Brady and Weil, 2002), which help the plant grow better and tend to produce large bulbs. The current result is in line with the results of Gessesew et al. (2015) who reported that bigger-size bulbs of onion were produced with wider spacing combined with a high level of N. Hordofa et al. (2020) have also reported similar results in shallot.

Fresh biomass (g/plant)

The fresh biomass of onions increased significantly with the increases in the rate of N and the widening of the spacing (Figure 3). As compared to S1 spacing, S2 and S3 spacing produced 26 and 70% higher fresh biomass, respectively. Likewise, compared to zero N, the N2, N3 and N4 nitrogen rates produced 46, 71 and 90.7% higher fresh biomass, respectively. The increases in N rates from N2 to N3 and N3 to N4 were not statistically significant concerning fresh biomass.

Table 4. Effect of interaction between nitrogen levels and plant and row spacing on growth and yield of onions

Plant and row spacing (cm)	Nitrogen (kg/ha)	Plant height (cm)	Number of leaves (per plant)	Bulb diameter (cm)	Bulb length (cm)
10×10	0	40.5^{e}	6.4^{f}	3.8^{g}	4.1^{f}
	50	45.8^{cde}	7.3^{ef}	4.7^{ef}	5.2^{de}
	100	50.5^{bcd}	8.6^{cde}	5.1^{cde}	5.5^{bcd}
	150	54.0^{abc}	9.1^{bcd}	5.4^{cde}	5.6^{abcd}
15×10	0	44.8^{de}	7.8^{def}	4.1^{fg}	4.6^{ef}
	50	52.2^{abcd}	8.9^{cde}	5.2^{cde}	5.2^{cde}
	100	53.3^{abc}	9.7^{bc}	5.7^{bcd}	5.8^{abc}
	150	56.5^{ab}	10.7^{ab}	5.9^{bc}	6.0^{ab}
20×15	0	50.0^{bcd}	8.2^{cde}	5.0^{ed}	5.3^{cde}
	50	54.7^{ab}	9.8^{bc}	6.3^{ab}	5.8^{abcd}
	100	56.2^{ab}	10.7^{ab}	6.4^{ab}	6.0^{ab}
	150	59.2^{a}	11.5^{a}	6.9^{a}	6.2^{a}
F-test		*	*	*	*
LSD (0.05)		8.51	1.67	0.85	0.64
CV (%)		9.75	10.86	9.31	6.89

CV stands for Coefficient of Variation; * stands for significance at $P < 0.05$. LSD stands for Least Significant Differences; values within columns followed by the same letter are not significant.

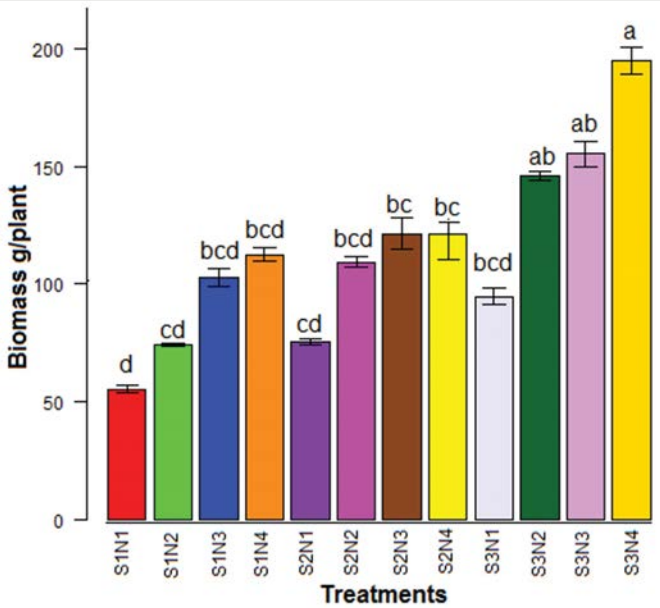

Figure 3. Effect of plant and row spacing and N levels on fresh biomass of onions

Fresh biomass increased at the same spacing as the N level increased. Likewise, fresh biomass increased as the spacing widened while maintaining the same level of nitrogen. The highest fresh biomass (194.3 g/plant) was obtained from the combination of 150 kg N/ha and wider spacing (S3N4), which was found to be 112% higher compared to zero N and closer spacing (S1N1). All other treatments produced significantly fresher biomass than narrow spacing with zero N (S1N1). The increases in fresh biomass per plant at wider spacing and a higher rate of N could be due to the availability of more nutrients, which permitted the plant to utilize P and K sufficiently (Brady and Weil, 2002). The higher rate of N leads to a rapid increase in overall crop assimilation, which contributes to increasing fresh biomass (Halvorson et al., 2002). These findings are in line with those of Ademe et al. (2012) and Hordofa et al. (2020), who noticed that shallot bulbs grow vigorously at wider spacing combined with a higher rate of N than those planted at narrow spacing with a lower rate of N.

Bulb Weight (g/bulb)

The main and interaction effects of N and spacing significantly ($P < 0.05$) influenced bulb weight (Table 5).

Table 5. Effect of plant and row spacing and N levels on onion yield

Plant and row spacing (cm)	Bulb weight (gr/plant)	Bulb yield (t/ha)
S1 (10×10)	62.8^{c}	48.3^{a}
S2 (15×10)	78.0^{b}	38.2^{b}
S3 (20×15)	112.0^{a}	25.2^{c}
F-test	*	*
LSD (0.05)	14.43	8.40
N levels		
N1 (0)	48.3^{c}	21.6^{c}
N2 (50)	84.0^{b}	36.3^{b}
N3 (100)	95.8^{ab}	43.3^{ab}
N4 (150)	109.0^{a}	47.8^{a}
F-test	*	*
LSD (0.05)	16.61	9.70
CV (%)	18.01	18.30

CV stands for Coefficient of Variation; * stands for significance at $P < 0.05$. LSD stands for Least Significant Differences; values within columns followed by the same letter are not significant

Bulb weight increased 78.9% with increasing spacing from S1 to S3 and S2 spacing produced 24.2% heavier bulbs compared to S1. Plants receiving no N produced significantly lower weights of bulbs (73.9, 98.3 and 125%, respectively) as compared to plants receiving N2, N3, and N4. The differences of N4 with N3 and N3 with N2 were statistically significant. Compared to S1N1 treatment, S3N4 treatment produced 284% heavier bulbs and was statistically significant to others (Table 6). The difference between S3N3 and S3N2 was not significant. Proper spacing and an adequate amount of N cause the availability of more nutrients and adequate soil moisture, which enhance plant growth and yield. The results are in line with the findings of Gessesew et al. (2015), who noticed that onion bulb weight increases with increasing spacing and N levels. Several other researchers have also reported similar results (Gebretsadik and Dechassa, 2018; Islam et al., 2015). Sinta and Garo (2021) reported a comparable finding in beetroot.

Table 6. Effect of interaction between nitrogen levels and plant and row spacing on onion yield

Plant and row spacing (cm)	Nitrogen (kg/ha)	Bulb weight (gr/plant)	Bulb yield (t/ha)
10×10	0	38.6[e]	29.7[de]
	50	58.2[de]	44.8[abc]
	100	74.1[cd]	57.1[a]
	150	80.3[cd]	61.8[a]
15×10	0	42.2[e]	20.7[de]
	50	77.3[cd]	37.8[bcd]
	100	94.2[bc]	46.1[abc]
	150	98.3[bc]	48.1[ab]
20×15	0	64.0[de]	14.4[e]
	50	116.6[b]	26.2[de]
	100	119.2[b]	26.8[de]
	150	148.5[a]	33.4[bcd]
F-test		*	*
LSD (0.05)		26.81	17.40
CV (%)		18.41	18.63

CV stands for Coefficient of Variation; * stands for significance at $P < 0.05$. LSD stands for Least Significant differences; values within columns followed by the same letter are not significant

Bulb yield (t/ha)

The main and interaction effects of nitrogen and spacing significantly ($P < 0.05$) influenced bulb yield (Table 5). Spacing determines the number of plants in the area. The number of plants increases with decreasing spacing. Bulb yield depends on the number of plants grown in a specific area. The highest bulb yield was recorded from plants grown at narrow spacing (S1), which was 26.9 and 91.6% higher than S2 and S3, respectively. Increasing the rate of N significantly increased the bulb yield. The highest bulb yield was recorded from plants receiving 150 kg N/ha (N4), which was 121, 31 and 10 % higher than N1, N2 and N3, respectively. The differences of N4 with N3 and N3 with N2 were not statistically significant.

As well, increasing the rate of N and narrowing the spacing significantly increased the production of bulb yield (Table 6). Plants received the highest rate of N with narrow spacing (S1N4) and produced the highest bulb yield, which was (124%) higher compared to wider spacing with zero N (S3N1). At S1 and S2 spacings, the increases in N from N3 to N4 did not differ significantly in influencing the bulb yield of onions.

The increased bulb yield at the increased rate of N and the closest spacing might be associated with the optimal amount of N and a higher number of plants per unit area, which leads to the maximum number of bulbs. The greater bulb size under wider spacing did not compensate for the decline in bulb yield per unit area produced at wider spacing. The results are in accord with those of Gessesew et al. (2015) and Gebretsadik and Dechassa (2018) who explained that the application of high N level and narrow spacing increased the bulb yield as compared to zero N and plants grown at wider spacing. The results reported by by Jilani (2004) and El-Tantawy and El-Beik (2009) indicate that high bulb yield of onions was produced with a higher level of N and narrow spacing. Similarly, Hordofa et al. (2020) in Shallot and Sinta and Garo (2021) in beetroot also reported comparable results.

Economic analysis

The economic analysis revealed that, net returns and the B:C ratio increased with increasing in the level of N and a narrowing of the space (Table 7). The highest net returns of 670077 AFN (Afghani currency) were obtained with the application of 150 kg N/ha at 10×10 cm spacing (S1N4), then the net returns of 616604 AFN, which were attained by applying 100 kg N/ha at the same spacing (S1N3). The lowest net returns (111790 AFN) were obtained from control N with 20×15 cm spacing (S3N1). As well, the same trend was noticed for the B:C ratio. A high B:C ratio was obtained from treatments that produced a high bulb yield. According to the analysis, by spending one AFN, 10.0 and 10.2 AFN may be obtained by applying 100 to 150 kg N/ha combined with 10×10 cm spacing, which is higher than the 2.8 B:C ratio acquired by applying zero N combined with wider spacing (S3N1). With an increase in N level at each spacing, gross income increased. Additionally, gross income increased at the same level as N with the narrowing of spacing. Onions' low cost and high bulb yield indubitably result in maximum profitability. The results align with those of Gebretsadik and Dechassa (2018) Gessesew et al. (2015) and Tekle (2015), who achieved great profitability at low cost and high bulb yield. As a result, it is advised to use 150 kg N/ha combined with a 10×10 cm spacing and 100 kg N/ha combined with a 10×10 spacing as a second option to boost the profitability of onion production in the area.

CONCLUSION

An increased yield of onions is obtained by combining the ideal N level with the right plant and row spacing, which is also very lucrative economically. The results of this study show that in the semiarid region of the Khost province, Afghanistan, nitrogen application at rates of 150 and 100 kg N/ha, along with a plant and row spacing of 10×10 cm contributed to maximum bulb yield and greater economic profit from the Balkhail cultivar.

Table 7. Effect of plant and row spacing and nitrogen levels on the economics of onions

Plant and row spacing (cm)	Nitrogen (kg/ha)	TCC	GR	NR	B:C
10×10	0	52700	356972	304272	6.8
	50	56480	538144	481664	9.5
	100	60295	685299	625004	11.4
	150	64110	742587	678477	11.6
15×10	0	52700	248440	195740	4.7
	50	56480	454719	398239	8.1
	100	60295	554287	493992	9.2
	150	64110	578199	514089	9.0
20×15	0	52700	172890	120190	3.3
	50	56480	314820	258340	5.6
	100	60295	321930	261635	5.3
	150	64110	400950	336840	6.3

TCC, GR, NR, and B:C stand for Total Cost of Cultivation, Gross Returns, Net Returns, and Benefit Cost Ratio, respectively. For each treatment, the costs and benefits were determined on an Afghani (AFN) basis for a single hectare.

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