Impact of Nitrogen and Spacing on Onion (*Allium Cepa* L.) growth in Southern Tigray, Ethiopia

ABSTRACT

The aim of the study was to evaluate the combined effect of nitrogen fertilizer rates and intra-row spacing on the growth, yield, and yield components of onion. The study was carried out using a factorial arrangement in a randomized complete block design. A field experiment was conducted in the experimental field of Alamata Agricultural Research Center kara Adishabo in 2020 with experimental treatments of Nitrogen fertilizer rates (0, 23, 46, 69, and 92 kg N/ha) and intra-row spacing (5, 10, and 15 cm) with three replications. Results indicated that the interaction effect of nitrogen and intra-row spacing significantly swayed most of the yield and yield components of the onion where The highest maturity date was recorded from the 92 Kg N/ha and 15 cm (140 days) and 69 Kg N/ha and 10 cm (127 days) respectively. The highest (40.01t/ha) and lowest (15.03 t/ha) marketable yields were recorded from the treatment combinations of 69 kg N/ha and 5 cm and 0 kg N/ha and 15 cm respectively. Application of 69 Kg N/ha and 5 cm of intra-row spacing in the study area can lead to maximum yield.

Keywords:*Onion, intra-row spacing, nitrogen, marketable bulb yield*

1. INTRODUCTION

Onion (*Allium Cepa* L.) is a significant crop in terms of its economic value. It belongs to the Allium genus of the Alliaceae family and is believed to have originated in Central Asia, specifically between Turkmenistan and Afghanistan. Some of its related species can still be found growing in the wild in this region [1].Onions are known for being one of the highest dietary sources of flavonoids, which have been linked to a decreased risk of cancer, heart disease, and diabetes[2].

Multiple factors contribute to the low productivity of onion in Ethiopia.The inadequate onion yield in the country is attributed to incorrect fertilizer application, substandard agronomic practices, disease and pest infestations, weed growth, insufficient high-quality seed supply, limited pesticide availability, and inadequate irrigation water [3,4].Nitrogen fertilization and plant spacing are among the most important factors that determine onion growth and yield.Nitrogen is crucial for achieving optimal onion yield as it is necessary for enhancing bulb size and overall crop productivity [5].

Regulating plant spacing is a cultural practice that influences bulb size, shape, and yield[6]. A higher yield and better control of over or under-bulb size could be obtained if plants are grown at optimum density. As population density increased, bulb neck diameters, mean bulb weight, and plant height all decreased.When plants are grown too closely together, they compete for sunlight, essential nutrients, water, and air, resulting in the production of small, low-quality bulbs. Conversely, plants that are grown too far apart may produce vigorous individual plants but yield less per given area[7, 8].

In Raya Valley various types of vegetables had been introduced to the farmers with plots in the irrigation sites. Traditionally, farmers in this area have been cultivating onions[9].However, onion yields have been low due to suboptimal fertilizer application and poor agronomic practices, particularly in plant spacing. Some farmers apply excessive nitrogen fertilizers to increase yields, while others apply insufficient amounts, leading to reduced onion yields. Additionally, most farmers use narrower intra-row spacing and the rest use wider spacing, highlighting the need to determine the appropriate intra-row spacing in this area [4]. Proposed that to maximize onion productivity, a comprehensive set of guidelines tailored to each specific growing region is necessary. Therefore, addressing this issue can be achieved by implementing optimal nitrogen fertilizer rates and suitable plant spacing in the study area. The overall aim of this study was to evaluate the combined effect of nitrogen fertilizer rates and intra-row spacing on the growth, yield, and yield components of onion.

2. MATERIALS AND METHODS

2.1. Description of the study area

The research was conducted at the Alamata Agricultural Research Center experimental site, situated in the Southern Zone of Tigray, Raya Azobo Woreda, Ethiopia, specifically in Kara Adishabo. The area is characterized by a dry semi-arid climate[10]. Geographically, it is positioned between 12°38’50" N and 12°44’36" N latitude and 39°35’10" E and 39°45’10" E longitude. The annual mean minimum, maximum, and average precipitation in the study area are 385.7 mm, 681.1 mm, and 543.6 mm, respectively, with a mean monthly maximum temperature of 29.9 °C and minimum temperatures of 15.9 °C. The Woreda’s altitude ranges from 1646 to 1670 m.a.s.l. It encompasses various soil types, including Vertisoils, Nitsoil, Combisols, and Luvisols. Vertisol (black soil with swelling characteristics) is the predominant soil type, covering over 70% of the study area [11,12].

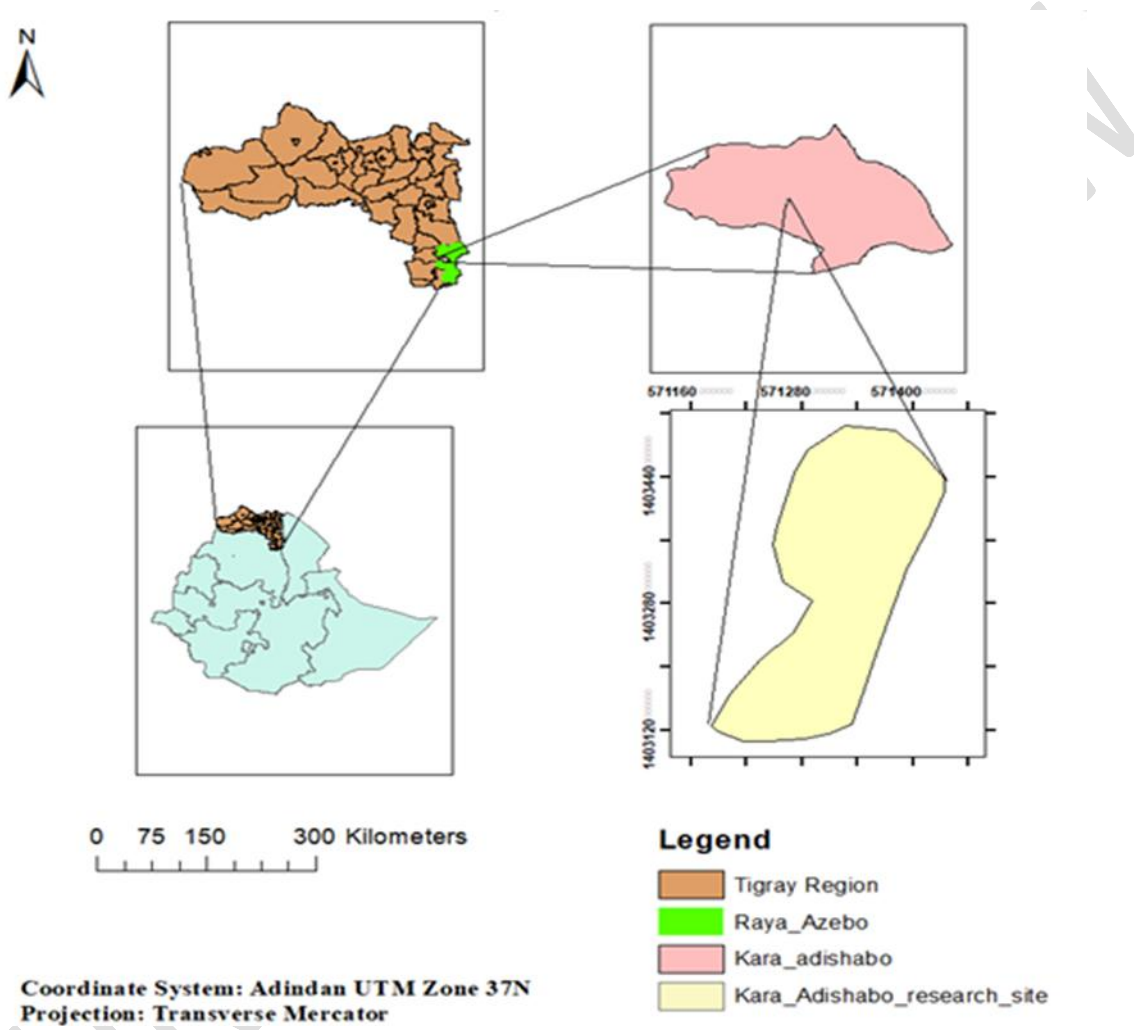

Fig.1. Map of the study area

2.2. Experimental Treatments, Designs and procedures

The experimental treatments included five nitrogen levels (0, 23, 46, 69, and 92 Kg/ha of N) and three intra-row spacing options (5, 10, and 15 cm). These factors were combined in a factorial design and arranged in a Randomized Complete Block Design (RCBD) with three replications.Spacing between blocks and plots was 1.5 m and 1 m, respectively with a 2 m x 3 m plot area. The spacing between furrows was kept at 40 cm and the spacing between the double rows in a furrow was 20 cm.The seedlings of the Bombay Red onion variety were grown on well-prepared nursery beds following the recommended management practices. This variety is well-suited and extensively grown in the study area. Prior to seedling transplanting, the experimental field was ploughed, pulverized, and leveled. Seedlings were transplanted to the experimental plots when they reached a height of 12-15 cm or at the 3-4 true leaf stage, carefully uprooted from the nursery bed. Only healthy, vigorous, and uniform seedlings were transplanted, and any gaps were filled within a week after transplanting. All plots received a uniform application of Triple superphosphate (46% P_2O_5) at a rate of 92 kg P_2O_5 as a source of phosphorus. Additionally, half rates of urea (46% N) were applied during transplanting, while the remaining half rates of urea (46% N) were applied after 30 days of transplanting. Soil moisture was maintained at field capacity during planting, and furrow irrigation was used for water application in each plot. A four-day irrigation interval was upheld for the first four weeks, after which it was extended to five to seven-day intervals until 15 days before harvest, at which point irrigation was completely stopped[13].

2.3. Soil Sampling

Prior to planting, soil samples were collected from ten random spots diagonally at six-meter intervals using an augur at a depth of 0-30 cm from the experimental site. The collected soil samples were combined into one composite sample. These composite soil samples were air-dried, thoroughly mixed, and ground to pass a 2 mm sieve size before laboratory analysis.

2.4. Data Collection

2.4.1. Soil data

Prior to planting, the soil's physical and chemical properties, including soil texture, pH, electrical conductivity (EC), cation exchange capacity (CEC), exchangeable potassium and sodium, total nitrogen, total organic carbon, and total available phosphorus, were assessed and recorded.

2.4.2. Crop data

Growth parameters (Number of leaves per plant, days to maturity and fresh biomass yield (g/plant), yield and yield components (Bulb diameter (cm), Dry biomass yield (g/plant), marketable bulb yield (t/ha) and unmarketable bulb yield (t/ha)) (See fig 2) of onions was collected from the eight central double rows (out of ten rows). Ten pre-tagged plants were randomly selected in each plot.

Fig.2. Field performance of onion

2.5. Data Analysis

2.5.1. Soil data analysis

The collected soil samples were composite to one sample. The bulked soil samples were air-dried, thoroughly mixed, and ground to pass 2 mm sieve size before laboratory analysis. Then the samples were properly labeled, packed, and transported to Mekelle Soil Laboratory for the analysis of major physical and chemical properties.

2.5.2. Crop data analysis

All data were presented as means and statistically analyzed using R software version 3.5.3. All the means data recorded of treatments were compared to each other for any significant differences using the least significant difference (LSD) method. The LSD (Least Significant Difference) was calculated based on the data, allowing for testing the differences among means. Separate analyses were performed for each data at the probability level for determination of significance (*P*=.05), where the analysis of variance indicated the presence of significant treatment differences.

3. RESULT AND DISCUSSION

3.1. Soil Physico-Chemical Properties of the Experiment

The results of the soil analysis (Table 1) before planting indicated that the soil pH value of the experimental site was 7.87 which were moderately alkaline [14].

Table 1. Physico-chemical properties of the experimental soil

Soil properties	Unit	Experimental field value	Ratings	Sources
Particle size distribution	%			
Sand	%	45		
Silt	%	35		
Clay	%	20		
Textural class			Loamy soil	[14]
Soil Ph		7.87	Moderately alkaline	[14]
Organic carbon	%	1.39	Low	[14]
Organic matter	%	1.79	Low	[14]
Total Nitrogen	%	0.114	Low	[14]
Total available phosphorus	mg /kg	14.89	Medium	[14]
Cation exchange capacity	Cmol(+)/kg	35.2	High	[14]
Exchangeable Sodium	Cmol(+)/kg	1.83	High	[15]
Exchangeable potassium	Cmol(+)/kg	0.71	Medium	[15]
Electrical conductivity	dS/m	0.29	Medium	[14]

3.2. Growth and phenology parameters

3.2.1. Leaf number per plant

The highest leaf number (18.17) was obtained from the combination of 92 Kg N/ha and 15 cm while the lowest mean number of leaves per plant (4.33 and 6.83, respectively) was recorded at nill Kg N/ha and 23 Kg N/ha with an intra-row spacing of 5 cm for each (Table 2).The study’s findings suggested that nitrogen significantly influenced the production of new shoots, leading to enhanced vegetative growth in onion plants and contributing to the increase in leaf number [16]. The increase in leaf numbers due to higher nitrogen rates and wider intra-row spacing in this study is linked to reduced competition among plants for nutrients, moisture, and light. This is attributed to the greater production of auxiliary branches at wider intra-row spacing compared to closely spaced plants. These findings align with those of[17].

3.2.2. Days to maturity

Onion plants that were grown at a combination of 92 Kg N/ha and 15 cm, 92 Kg N/ha, and 10 cm, and those grown at 69 Kg N/ha and 15 cm and 69 Kg N/ha and 10 cm need the highest number of days to reach maturity stage. However, onion plants that were grown at a combination of 0 Kg N/ha and 5 cm and 23 Kg N/ha and 5 cm require fewer days to mature. The days to maturity of onion plants increased by 42% when grown with a nitrogen rate of 92 Kg N/ha and 15 cm, compared to plants grown without nitrogen (nil Kg N/ha) and 5 cm (Table 2).The duration to reach maturity was prolonged with higher nitrogen rates and wider intra-row spacing. Hence, plants treated with a higher rate of nitrogen and grown at wider intra-row spacing need more days to mature than those supplied with fewer rates of nitrogen and narrower intra-row spacingThe postponement of maturity resulting from higher nitrogen rates and wider intra-row spacing may be attributed to nitrogen excess, which delays onion maturity by prolonging the vegetative growth period through enhancing the biochemical processes of plants, rather than accelerating the maturity time [16].

3.2.3. Fresh Total Biomass Yield

The highest fresh total biomass yield (116.93 g/plant) was obtained from the combined effect of 92 kg N/ha and wider intra-row spacing of 15 cm while the lowest was recorded from nil N fertilizer application combined with 5 cm intra-row spacing (32.33 g/plant) (Table 2).The observed rise in fresh total biomass yield per plant, resulting from higher nitrogen rates and wider intra-row spacing, can be attributed to enhanced leaf growth. This facilitated the accumulation of more assimilates in the bulbs, leading to increased bulb length, bulb diameter, mean bulb weight, root growth, and overall vegetative growth. These factors collectively contributed to the increased fresh biomass yield of onion plants under higher nitrogen rates and wider intra-row spacing, as they provided ample growth factors that allowed for greater assimilate accumulation [18].

3.2.4. Dry Total Biomass Yield

The highest dry total biomass yield (26.00 g/plant) was obtained from the combined effect of 92 Kg N/ha and 15 cm of intra-row spacing while the lowest dry total biomass yield (2.90 g/plant) was obtained from nil Kg N/ha and 5 cm of intra-row spacing (Table 2).The substantial increase in total dry biomass yield of onion plants with higher nitrogen fertilizer rates and wider intra-row spacing can be attributed to enhanced leaf growth, promoting the accumulation of more assimilates in the bulbs. This, in turn, led to increased bulb length, bulb diameter, mean bulb weight, root growth, and overall vegetative growth. These factors collectively contributed to the increased fresh biomass yield of onion plants under higher nitrogen rates and wider intra-row spacing, as they provided ample growth factors that allowed for greater assimilate production in the vegetative part and partitioning to the bulbs [19].Furthermore, Plants grown at the widest spacing exhibited the highest dry total biomass, likely due to reduced competition for growth factors among them. This finding aligns with the results reported by [20].

Table 2. Interaction effect of intra-row spacing and nitrogen fertilizer rates on leaf number per plant, days to maturity, fresh total biomass yield and dry total biomass

N rates (kg/ha)	Intra Row Spacing (cm)	Leaf Number Per Plant	Days To Maturity	Fresh Total Biomass Yield(g/plant)	Dry Total Biomass Yield(g/plant)

92	15	18.17a	140.67a	116.93a	26.00a
	10	16.33b	133.00b	104.30b	18.80b
	5	14.67c	120.00de	97.77c	17.20bc
69	15	14.00c	127.67c	91.40d	17.10bc
	10	12.17d	121.67d	86.90e	13.90de
	5	9.833e	116.67e	84.00e	12.74def
46	15	9.17ef	120.33de	76.40f	14.80cd
	10	8.83ef	111.67f	71.30g	11.90ef
23	5	8.17fg	109.33fg	66.70h	10.90f
	15	7.33gh	110.00fg	61.40i	10.30fg
	10	6.93ghi	105.33ghi	50.80j	7.94gh
	5	6.83hi	100.67ij	48.00j	7.50hi
0	15	6.47hi	106.67gh	40.10k	5.00ij
	10	6.00i	102.00hij	35.50l	3.80j
	5	4.33j	99.33j	32.33l	2.90j
LSD (5%)		1.26	4.81	4.38	2.69
CV (%)		7.6	2.5	3.7	13.3

3.3. Yield and yield components

3.3.1. Bulb diameter

The widest bulb diameter was recorded from the combination of 92 Kg N/ha and an intra-row spacing of 15 cm. The narrowest bulb diameter was obtained from the combination of nil Kg N/ha and intra-row spacing of 5 cm (Table 3).The observed increase in bulb diameter with wider intra-row spacing and higher nitrogen fertilizer rates can be attributed to the positive impact of applied nitrogen on vegetative growth and enhanced photosynthesis in plants. This, in turn, promotes the translocation of photosynthates to the storage organ or bulb, resulting in an overall increase in bulb diameter [21].The current finding is consistent with the results reported by [22] , who observed that the bulb diameter of onion increases with higher nitrogen fertilizer rates and wider intra-row spacing.The observed increase in bulb diameter at wider spacing can be attributed to the presence of ample nutrients and moisture, resulting from reduced competition effects. This favorable condition facilitates various physiological and metabolic processes, ultimately leading to an increase in dry matter production [23].

3.3.2. Marketable Bulb Yield

Increasing the rate of nitrogen application significantly increased the production of marketable bulb yield across the decreasing rate of the intra-row spacing. The combined application of 69 Kg N/ha with 5 cm of intra-row spacing produced 40.01 t/ha of marketable bulb yield and the lowest marketable bulb yield

(15.03 t/ha) was obtained from treatments treated with nil Kg N/ha and wider intra-row spacing of 15 cm (Fig. 3).The observed increase in marketable bulb yield with closer spacing and higher nitrogen rates can be attributed to the greater number of bulbs with marketable size per unit area. Additionally, the higher nitrogen rates facilitated the uptake of readily available nutrients, enhancing growth and ultimately leading to improved assimilate partitioning to the storage organ, the bulb [16].The present study aligns with the results reported by [16], who observed that the combination of higher nitrogen rates and narrower intra-row spacing (123 Kg N/ha and 6 cm) resulted in a higher marketable bulb yield.

Fig 1:Differentiating marketable and unmarketable bulb yield of onion

3.3.3. Unmarketable Bulb Yield

The highest unmarketable bulb yield of onion was recorded in nil nitrogen fertilizer application at the intra-row spacing of 5 cm followed by 23 Kg N/ha and 5 cm of intra-row spacing. But, the lowest unmarketable bulb yield of onion was attained in the combination of 92 kg N/ha with an intra-row spacing of 5 cm, 10 cm, and 15 cm, 69 Kg N/ha with an intra-row spacing of 5 cm, 10 cm, and 15 cm and 46 Kg N/ha with an intra-row spacing of 10 cm and 15 cm (Table 3). The observed high unmarketable bulb yield of onion in the treatment combination of no nitrogen and 5 cm intra-row spacing can be attributed to increased plant competition for nitrogen; those competitions reduces vegetative growth and assimilate production, resulting in the production of very small-sized bulbs that are not preferred by consumers [2].The current study aligns with the results reported by [16], which indicated that the combination of no nitrogen and 6 cm intra-row spacing resulted in the highest unmarketable yield of 1.05 t/ha.

Table 3. Interaction effect of intra-row spacing and nitrogen fertilizer rates on Intra row spacing, bulb diameter, neck thickness diameter, marketable bulb yield, and unmarketable bulb yield of onion

N rates (kg/ha)	Intra Row Spacing (cm)	Bulb diameter (cm)	Marketable bulb yield (t/ha)	Unmarketable bulb yield (t/ha)
92	15	8.83a	24.10cde	0.03f
	10	7.27b	29.63bc	0.04f
	5	5.80cde	38.30a	0.48ef
69	15	6.60bc	24.10cde	0.09f
	10	6.10cd	32.00b	0.14f
	5	5.63de	40.01a	0.2f
46	15	5.40def	22.20defg	0.16f
	10	5.00efg	23.30def	0.21f

	5	4.70fg	27.00bcd	1.53c
23	15	4.27gh	18.20fgh	0.88de
	10	4.23gh	18.75efgh	0.97d
	5	3.63h	19.42efgh	2.96b
0	15	2.50i	15.03h	0.76de
	10	1.39j	16.75gh	1.1cd
	5	1.03j	17.93fgh	4.96a
LSD (5%)		0.84	5.85	0.48
CV (%)		10.4	14.3	10.1

4. CONCLUSION

Onion (*Allium Cepa* L.) is a commercially important bulb crop grown worldwide. Enhancing onion productivity and production can be achieved through various growth factors. In the study area, improper agronomic practices are a major constraint leading to low onion production and productivity. Among these practices, nitrogen fertilizer rates and intra-row spacing significantly impact onion bulb yield, leaf number per plant, fresh total biomass yield, dry total biomass yield, days to maturity, bulb diameter, marketable bulb yield, and unmarketable bulb yield. The treatment combination of 69 Kg N/ha and 5 cm of intra-row spacing resulted in the highest marketable yield. Therefore, it can be concluded that planting Onion Bombay Red cultivar under irrigation with 5 cm of intra-row spacing and the application of 69 Kg N/ha in the Kara Adishabo area can lead to maximum yield.

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6. Competing interest

The author has no conflict of interest

7. Authors' Contributions

Author 1.Conceived and designed the study, collected and analyzed the data, and wrote the manuscript.

Author 2. Provided guidance on the research concept, data interpretation, and critically reviewed the manuscript.

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