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Effects of Intra-row Spacing and Nitrogen Fertilizer Rates on Growth, and Yield of Onion (*Allium cepa* L.) Under Irrigation in Mecha District of Amhara, Ethiopia

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Abstract: The productivity of onion is low due to many factors such as *poor soil fertility, under or above optimum plant population***.** Moreover, farmers are complaining that the present recommended 10 cm intra row spacing produces large sized bulbs, which do not preferred by consumers for home consumptions. Therefore, the present study was initiated with the objective of investigating the effects of intra row- spacing and nitrogen fertilizer rates on growth and yield of onion. The treatments consisted of four rates of Nitrogen fertilizer rate (0, 41, 82, 123 kg ha^{-1} N) and three-intra row spacing (4, 7. 10 cm). The experiment was laid down in Randomized Complete Block Design (RCBD) with factorial arrangement was used three replications. Date on growth, yield and yield components of onion were collected and subjected to ANOVA using SAS (version 9.0) software. The higher significant difference for plant height (60.53cm), leaves number per plant (14.10cm), leaves length (60.90cm), day to maturity (115 days) and bulb weight (96.05 g) were recorded from onion plants supplied with 82 kg ha^{-1} N and 123 kg ha^{-1} N both combined with 10 cm of intra row spacing. The highest marketable bulb yield (43.80 t/ha) was recorded from treatment combination of 82 kg ha^{-1} N and 4 cm of intra row spacing. Onion plants without nitrogen fertilizer application and narrow intra row spacing were inferior in almost all growth and yield components. Based on the results of the present study, the combination of 82 kg ha^{-1} N and 4 cm of intra row spacing can be recommended for production of onion Since the results are limited to one season and location, it is advised to repeat the experiment in different area and season for forceful recommendation.

Keywords: Irrigation, Nitrogen, Onion, Parameters and Spacing

1. Introduction

In Ethiopia, onion (*Allium cepa*L.) is one of the cool season bulb vegetables widely produced by smallholder farmers mainly as a source of cash income [1]. Onion contributes a significant nutritional value to the human diet and has medicinal properties. The crop primarily consumed for its unique flavor or ability to enhance the flavor of other foods [2]. All the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasoning or as vegetables in stews [3]. It is one of the richest sources of flavonoids in the human diet and flavonoid where its consumption has been associated with a reduced risk of cancer, heart disease and diabetes. Flavonoids are not only anti-cancer, but also known to be anti-bacterial, antiviral, anti-allergenic and anti-inflammatory.

The production and productivity of onion is very low in Ethiopia although the country has huge potentials to the crop production and utilization. The low rates of vegetable production in general and that of onion in particular is associated with poor agronomic practices, shortage of seeds of improved varieties, diseases and insect pests, poor extension services, high costs of agricultural chemicals including fungicides, insecticides and fertilizers and sometimes their unavailability to small-scale farmers [4]. Moreover, quality and yield of particular onion variety are greatly affecting planting density even if grown in the same environment [5].

Mineral fertilizers are one of the principal factors that materially set up onion growth and production. However, due to ever increasing prices, smallholder farmers do not apply full dose of inorganic fertilizers which are required to sustain and increase yields [6]. Moreover, onion growers in the study area produce onion with the application of nitrogen fertilizer rates and intra-raw spacing which they feel as best for obtaining higher yields of onion crop (Personal communication). However, the blanket recommended rates of fertilizers are 200 kg ha^{-1} of DAP and 100 kg ha^{-1}.

In addition to nutrients, plant spacing is an important factor determining onion yield and quality. Manipulating row spacing and plant population influences crop canopy. Planting density greatly influence texture, quality, taste and yield of onion even within a particular variety [7]. Thus, spacing is an important factor for the production of onion since it affects both bulb yield and quality.

Onion is one of the most important vegetable crops cultivated mostly under irrigated condition in Mecha district in West Gojam Zone of Amhara Region. However, the crop productivity is remained very low compared to the world average [8]. According to Yemane, wider intra row spacing (10 cm) produces large sized bulbs which are liable to highest rotting percentage compared those produced with intra-row spacing (5 and 7.5 cm). Bosekeng [9] also observed that large plants grown at wider spacing are associated with split bulbs and sensitive to a cold stimulus causing bolting. Optimization of plant population is thus important and needs to be optimized. Therefore, the present study initiated to determine the effects of plant spacing and nitrogen fertilizer on growth and yield of onion.

2. Material and Methods

2.1. Description of Study Area

The study was conducted at Koga Irrigation Scheme of Mecha district during the irrigation season of 2018. The scheme is found about 35 km far to Southwest of Bahir Dar, Capital city of Amhara National Regional State located at 11° 10′N to 11° 25′N latitude and 37° 02′E to 37° 17′E longitude. The elevation of scheme is 1960 m.a.s.l. According to Bahir Dar Meteorology station, the study area received an annual mean rain fall of 1395.23 mm. The mean maximum and minimum temperature of the study area are 27°C and 12.8°C respectively. Major crops grown includes, maize, finger millet, bread wheat and teff during the main cropping season while; bread wheat, potato, onion, tomato and cabbage during the irrigation season (MelkamuAlemayehu*et al.,* 2015).

2.2. Experimental Materials, Treatments and Design

Bombay Red variety of onion was used as a test crop, which was collected from Adet Agricultural Research Center (AARC). The variety was recommended by Melkasa Agricultural Research Center, for its high yielding and promising agronomic performances. It is an early maturing variety, takes less than 120 days to maturity [11]. The cultivar is well adapted to the experimental areas and preferred by smallholder farmers in the locality as well as by commercial farmers throughout the country. The variety can be grown in the areas, which have an altitude of 700-1800 m.a.s.l.

The field experiment was conducted on three intra spacing (4cm, 7cm, 10cm) and four nitrogen fertilizer rates (0kg, 41kg, 82kg, 123kg/ha). Factorial combined to make a total of 12 treatments. The experiment was laid out in Randomized Complete Block Design with three replications. The size of each plot was 2mx1.8m, which accommodates different net plot areas. The distance between furrow, blocks and plots was 40cm, 1.5 m and 1 m, respectively.

2.3. Experimental Field Management

Good quality seeds of Bombay Red variety was sown in rows on 1m x 5m well prepared seedbed at seeding rate of 3-4 kg/ha to raise seedlings. The management of seedlings such as watering, cultivation, fertilization, control of diseases and insect pests were done as per the recommendation. The experimental site was prepared well by broken down large clods in order to make the fine tilth of the experimental plots. The whole field was divided in to three blocks each containing twelve (12) plots. The plots were prepared with a distance of 1 m between plots, 1.5 m between blocks and 40 cm between furrows. Each of the twelve-treatment combination was assigned to the experimental plots with three replications randomly.

After 55 days of sowing, seedling which have 3 to 4 true leaves stage with 12-15 cm height, healthy and vigorous seedling were transplanted on well prepared experimental plots where they were plowed and harrowed using oxen. Replanting of dead seedlings in the field was done one week after transplanting on the place where the first seedlings were planted.

The nitrogen fertilizer was applied as per of the treatmentto the plants in two equal splits where one half was applied 25 days after transplanting and the remaining one half after 45 days of transplanting.

Experimental units were irrigated using furrow irrigation method in each plot and row in plots received water from the source without passing any of the experimental plots to prevent mixing of fertilizer rates agreed to different plot. Transplanted seedlings were irrigated using furrow irrigation at 4-5 days interval until their establishment and at 5-7 days intervals until maturity. Fifteen days before harvesting however, irrigation of plants was stopped for curing purpose as recommended by [12].

2.4. Data Collection

2.4.1. Growth Parameters of Onion

Days to 80% maturity (days):- The number of days elapsed from the time of transplanting up to the date when 80% of plants became dry and collapsed at the neck was counted and the mean values were computed and used for further analysis. Plant height (cm):- Plantheights from the soil surface to the longest leaf of ten randomly selected plants grown in the net plot area was measured using a ruler at physiological maturity and the mean values were computed and used for further analysis.

2.4.2. Yield Related Parameters of Onion

Bulb diameter (cm):- The widths of ten randomly selected bulbs, which were harvested from the net plot area was measured at the middle of the bulb-using caliper and the mean values were computed and used for further analysis. Bulb weight (g):- The weights of ten randomly selected bulbs which were harvested from the net plot area was measured using sensitive balance and the mean bulb weight was computed and used for further analysis (NigatuMuluneh, 2016).

Marketable bulb yield (t/ha):- Bulbs harvested from the net plot area which were free from damages and greater than or equal to 20g in weight were considered as marketable [14]. The weight of such bulbs was weighedusing sensitive balance and expressed in ton per hectare. Unmarketable bulb yield (t/ha):-Bulbs harvested from the net plot area which were thick necked, physiological disorder, splitted, rotten, damaged, and discoloreddiseased and insect attacked and under sized (<20g), were considered as unmarketable [15]. The weight of such bulbs was weighed using sensitive balance and expressed in percentage of the total yield. Total bulb yield (t/ha):- It was obtained by summation of marketable and unmarketable bulb yield.

2.5. Data Analysis

The collected data were subjected to Analysis of variance (ANOVA) using the Statistical Analysis System (SAS) Software version (9.0). Mean separation between treatments was done using Least Significance Difference at 5% probability base on the ANOVA results as indicated by Gomez and Gomez [16].

3. Results and Discussion

3.1. Effects of Nitrogen Fertilizer and Intra-row Spacing on Growth of Onion

3.1.1. Days to Maturity

The analysis of variance revealed that the main effects of intra-row spacing and nitrogen fertilizer rates as well as their interaction highly significantly ($P < 0.01$) influenced maturity days of onion plant (Table 1).

Increasing intra row spacing as well as rate of nitrogen markedly prolonged the days to maturity of the onion crop. In the interaction effect, the highest days to maturity (115 days) were recorded by application of highest rates of nitrogen on plant spaced at wider intra-row spacing. On the other hand, the shortest days to maturity was recorded when onion plants were planted at narrower intra row spacing without nitrogen application. Therelatively long maturity due to higher nitrogen rate could be associated to prolonged canopy growth and thereby continuing photosynthesis. This indicates that the nitrogen taken up by plant roots may be used for cell division thus, predominantly partitioned to the vegetative sink of the plants that resulting with a luxurious foliage growth of plants [17].

The results are consistent with the findings of [18] who reported that plants grown with higher nitrogen fertilizer (123 kg ha^{-1} N) at higher intra row spacing (10cm) took longer time for maturity.

On the other hand, plants supplied with low rate of nitrogen and planted at narrower intra row spacing matured earlier. The results of the present study are also in agreement with the findingsof [20] who noted that application of higher nitrogen fertilizer rate was prolonged maturity of onion plant. Similarly, In agreement with the present study, [21] reported that increasing the rate of nitrogen from nil to 32 kg N ha^{-1} significantly extended the number of days required to reach maturity by onion plants. Similar findings were reported that plants grown at widest intra row spacing took longer time to reach maturity while those at lowest intra row spacing matured earlier [22].

Table 1. *Interaction effects of intra-row spacing and nitrogen fertilizer rates on growth of onion plants.*

Intra rowspacing (cm)	N- rates (kg/ha)	Day to maturity (days)	Plant height (cm)
4	0	105.0^{g}	49.4^{f}
	41	106.7^{efg}	53.57^{cde}
	82	108.3^{def}	54.57^{cde}
	123	111.0^{cd}	56.03^{c}
7	0	106.0^{fg}	51.53^{ef}
	41	107.0^{efg}	53.67^{cde}
	82	109.0^{de}	55.0^{cd}
	123	112.0^{bc}	56.47^{bc}
10	0	106.0^{fg}	52.57^{def}
	41	107.6^{efg}	54.17^{cde}
	82	114.0^{ab}	59.63^{ab}
	123	115.0^{a}	60.53^{a}
P-value		**	**
CV (%)		1.13	2.64
SE ±		1.24	1.44

Means followed by the same letters within a column are not significantly different at ($P<0.01$); ** denotes highly significance difference at ($P<0.01$); CV = coefficient of variation; SE= standard error.

3.1.2. Plant Height

The analysis of variance revealed that main effects of intra-row spacing and nitrogen fertilizer rates and their interaction effect highly significantly ($P < 0.01$) influenced plant height of onion (Table 1).

Increasing intra row spacing as well as nitrogen generally increased height of onion plant. In the interaction effect, application of highest rate of nitrogen on plant spaced at wider intra row spacing recorded highest plant height (60.53cm). On the other hand, plants planted at narrower intra row spacing without nitrogen fertilizer recorded the lowest plant height (49.4 cm) as indicated in (Table 1). This might be due to the application of nitrogen mainly related to the production of new shoots and improvement of vegetative growth, which is directly related to the increase in plant height. Additionally, there is less competition for nutrients, moisture and light among the plants to achieve the required food for their growth due to the wider intra-row spacing. Similar findings were reported by [23] who reported that higher plant height of onion was recorded from the interactions effect of 100 kg ha^{-1} combined with 20 and 25 cm intra row spacing while lower plant height of onion was recorded from the interaction effect of control plants without nitrogen and narrow intra-row spacing.

Corgan J. N. M. et al alsoreported that onion plants grown at the highest intra row spacing of 10 cm recorded the highest weight (51.42 cm)[24]. On the other hand, onion plants grown with the lowest intra row spacing of 4 cm had the lowest plant height (45.35 cm).

3.2. Effects of Nitrogen Fertilizer and Intra-row Spacing on Yield Components

3.2.1. Bulb Diameter

The main effects of nitrogen and intra-row plant spacing as well as their interaction effect highly significantly (P < 0.01) influenced the onion bulb diameter (Table 2).

Table 2. *Main effects of intra-row spacing and nitrogen fertilizer rates on diameter and weight of onion bulb.*

intra row (cm)	N-rate (kg/ha)	Bulb diameter (cm)	Bulb weight (g)
4	0	4.15^{g}	63.52^{e}
	41	4.97^{efg}	77.56^{d}
	82	5.69^{cde}	90.51^{ab}
	123	6.44^{abc}	92.37^{ab}
7	0	4.49^{g}	65.44^{e}
	41	5.34^{def}	81.13^{ab}
	82	6.05^{ab}	91.14^{ab}
	123	7.80^{a}	95.28^{a}
10	0	4.67^{fg}	73.49^{d}
	41	5.48^{def}	86.84^{bc}
	82	6.59^{ab}	94.48^{ab}
	123	7.20^{a}	96.05^{a}
P-value	**	**	**
CV (%)		6.43	4.15
SE ±		0.37	3.48

Means followed by the same letters within a column are not significantly different at (P<0.01); ** denotes highly significance difference at (P<0.01); CV = coefficient of variation; SE= standard error.

Increasing the rate of nitrogen as well as widening of intra row spacing consistently increased the bulb diameter of onion (Table 2). Application of highest rate of nitrogen (123 kg ha^{-1}) on plants spaced at widest intra row spacing (10 cm) was resulted in the highest bulb diameter as indicated in Table 2. On the otherhand, combination of 4cm intra row spacing and nil rate of nitrogen produced the smallest bulb diameter.

The development of wider bulb diameter with increased intra-row spacing and rate of nitrogen observed in the present study could be associated with the supply of enough nitrogen, which promotes cell elongation, above ground vegetative growth and due to less competition within plants. This may be linked to more metabolic processes that increase dry matter production and translocation to the bulbs. The results of the present study are in agreement with the findings of who reported that increasing the rate of nitrogen fertilizer consistently increased the bulb diameter of onion across the increasing intra-row spacing. The author obtained widest bulb diameter in response to the application of 123 kg ha^{-1} N on widest spaced onion plants 12.5 cm. On the other hand, the lowest average bulb diameter was obtained from plants supplied with lower rate of nitrogen and planted at narrower intra row spacing of 2.5 cm and 5cm. [25] also reported that application of nitrogen fertilizer up to 136 kg ha^{-1} significantly improved the weight of onion bulbs. [26] Also recorded highest bulb diameter (5.63 cm) when onion plants were spaced at 13 cm intra-row spacing followed by 10 cm intra-row spacing (5.50 cm). Similar to the results of the present study, [27] also reported in the highest bulb diameter (6.69 cm) at 15 cm intra row spacing followed by 12.5 while significantly minimum bulb diameter (5.26 cm) obtained at closer spacing of 7.5 cm. The results are also consistent with the finding of [28] where wider intra row spacing was resulted in highest bulb diameter.

3.2.2. Bulb Weight

The analysis of variance revealed that the main effects of intra-row spacing and nitrogen fertilizer rates and their interaction highly significantly (P < 0.01) influenced bulb weight of onion (Table 2). Increasing the nitrogen rate and widening intra row spacing generally increased average bulb weights of onion plants.

The highest average bulb weights were recorded at treatment combination of highest rate of nitrogen (123 kg ha^{-1} N) and wider intra-row spacing (10cm) while the lowest average bulb weight was recorded at treatment combination of nil rate of nitrogen rate and narrower intra-row spacing (Table 2). This might be the fact that wider spacing accommodates less number of plants, which received adequate nutrient, moisture, and light and thus helped to improve the bulb weight of onion plants [29].

3.2.3. Marketable Bulb Yield

The main effects of nitrogen highly significantly (P < 0.01) and that of the intra-row spacing significantly (P < 0.05) influenced marketable bulb yield of onion. The interaction effect of intra row spacing and nitrogen highly significantly (P < 0.01) influenced the marketable bulb yield of the onion (Table 3).

The highest marketable bulb yield (43.8 t/ha) of onion was recorded at treatment combination of 82 kg ha^{-1} N and 4cm intra-row spacing. On the other hand, onion plants spaced at widest intra-row spacing without nitrogen were resulted in lowest marketable bulb yield of onion (Table 3).

The closer intra row spacing and application of optimum rate of nitrogen leads to highest number of bulbs with marketable size. Although plant height, number of leaves per plant and leaf length increased with increasing spacing in the present study, higher number of plants per unit area with enough supply of nitrogen increased marketable bulb yield. The marketable bulb yield of onion per unit area does not completely depend up on the performance of individual plants but also related with the total number of plants per unit area and yield contributing parameters [30].

Table 3. *Interaction effect of intra-row spacing and rates of nitrogen fertilizer on yields of onion.*

Intra row spacing (cm)	N- rate (kg/ha)	Marketable Yield (t/ha)	Unmarketable Yield (%)	Total bulb Yield (t/ha)
4	0	17.97^{g}	28.8^{a}	25.24^{e}
	41	25.41^{ef}	12.86^{c}	29.16^{e}
	82	43.80^{a}	3.52^{ed}	45.4^{a}
	123	41.63^{b}	3.63^{ed}	43.20^{ab}
7	0	21.20^{fg}	19.6^{b}	26.37^{e}
	41	24.81^{e}	6.41^{d}	28.51^{e}
	82	36.17^{bc}	4.16^{ed}	37.74^{b}
	123	34.02^{d}	2.04^{ef}	34.73^{c}
10	0	21.51^{fg}	16.3^{c}	25.71^{e}
	41	27.40^{e}	5.81^{d}	29.10^{e}
	82	33.22^{d}	4.4^{ed}	34.78^{d}
	123	33.23^{d}	1.54^{f}	33.75^{d}
P-value		**	**	**
CV (%)		6.01	15.95	5.23
SE ±		1.85	0.42	1.74

Means followed by the same letters within a column are not significantly different at (P <0.01); ** denotes highly significance difference at (P<0.01); CV = coefficient of variation; SE= standard error.

3.2.4. Unmarketable Bulb Yield

The analysis of variance revealed that the main effects of intra row spacing and nitrogen rate as well as their interaction highly significantly ($P < 0.01$) influenced the unmarketable bulb yield of onion (Table 3). With the increase in the intra-row spacing and nitrogen fertilizer rate, unmarketable bulb yield of onion decreased significantly (Table 3). The highest value of unmarketable bulb yield (28.8%) was recorded in control plots at 4cm intra-row spacing followed by 7cm without nitrogen (19.6%). On the other hand, onion plants fertilized with 123 kg ha^{-1} N at spacing of 7 and 10 cm was resulted in minimum unmarketable bulb yield.

This might be due to higher interplant competition for nutrient, water, light and air in narrowest plant spacing, which influences the growth of onion plants [31]. The results of the present study in agreement with the findings of [32] who reported highest unmarketable bulb yield of 7 t/ha at lowest intra row spacing of 4 cm. On the other hand, onion plants spaced at wider intra row spacing (10 cm) produced the lowest unmarketable bulb yield of 2 t/ha. Likewise, [33] also reported that nil nitrogen fertilizer rates resulted in more unmarketable bulb yield.

3.2.5. Total Bulb Yield

The main effects of nitrogen and intra-row spacing as well as their interaction highly significantly ($P < 0.01$) influenced the total bulb yield of onion (Table 3). Total bulb yield increased significantly in response to increasing rate of nitrogen fertilizer application. In the interaction effect, plants supplied with 82 kg ha^{-1} N and planted at 4cm intra row spacing was resulted in the highest total bulb yield. On the other hand, the treatment combination of 10 cm intra row spacing and nil nitrogen was resulted in the lowest total bulb yields (Table 3).

The higher total bulb yield in response to the treatment combination of 4cm intra row spacing and 82 kg ha^{-1} Nin the present study might be due to application of optimum rate of nitrogen fertilizer required for plants per unit area as described by [34]. Moreover, onion plants planted at optimum density also helps for attaining their optimum bulb size [35]. These results agree with the findings of [36] who reported that the highest onion bulb yields were recorded at closest spacing.

4. Conclusions

Based on the results of the study, application of site and plant density specific rate of nitrogen is necessary for economic production of onion. Accordingly, application of 82kg ha^{-1} nitrogen fertilizer for onion plants, which were planted at 4 cm intra row spacing, is recommended for economically and agronomical production of onion in the study area and similar agro-ecologies. Hence, onion producing farmers in the study area can be advised to applying of 82kg ha^{-1} nitrogen fertilizer and at 4 cm intra row spacing for onion plants to increase the production.

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