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Onion (*Allium cepa* l. Var. Cepa) Bulb Traits as Affected by Nitrogen Fertilizer Rates and Intra-Row Spacing under Irrigation in Gode, South-Eastern Ethiopia

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Abstract

Shebelle river basin along the Gode district is one of the most suitable areas for the production of dry bulb onion, which is an important cash crop for farmers in the study area. However, the productivity of the crop is low due to poor agronomic practices and managements. Therefore, a field experiment was conducted at Gode Polytechnic College demonstration farm in 2013 under irrigation to assess the effect of N fertilizer rates and intra-row spacing on bulb triats of onion (*Allium cepa* L.). The treatments were consisting six rates of N fertilizer (0, 46, 69, 92, 115, 138 kg ha^{-1}) and four levels of intra-row spacing (7.5, 10, 12.5 and 15 cm). The experiment was designed in randomized complete block design with three replications. Results of the analysis revealed that the interaction effects of N rates and intra-row spacing showed highly significant (P<0.01) effect on bulb diameter and mean bulb weight parameters whereas the two factor show again a significant (p<0.01) independent effect on bulb length and bubl dry weight. The correlation analysis revealed that bulb length (cm) has a significant (p<0.05) positive correlation with bulb diameter parameter (r=0.24*), bulb weight (r=0.77**) and bulb dry weight (r=0.73**) and inversely correlated with that of nek thickness (r=-0.28*). Thus, It can be concluded that almost all bulb traits of onion can respond well at higher N rate (138kg N ha^{-1}) combined with 15cm inra-row spacing under Gode condition.

Keywords: Bulb; Intra-row; Irrigation; Nitrogen; Onion; Rate; Spacing

Introduction

Onion (*Allium cepa* L.) is considered as one of the most important vegetable crops produced on large scale in Ethiopia and also occupies economically important place among vegetables in the country [1]. The area under onion is increasing from time to time mainly due to its high profitability per unit area and ease of production, and the increases in small scale irrigation areas. Ethiopia has a great potential to produce onion throughout the year both for local consumption and export [2]. Onion is grown primarily for its bulb which is used for flavoring the local stew, 'wet' which is considerably important in the daily diet, mostly used as seasonings or as vegetables in stews. It is one of the richest sources of flavonoid in the human diet and flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. In addition it is known for anti-bacterial, antiviral, anti-allergenic and antil-inflammatory potential [3].

The crop is produced both under rainfed in the 'Meher' season and under irrigation in the dry season. In many areas of the country, the dry season cropping (under irrigation) constitutes much of the area under onion production. Despite the increase in cultivated areas, the productivity of onion is much lower than other African countries and the world average. The low productivity could be attributed to the limited availability of quality seeds and associated production technologies used [1]. According to [4], for private farmers' holdings in 'Meher' season 2012/2013, the total area coverage by onion crop in the country was 21,865.4 ha, with total production of 219,188.6t with average productivity of 10.02t ha^{-1}. This is very low yield compared to the world average of 19.7t ha^{-1} [5]. The low yield level could be due to low soil fertility, salinity effect and inappropriate cultural practice [6].

The Shebelle river banks and sinks along the Gode district are one of the most suitable areas for the production of onion. Recently onion growers in the study area started producing onion for home consumption as well as cash crop by irrigation. Farmers in the study area are mostly engaged in livestock production and few have recently started sedentary agriculture. Thus, productivity of most of the crops, including onion, is low due to poor agronomic and management practices. Moreover, lack of improved varieties and seed, absence of recommended N fertilizer rate and plant spacing are the pertinent problems of the study area. Currently the nationally recommended fertilizer rate of 100 kg DAP ha^{-1} (46 kg P_2O_5 ha^{-1}) and split application of 150 kg Urea ha^{-1} are used along with 10cm plant spacing for onion production with no consideration of soil types [1,7]. However, farmers in Gode area have no experience of applying the nationally recommended fertilizer rate and plant spacing rather they randomly practice undetermined fertilizer rate and plant spacing. Therefoe, the objective of the study was to determine the effect of N fertilizer rates and intra-row spacing on bulb yield characters of onion.

Materials and Methods

Description of the study area

A field experiment was conducted in 2013 from January to June under irrigation at Gode, Polytechnic College crop production and marketing management department demonstration farm, which is found in Somali National Regional State, South-eastern Ethiopia. The site is situated at latitude of 5o 57'N and longitude of 43o 27'E. Gode is

1,225 km far from Addis Ababa city and 580 km far from capictal city of the region Jigjiga town. The experimental site lies at an altitude of about 300 m above sea level and It is characterized by high temperature, erratic rainfall and sandy clay loam soil texture. Gode district has a vast area of plain suitable for large scale irrigated agriculture and livestock production [8].

Description of the experimental materials, treatments and experimental design

Onion cultivar called Seiyunn-Hadhramout-R.Y (Yemen F_1-hybrid seed), locally named as 'Qalafo' onion, which is well adapted and widely cultivated in the study area was used as a test crop for the field experiment. It has light red colour, globe shaped bulb with pungent smell and mature in 115-130 and have yield potential of 35-46t ha^{-1}. Urea (46% N) fertilizer was used as a source of N for the field experiment. The national recommended rate of N fertilizer which was found adequate for dry bulb production in upper awash region was 92 kg N ha^{-1} and 10cm plant spacing was investigated at Melkassa and Were Research centers [1] and they were used as the basis to set the N fertilizer rates and intra-row spacing in this study.

The treatments consists of factorial combination of six rates of N fertilizer (0, 46, 69, 92, 115 and 138 kg N ha^{-1}) and four levels of intra-row spacing (7.5, 10, 12.5 and 15 cm). There were a total of 24 treatment combinations. The experiment was laid out in randomized complete block design (RCBD) with three replications. The size of each plot was $2 \times 3m^2$ accommodating ten rows (five double rows) with 40, 30, 24 and 20 plants per row for the intra-row spacing of 7.5, 10, 12.5 and 15 cm, respectively. The recommended inter-row spacing of 40 cm was maintained for all plots. The distance between plots and blocks were 1 m and 1.5 m, respectively. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants. Internal single rows of the outer double rows at both sides of the plot were used for destructive samples (bulb dry weight).

Experimental procedure

Seedlings were raised, on three sunken beds with size of $1.2 \times 5\ m^2$, from Yemen origin seed locally named 'Qalafo' onion and were obtained from vegetable seed supplier shop and were sawn on January 01, 2013 at 10 cm distance between rows, lightly covered with soil and mulched with grass until seedlings are emerged (2-5 cm from the soil). Each bed was supplied with 100 g Urea and managed for about six weeks and then after transplanted to the main experimental plots [7].

Before transplanting seedlings, the main experimental field was ploughed and harrowed by tractor. Large clods were broken down in order to make the land fine tilth. Plots were leveled and furrows and ridges were prepared at a spacing of 40 cm. Then seedlings were transplanted when they reached 12-15 cm height or 3-4 true leaves stage by carefully uprooting [1]. One day before transplanting of seedlings, beds were irrigated for safe uplifting of seedlings. During transplanting only healthy, vigorous and uniformly standing seedlings grown at the center of beds were transplanted and gap filling was done within a week after transplanting.

The experiment was conducted under furrow irrigation method. Four day irrigation interval was maintained for the 1st four weeks and then extended to seven days interval until 15 days to harvest, when irrigation was stopped completely. All other agronomic practices were applied as per the recommendation made for the crop for all plots throughout the experimental period. Harvesting of onion bulbs was done when 70% plants in each plot show neck fall. Harvested onion bulbs were cured for four days by windrowing on the ground before topping [7].

Soil sampling

Soil sampling was done before transplanting of seedlings from five entire representative points of the experimental site from depth of 0-30 cm then mixed to form composite sample. This composite sample was sub-divided in to working samples for analysis. Soil analysis for specific parameters was carried out at Addis Ababa city government environmental protection authority and water works design and supervision enterprise soil laboratories. The composite pre-planting soil samples were analyzed for soil EC and pH at 1:2.5 soils to water ratio using a glass electrode attached to pH digital meter, organic matter was determined by using [9] method, total N was determined using Kjeldhal method as described by [10], available P was determined by the methods of [11], exchangeable K and Na was determined by potentiometericaly with 1M ammonium acetate at pH 7.0, Soil cation exchange capacity (CEC) was determined by ammonium acetate method [12] and Soil texture was determined by Bouyocous hydrometer method [13].

Data collection

Bulb traits were collected from 10 randomly selected and pre-tagged plants from the six central rows of each plot. Data were collected as per the procedures mentioned below for each parameters.

Neck thickness (cm): The average neck thicknesses of sampled plants were obtained by measuring the neck of bulbs at the narrowest point at the junction of bulb and leaf sheath using a caliper.

Bulb length (cm): was the vertical average length of the matured bulb of sampled plants which was measured with a caliper.

Bulb diameter (cm): was the horizontal cross sectional length of the matured bulbs of sampled plants which was measured using a caliper at the widest point in the middle portion of bulbs and the average was taken as bulb diameter per plant for each plot.

Mean bulb weight (g $plant^{-1}$): was the average weight of matured bulbs of sampled plants, which was taken using a sensitive balance after harvesting and curing.

Bulb dry weight (g $plant^{-1}$): bulbs of sampled plants were chopped in to small pieces with the help of stainless steel knife, samples were placed on drying materials and kept under open sun for seven days and then placed in paper bags and dried in an oven at 65°C for 48 hr to obtain a constant weight. Each sample was weighed after drying using digital sensitive balance and the average was computed and recorded as dry weight of bulb per plant.

Data analysis

The data were subjected to analysis of variance (ANOVA) and correlation coefficient analysis using SAS version 9.1 GLM procedures and least significant difference (LSD) was used to separate means at $p<0.05$ probability levels of significance.

Results and Discussion

Selected soil physico-chemical properties of the study area

The results of the laboratory analysis of some selected physico-chemical properties of the soil of experimental site are presented below (Table 1). Results of the soil analysis before planting showed that the soil of the site is sandy clay loam in texture with alkaline (pH 8.3) reaction. The soil had a bulk density of 1.08g cm^{-3}, and 0.02%, 29.34 ppm, 0.70% of total N, available P and, organic matter content, respectively. It had also 0.40%, 14.6 c.mol kg^{-1} soil, 0.729dS m^{-1} and 0.70 c.mol kg^{-1} of organic carbon, CEC, EC, and exchangeable Na respectively. The rating under remark (Table 1) was done according to Hazelton, et al. [14] and Donald, et al. [15] suggestions.

According to the limit suggested by [9], the organic carbon (1.43%) or organic matter content (2.46%) of the soil was rated as very low before planting. According to the rating suggested by Landon [16], the N content (0.15%) and CEC (39.13) before planting was rated as low and high before planting respectively. According to the rating suggested by Olsen, et al. [17] the P content (15.5 ppm) before planting was rated as medium.

Soil properties	Results	Remark
Soil depth(cm)	0-30	
Particle size distribution (%)		
Clay (%)	23.08	
Silt (%)	25.84	
Sand (%)	51.08	
Soil textural class		Sandy clay loam
Bulk density (g/cm3)	1.08	Satisfactory/ moderate
Organic carbon (%)	0.4	Low
Organic matter content (%)	0.7	Low
Total N(%)	0.02	Very Low
Available Phosphorus (ppm)	29.34	High
CEC (c.mol/kg soil)	14.6	Moderate
Exchangeable Sodium c.mol kg-1	0.7	Moderate
EC (dS m-1)	0.729	slightly saline
Soil pH	8.3	alkaline

Table 1: Soil physico-chemical properties of the experimental site before planting Source: Addis Ababa city government environmental protection authority and water works design and supervision enterprise soil laboratories.

Bulb traits

Bulb length and bulb dry weight were significantly (P<0.01) influenced by N rates and intra-row spacing but not by the interaction of the two factors. Similarly, bulb diameter was highly significantly (P<0.01) influenced by N fertilizer rates and significantly (P<0.05) affected by intra-row spacing and the interaction of intra-row spacing and N fertilizer rates. The two main effects N rates and intra-row spacing as well as their interaction exerted highly significant (P<0.01) influence on mean bulb weight. However, both the main effects and their interaction did not show significant influence on bulb neck thickness.

Bulb length: In view of the independent effect of N rates, the increasing level of N from 0 to 138 kg N ha^{-1} linearly increased the bulb length of 'Qalafo' onion variety. The highest bulb length was recorded from plants which received 138 kg N ha^{-1} followed by 115 kg N ha^{-1} application whereas the lowest bulb length was registered in treatment with null N fertilizer (Table 2).

Considering the effect of plant spacing alone, higher bulb length (5.86 cm) was obtained from plants grown in wider intra-row spacing of 15 cm followed by those plants at 12.5 cm (5.67 cm) which was closely followed by plants spaced at 10 cm (5.61 cm), where the former two showed statistically non-significant difference. On the other hand, significantly smaller bulb length (5.46 cm) was obtained from plants of 7.5 cm spaced. The increase in bulb length was about 7.3% as intra-row spacing increased from 7.5 cm to15 cm, which might be attributed to reduced limitations of growth factors at wider spacing that allows better foliage growth and the bulbs to have more assimilates available for storage and thus resulted in higher bulb length. Dawar, et al. [18] reported that generally high planting density results in less availability and due to these bulbs do not attain their potential sizes.

Bulb diameter: The interaction effect of N fertilizer at the rate of 138 kg ha^{-1} and intra-row spacing of 15 cm produced longest bulb diameter of 6.79 cm which was statistically at par with the bulb diameter obtained from the application of same fertilizer rate at 10 and 12.5 cm plant spacing, 92 and 115kg N ha^{-1} at 12.5 and 15 cm intra-row spacing as well as 46 kg N ha^{-1} at 15 cm intra-row spacing. Bulbs with shortest diameter were observed at treatments with null N fertilizer rate and 46 kg N ha^{-1} at 7.5 cm intra-row spacing, which was statistically in correspondence with result of same N rate at 10 and 12.5 cm plant spacing, with the application of 69 kg N ha^{-1} planted with the first three spacing and with 92 kg N ha^{-1} at intra-row spacing of 7.5 cm (Table 3).

Treatments	Bulb length (cm)	Bulb dry weight (g)
N (kg ha^{-1})		
0	5.18^{d}	6.44^{e}
46	5.44^{c}	7.54^{d}
69	5.52^{c}	8.37^{d}
92	5.59^{c}	9.56^{c}
115	5.82^{b}	11.35^{b}
138	6.35^{a}	12.84^{a}
LSD (5%)	0.23	0.90
Intra-row spacing (cm)		
7.5	5.46^{c}	8.25^{c}
10'8	5.61^{bc}	9.23^{b}
12.5	5.67^{b}	9.75^{ab}
15	5.86^{a}	10.17^{a}

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LSD (5%)	0.19	0.74
CV (%)	4.95	11.79

Table 2: Main effects of Nrates and intra-row spacing on bulb length (cm) and bulb dry weight (g) of Qalafo onion variety grown at Gode under irrigated condition. Means values in column followed by the same letter are not significantly different at P<0.05, LSD=least significant difference; CV= coefficient of variation in percent.

The increase in bulb diameter at higher N and wider intra-row spacing might be attributed to the availability of sufficient growth factors that permit the bulb to accumulate more assimilates available for storage and result in higher bulb diameter.

The result of current study is in line with the finding of McGeary [19], Frappell [20], Rogers [21] who reported that size of onion bulbs grown in high densities were smaller and irregular in shape and there was a progressive shift of the modal-size grade to smaller grades as plant density increased. Many other researchers, were also reported similar results [18,22,23]. Geremew et al. [24] also found that Adama Red onion variety grown at intra-row spacing of 10 cm gave the highest bulb diameter (5.78 cm) as compared to intra-row spacing of 8 cm (5.65 cm) and 6cm (5.28 cm). Nitrogen stimulates root growth and development as well as the uptake of other nutrients [25] which help the onion plants to have better foliage growth that enable to produce bulbs with large diameter.

Intra- row spacing (cm)	N (kg ha^{-1})					
	0	46	69	92	115	138
7.5	4.91^{j}	5.06^{j}	4.99^{ij}	5.70^{d-j}	5.84^{c-h}	5.97^{c-g}
10	5.33^{f-j}	5.08^{hij}	5.14^{hij}	6.09^{a-f}	5.99^{b-g}	6.23^{a-e}
12.5	5.49^{e-j}	5.21^{g-j}	5.38^{f-j}	6.14^{a-f}	6.49^{a-d}	6.31^{a-d}
15	5.75^{d-i}	6.58^{abc}	5.75^{d-i}	6.36^{a-d}	6.79^{ab}	6.90^{a}
LSD (5%)	0.81					
CV (%)	8.49					

Table 3: Interaction effect of Nfertilizer rates and intra-row spacing on bulb diameter (cm) of Qalafo onion variety grown at Gode under irrigated condition. Means values in columns and rows followed by the same letter are not significantly different at P<0.05, LSD=least significant difference; CV=coefficient of variation in percent.

Mean bulb weight: Mean bulb weight appeared to be highly significantly (P<0.01) affected due to the effect of applied N fertilizer at different rates, intra-row spacing and the interaction of the two factors. Onion plants produced bulb with highest weight (92.21 g) due to the interaction effect of 138 kg N ha^{-1} and 15 cm intra-row spacing, which was 119.7% higher than the lowest mean bulb weight (41.97 g) recorded from plants that did not receive N fertilizer planted at the narrower intra-row spacing. In this study, it was observed that plants grew in wider intra-row spacing at higher rates of N fertilizer tend to produce heavy weight bulbs.

The increased N fertilizer which increased the mean weight of bulbs might be due to that N supply in plants increases the rate of metabolism and synthesized more carbohydrate thus increases bulb weight. This study seems to indicate that N fertilization contributed towards the mean bulb weight increment probably due to effect of N on increase of leaf size and assimilate production and partition to the bulbs, thereby increased weight of bulbs [26]. This result is in line with the findings of Vochhani, et al. [27], Singh, [28], Mozumder, et al. [29] who reported that mean bulb weights of onion significantly increased with increase in N fertilizer upto 150 kg N ha^{-1}. The results are also comparable with the finding of several researchers including Islam, et al. [30], Nasreen, et al. [31] who mentioned that application of 120 kg N ha^{-1} produced the highest mean bulb weight of onion. The closer spacing between plants and rows may cause competition for moisture, nutrients and light, thus reducing amount of assimilate available to be stored in the bulbs, which accordingly reduced their bulb weight [32]. This result is in agreement with observation made by Khan, et al. [33] who reported that plants spaced at 9 cm gave the lowest average weight for a single onion bulb while in 15cm spaced plants, the weight of the bulbs was maximum. Similar result was also reported by Dereje, et al. [34] where bulbs of “Huruta” shallot planted at 20 cm intra-row spacing produced the highest bulb weight per plant while those planted at 10 cm intra-row spacing produced the lowest bulb weight per plant. The result is in accord with Kahsay, et al. [35] who reported an increased mean bulb weight was observed as intra-row spacing increased from 5 cm to 10 cm.

Intra- row spacing (cm)	N (kg ha^{-1})					
	0	46	69	92	115	138
7.5	41.97^{n}	47.70^{m}	52.59^{k}	62.87^{hi}	71.74^{f}	78.07^{cd}
10	42.133^{n}	48.67^{m}	53.50^{jk}	64.73^{h}	72.63^{f}	80.49^{c}

12.5	42.87^{n}	49.23^{lm}	55.51^{j}	67.58^{g}	74.30^{ef}	87.75^{b}
15	43.88^{n}	51.50^{kl}	60.29^{i}	68.68^{g}	76.39^{de}	92.21^{a}
LSD (5%)	2.64					
CV (%)	3.76					

Table 4: Interaction effect of N fertilizer rates and intra-row spacing on mean bulb weight (g) of Qalafo onion variety grown at Gode under irrigated condition. Means values in columns and rows followed by the same letter are not significantly different al2t P<0.05, LSD=least significant difference; CV=coefficient of variation in percent.

Bulb dry weight: The highest bulb dry weight (12.84 g) was recorded from N fertilizer rate of 138 kg ha^{-1}. The increased levels of N from 0 to 46, 69, 92, 115 and 138 kg N ha^{-1} resulted in an increase in bulb dry weight by 17.08, 29.97, 48.44, 76.24, and 99.38%, respectively. The increased dry bulb weight due to the increased application of N is because of the fact that N is the most limiting factor in crop production and application of N fertilizer results in higher biomass yields. This might be attributed due to the physiological function of N in which cell elongation and aboveground vegetative growths are enhanced [36]. The current study result is in agreement with the findings of Kumar, et al. [37], Yadav, et al. [38] who reported that the highest bulb dry weight of onion was obtained at the rate of 150 kg N ha^{-1}.

The main effect of intra-row spacing was also highly significantly influenced bulb dry weight. Heavy bulb dry weight was recorded at the wider plant spacing which was at par with 12.5 cm statistically. Generally, as intra-row spacing increased from 7.5 cm to 15 cm, the bulb dry weight was also increased from 8.25 to 10.17 g (Table 4). This might be due to the fact that closer spacing between plants resulted in competition for nutrients, moisture and light, thus reducing amount of assimilate produced and stored in the bulbs which reduced their bulb weight. This result is in line with the findings of Khan, et al. [33] who reported that plants spaced at 9 cm gave the lowest average weight for a single onion bulb while in 15 cm spaced plants, the weight of the bulb was maximum. Similar result was also reported by Dereje, et al. [34] who observed that shallot bulbs planted at 20 cm intra-row spacing produced greater bulb dry weight per plant than those planted at 15 and 10 cm intra-row spacing. Abubaker [39] also reported that pod dry weight of bean tended to be higher under the lower plant density. In crop plants, dry matter accumulation is a result of nutrient uptake and one of the measures of plant growth [40].

Correlation analysis

Correlation coefficient (r) was computed to display the relationship between bulb traits of 'Qalafo' onion variety (Table 5). The correlation values showed the apparent association of the parameters with each other. The correlation analysis revealed that bulb length (cm) has a significant (p<0.05) positive correlation with bulb diameter parameter (r=0.24*) and significantly (p<0.01) and positively correlated with mean bulb weight (r=0.77**) and bulb dry weight (r=0.73**), this revealed that the presence of positive and strong association of bulb length with the other bulb traits except with that of nek thickness (r=-0.28*) wihich has significant (p<0.05) negative coorelation. These suggested that the application of N fertilizer rates in combination with optimal plant population could improve parts of the onion plant which improves the physiological capacity of the crop to mobilize and translocate photosynthates to the organ of economic value mostly the bulb traits by increasing individual bulb size and consequently contribute to harvet good yield per unit area.

	NT	BL	BD	MBW	BDW
NT	1				
BL	-0.28*	1			
BD	-0.22NS	0.24*	1		
MBW	-0.19NS	0.77**	0.13NS	1	
BDW	-0.21NS	0.73**	0.12NS	0.89**	1.00

Table 5: Correlation coefficient of onion yield and yield component parameters. NT=neck thickness, BL=bulb length, BD=bulb diameter, MBW=mean bulb weight, BDW=bulb dry weight * and ** indicate significant differences at P<0.05 and p<0.01, respectively.

Conclusion

Results of the field experiment revealed that the main effects of N rates and intra-row spacing showed a significant (p<0.05) effect on bulb length and bulb dry weight while neck thickness was not significantly affected by both factors. Besides, the interaction effect of N rates and intra-row spacing had significant (p<0.05) effect on bulb diameter and mean bulb weight. The correlation analysis result revealed also bulb length has a significant (p<0.05) positive correlation with bulb diameter parameter (r=0.24*), bulb weight (r=0.77**) and bulb dry weight (r=0.73**) and inversely correlated with that of nek thickness (r=-0.28*). Thus, It can be concluded that for good production of onion most bulb traits may responding well at higher N rate (138 kg N ha^{-1}) combined with wider (15 cm) inra-row spacing under Gode area condition.

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