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Growth and Bulb Yield of Onion (*Allium cepa* L.) in Response to Plant Density and Variety in Jimma, South Western Ethiopia

Demisie R[1] and Tolessa K[2*]

[1]*Department of Horticulture and Plant Science, College of Agriculture and Veterinary Medicine, Jimma University, Ethiopia*

[2]*Ethiopian Institute of Agricultural Research, Agricultural and Nutrition Research Laboratories Directorate, PO Box 2003, Addis Ababa, Ethiopia*

[*]**Corresponding author:** Tolessa K, Ethiopian Institute of Agricultural Research, Agricultural and Nutrition Research Laboratories Directorate, PO Box 2003, Addis Ababa, Ethiopia, Tel: +251-917-10-51-48; E-mail: kasech_tolassa@yahoo.com

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Abstract

In appropriate use of plant spacing and lack of evaluation of improved varieties across agro ecologies are the predominant agronomic practices that reduce the productivity of onion. The present study therefore, has been designed to investigate the influence of variety, intra-row spacing and their possible interaction on growth and yield of onion. The study was conducted under irrigation during the year 2016/2017 at Jimma University College of Agriculture and Veterinary Medicine, on experimental site of horticultural crops. Four onion varieties (Adama Red, Nafis, Melkam and Nasik Red) and three intra-row spacing (7,10 and 13 cm) with inter-row spacing of 20 cm. The experiment was designed in RCBD with three replications. The results of the study showed that both variety and intra-row spacing had a significant effect ($P<0.05$) on all parameters, except for the leaf diameter which was only affected by intra-row spacing. Leaf number per plant was significantly affected by interaction of variety and intra-row spacing. The highest leaf number (13.9) obtained from variety Nafis with intra-row spacing of 13 cm. In general, leaf number per plant, leaf length, plant height and leaf diameter were higher at wider intra-row spacing (13 cm). Nafis variety was superior in terms of leaf number per plant (13.9), bulb diameter (5.67 cm), average bulb weight (74.50 g), marketable yield (36.26 t ha^{-1}) and total bulb yield (36.28 t ha^{-1}). Onion plant grown at closer intra-row spacing (7 cm) showed very promising result for average bulb weight, marketable yield and total tuber yield. Moreover, the closest intra-row spacing (7 cm) gave higher marketable and total bulb yield than the wider intra-row spacing. Thus, growers in the study area can be benefited from closer intra-row spacing, however, it is paramount important to test the feasibility of the other closest intra-row spacing e.g., 6 cm and 4 cm.

Keywords: Onion (*Allium cepa L.*); Variety; Adama red; Nafis; Melkam; Nasik red; Intra-row spacing; Growth; Bulb and yield

Introduction

Onion (*Allium cepa L.*) is one of the most important vegetables which belong to the family *Alliaceae* [1]. It is originated in central Asia between Turkmenistan and Afghan where some of its relatives still grow as wild plants. It is a recently introduced crop to Ethiopia from Sudan and then distributed to different parts of the country and now became important vegetable crop for markets and in a daily life of people the country [2].

Onion is valued for its distinct pungency or mild-flavoured form of essential ingredients of many dishes. Fresh onion has about 86.6% moisture, 11.6% carbohydrate including 6-9 soluble sugars, 1.2% protein, 0.1% fat, 0.2-0.5% Ca, 0.05% P, traces of Al, Cu, Fe, Mn, Zn and vitamin A, B and C [3]. It is consumed universally in small quantities almost daily in many homes primarily as a seasoning for flavouring of dishes and sandwiches in the world [4]. It has nutritional value that helps alkaline reaction in our body and important in neutralizing the acid substance produced during the course digestion of meat, cheese and other food [5].

In Ethiopia, it has an economically important place among other vegetable crops due to ease of production, high profitability per unit area and increase in small-scale irrigation schemes, the area under production of the onion is increasing from time to time. According to CSA [6] 10.05 and 10.13 t ha^{-1} yields were obtained during the year 2013 and 2014/2015. Land covered by onion plant in the country increased to 33, 063.37 ha and 327,475.25 tons were obtained in 2016/2017 which correspond to 9.74 t ha^{-1} [7].

Despite its importance in the human diet and its increasing area coverage, the productivity of onion in the country is much lower than of other African countries with an average value of 10.1 t ha^{-1} [6]. One of the major problems associated with its production is inappropriate agronomic practices used by farmers which have quite a great contribution to lowering crop yields. Yemane et al. [8] also reported the limited use of improved seeds and fertilizers by small scale farmers. Moreover, quality and yield of particular onion variety greatly affected by planting density even if grown in the same environment [9].

The optimum level of any agronomic practice such as plant population, planting and harvesting date and fertilizer requirement vary with growing environment and variety. Thus, it is very difficult to give a general recommendation for agronomic management that can be applicable to different varieties and agro-ecological zones. Some studies indicated that varieties responded differently to different plant spacing as the result of variation in their growth pattern (e.g., roots and leaf). For instance, in mid-rift valley areas, variety Adama Red and Bomby Red gave higher bulb yield at 4 cm intra- row spacing than 6 and 8 cm intra row-spacing [4]. However, Yemane et al. [10] pointed out that better plant growth and bulb yield from 10 and 7 cm intra-row spacing in Aksum area. In another study, Tesfalegn [11] has observed higher yield at 4 and 7 cm intra-row spacing for Kobo area. These

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contradicting reports show that optimum plant density for a certain variety is highly site specific and need further study to give concrete recommendation across locations including Jimma zone. Therefore, the study was designed to determine the optimum population density for better plant growth and yield for different onion varieties under Jimma condition and to determine the possible interaction of variety and plant population for plant growth and yield of onion.

Materials and Methods

Study site

The experiment was conducted at Jimma University College Agriculture and Veterinary Medicine on experimental site during the year 2016/17 under irrigated condition. The area is situated in Oromia region, Jimma zone in south western part of Ethiopia. It is located at an elevation of 1710 m above sea level and at 70 42' 9"N latitude and 360 47' 6" E longitudes in Ethiopia. The experimental site receives an average annual rainfall of 1495mm with maximum and minimum temperatures of 26.5°C and 12°C, respectively. The soil of the experimental site is reddish brown clay classified as Nitisol with pH range of 5.0 to 6.0 [12].

Study materials

Four improved onion varieties (Melkam, Nafis, Adama Red and Nasik Red) were used in the study. The seeds of these varieties were obtained from Melkasa Agricultural Research Centre in 2016.

Treatments and experimental design

The treatment consists of four onion varieties (Adama Red, Nafis, Nasik Red, and Melkam) and three intra-rows spacing (7, 10 and 13 cm). Inter-row spacing was maintained at 20 cm. A total of twelve treatments were arranged in 4 × 3 factorial combination in randomized complete block design (RCBD) with three replications. Each treatment combination was assigned randomly to the experimental units within blocks. In general, there were 36 experimental units (plots).

Data collection

Growth, yield and yield components were measured using five selected and pre-tagged plants per plot. Bulb yield was obtained for the net plot.

Growth parameters

Number of leaves per plant: Fully developed leaves of five randomly selected plants counted from the middle rows of net the plot size at physiological maturity and the average was computed for each plant.

Leaf length (cm): The length of the longest leaves of five randomly selected plants were measured using measuring tape at physiological maturity and their averages were computed.

Plant height (cm): Plant height was measured from the ground level up to the tip of the longest leaf using a measuring tape. It was measured using five randomly selected plants from the two central rows of each plot at physiological maturity of the crop and the average values competed.

Leaf diameter (cm): It was taken from the widest parts of leaves of five randomly selected plants by using Vernier caliper (model 141) at physiological maturity and the average value was calculated.

Yield components and bulb yield

Bulb length (cm): The vertical average length of matured bulbs of five randomly selected plants in each plot was measured by veneers caliper.

Bulb diameter (cm): Bulb diameter was measured at right angles to longitudinal axis at the widest circumstance of the bulb of five randomly selected plants in each plot by using veneer caliper (model 141).

Average bulb weight (g plant^{-1}): The average weights of five randomly selected plants from the net plot was taken and calculated as the mean fresh bulb weight after harvesting and curing.

Marketable bulb yield (t ha^{-1}): Marketable yield further categorized by weight in to large (100-160 g), medium (50-100 g) and small (21-50 g) and expressed as kg/plot and converted into t ha^{-1}. Total weight of clean, disease and damage free bulbs with greater than 21g in weight was considered as marketable bulb yield [13].

Total bulb yield (t ha^{-1}): The yield that includes both marketable and unmarketable bulb weight and expressed as kg per plot and converted into t ha^{-1}.

Data analysis: All measurements were checked for normality before analysis and subjected to analysis of variance (ANOVA) and correlation analysis using SAS version 9.3 procedures and least significant difference (LSD) test was used to separate means at 5% probability level.

Results and Discussion

Growth parameters

Number of leaves per plant: Significant interactions between variety and intra-row spacing were observed for leaf number per plant ($P<0.05$; Table1). The highest leaf number (13.7) was obtained from variety, Nafis with intra-row spacing of 13 f cm while the lowest (7.8) was from variety, Adama Red with intra-row spacing of 7 cm (Table 1). The increase in leaf number along wider intra-row spacing than closer intra-row spacing might be due to less competition of onion plants for growth factors and abundant utilization of resources which accelerate leaf initiation. Recent study also revealed that plants grown at wider spacing produced more leaf number than at closer intra-row spacing [14].

Leaf length: Leaf length significantly influenced by variety and intra-row spacing ($P<0.0001$), however, their interactions did not show significant difference in the leaf length (Table 2). The highest (57.10 cm) leaf length was obtained from a variety Nasik Red while the lowest was from variety Melkam (51.6 cm). The differences in leaf length among varieties could be due their differences in their genetic traits. Similarly, Mekdes [13] reported the highest leaf length (43.24 cm) from variety Nasik Red compared to other varieties. Leaf length increased as intra-row spacing expanded from 7 to 13 cm. The longest leaf length was observed (57.10 cm) in plants spaced at 13cm an intra-row spacing followed by plants spaced 10cm (55.37 cm). Whereas plants spaced at 7cm apart showed the lowest (52.82 cm) leaf length (Table 2). This possible due to the availability of more nutrient and moisture at wider intra-row spacing whereas the closest intra-row spacing leads to strong competition for nutrient and moisture and thereby cause shorter plant. Yemane [15] and Tesfalegn [11] reported similar results in which the highest leaf length was obtained from wider intra-row spacing.

Variety	Intra- row spacing (cm)		
	7	10	13
Adama Red	7.8^{h}	11.0d^{e}	12.7^{bc}
Nafis	8.1^{g}	11.9^{cd}	13.9^{a}
Melkam	8.4^{gh}	8.4^{gh}	13.7^{ab}
Nasik Red	9.3^{gh}	10.2^{ef}	11.9^{cd}
LSD (5%)	1.19	1.19	1.19
CV (%)	6.29	6.26	6.26

Table 1: Leaf number of onion as influenced by interaction of variety and intra-row spacing. LSD (5%)=Least significant difference at P=0.05, CV (%)=Coefficient of variation in percent, means with the same letter(s) within a column are not significantly different at 5% of significance.

Plant height: Variety and intra-row spacing had a significantly effects on plant height (P<0.0001; Table 2). The interactions between variety and intra-row spacing, on the other hands, did not show significant differences. Variety Nafis gave the highest (64.33 cm) and Melkam recorded the lowest (59.70 cm) plant height. The genetic make of the varieties could be the possible reason for this variation.

Treatment		LL (cm)	PH (cm)	LD (cm)
	Variety			
	Adama Red	54.51^{b}	60.48^{c}	1.22^{a}
	Nafis	57.08^{a}	64.33^{a}	1.20^{a}
	Melkam	51.60^{c}	59.70^{c}	1.01^{a}
	Nasik Red	57.10^{a}	62.62^{b}	1.16^{a}
LSD (5%)		1.32	1.63	ns
Spacing				
	7	52.83^{c}	58.89^{c}	0.89^{c}
	10	55.37^{b}	61.77^{b}	1.07^{b}
	13	57.01^{a}	64.79^{a}	1.48^{a}
LSD (5%)		1.15	1.41	0.15
CV (%)		2.14	2.71	16.10

Table 2: Leaf length, plant height and leaf diameter of onion as affected by variety and intra-row spacing. LSD (5%)=Least significant difference at P=0.05, CV (%)=Coefficient of variation in percent, means with the same letter(s) within a column are not significantly different at 5% of significance, ns=non-significant, DM=Days to maturity, LH=Leaf height, PH=Plant height, LD=Leaf diameter.

In other study, Simon et al. [16] also found the highest plant height from variety Nafis than Adama Red and Bombey Red. As intra-row increased from 7 to 13 cm, the plant height also increased from 58.79 cm to 64 cm. Augmentations of plant height as intra-row push increments may be ascribed because of accessibility of plant supplement, water and daylight at more extensive intra-row push separating. This result is in line with the findings of Weldemariam et al. [17] who found the tallest onion plant from 15 cm intra- row spacing than plants grown 10 and 7.5 cm.

Leaf diameter: A significant difference was observed among intra-row spacing for leaf diameter (P<0.0001; Table 2). Variety and interaction, however, effect of variety and the interaction between variety and intra- row spacing did not show a significant difference.

Increasing intra-row spacing from 7 to 13 cm increased the leaf diameter of onion plants from 0.89 to 1.48 cm (Table 2). The wider leaf diameter produced at wider intra- row spacing might be due to wider spaced plants get proper light intensity which is very important for photosynthesis and nutrient as compared to the closely spaced plants. Similar result was reported by recorded. The highest leaf diameter was obtained for plants grown at wider intra-row spacing compared to the plant grown at closer spacing [15,18,19].

Yield components

Bulb length: Significant effect of variety and intra-row spacing was found on bulb length but their interaction did not show a significant difference (Table 3). Variety Adama Red gave the longest (5.85 cm) bulb length while variety Melkam had the shortest (5.09 cm) bulb length. This is due to the reality that varieties can have different genetic makeup that makes them different. Similarly, Jilani et al. [20] and Yemane [15] reported variation among onion varieties for bulb length.

Moreover, bulb length increased as intra-row spacing increased. The highest bulb length (5.69 cm) was recorded at the largest intra-row spacing (13 cm) whereas the narrowest intra-row spacing (5 cm) showed the lowest (5.25 cm) bulb length. This could be attributed to the adequate availability of growth resources at a wider spacing that allows the bulbs to have more assimilates available for storage. Dawar et al. [1] also reported that high planting density results in less availability of resources and due these bulbs do not attain their potential sizes. In agreement with present result, Dereje et al. [21] found higher bulb length (6.02 cm) from planted grown in wider spacing of (15 cm) followed by those planted at (12.5 cm) while significantly smaller bulb length (5.48 cm) was obtained from closer spacing (7.5 cm), which was also statistically similar to those planted at 10cm spacing.

Bulb diameter: Bulb diameter was significantly affected both by variety and intra-row spacing (P<0.05) (Table 3). Variety Adama Red gave the highest (5.67 cm) bulb diameter. The highest bulb diameter (5.63 cm) was found from onion plants grown at 13cm intra-row spacing, followed by plants those grown 10 cm intra-row spacing (5.50 cm). Plants spaced on 7 cm intra-row gave the lowest (5.13 cm) bulb diameter. There was no significant difference between plants grown at 10 and 13 cm intra-row spacing. However, plants grown at 7 cm intra-row spacing apart showed a statistical difference (Table 3). The increased in bulb diameter at wider plant spacing could be probably attributed to more nutrients, space, moisture availability and resulting in enlargement of their bulb size. Similarly, high plant density implies closer spacing and ultimate reduction in space available per plant, and then the tendency is real that bulb expansion might be limited due to smaller space for bulbing [22]. The present finding is in line with Nigulle and Biwas [23] who found the highest bulb diameter from wider intra-row spacing.

Treatment	BL (cm)	BD (cm)	ABW (g)
Variety			
Adama Red	5.85[a]	5.18[b]	62.88[c]
Nafis	5.49[a]	5.67[a]	74.50[a]
Nasik Red	5.48[a]	5.29[ab]	6 1.93[c]
Melkam	5.09[b]	5.55[ab]	70.44[b]
LSD (%)	0.37	0.38	1.86
Intra-row spacing (cm)			
7	5.25[b]	5.13[b]	63.32[c]
10	5.49[ab]	5.50[a]	66.93[b]
13	5.69[a]	5.63[a]	72.06[a]
LSD (5%)	0.32	0.33	1.61
CV (%)	7.00	7.22	2.82

Table 3: The effects of variety and intra-row spacing on yield and yield components of onion. LSD (5%)=Least significant difference at P=0.05, CV (%)=Coefficient of variation in percent, means with the same letter(s) within a column are not significantly different at 5% of significance, BL=Bulb length, BD=Bulb diameter, ABW=Average bulb weight.

Average bulb weight: The average fresh bulb of onion was highly ($P<0.0001$) influenced by variety and intra-row spacing, but the interaction did not show significant differences (Table 3). Variety Nafis had significantly higher bulb weight (74.50 g) followed by variety Melkam (70.44 g) and Adama Red (62.88 g). Variety Nasik Red recorded the lowest (61.93 g) average bulb weight. This result is in agreement with Geremew et al. [4] and Simon et al. [16] who reported the mean fresh weight variety Adama Red preceded by other varieties. Average bulb weight per plant was significantly decreased with decreased intra-row spacing. The highest and the lowest average bulb weight were recorded at a wider intra-row spacing of 13 and 7 cm intra-row spacing respectively. In general, mean fresh bulb weight was increased as intra-row spacing increased from 7 to 13 cm. Heavier bulbs in wider spacing might be attributed to the lower competition of plants for limited resources as compared to plants in narrower spacing which allowed higher assimilation and accumulate more dry matter in the bulbs. Gessesew et al. [24] also reported that increase of mean fresh bulb weight from 41.97 to 92.2 g as an intra-row spacing increase from 10 to 15 cm.

Marketable bulb yield: Both variety and intra-row spacing had a significant effect ($P<0.0001$) on marketable bulb yield (Table 4). Variety Nafis gave significantly higher marketable bulb yield (36.24 t ha^{-1}) followed by variety Melkam (31.77 t ha^{-1}) and Nasik Red (30.24 t ha^{-1}). The lowest marketable bulb yield (27.68 t ha^{-1}) was obtained from variety Adama Red (Table 4). The variation observed among onion varieties might be due to capacity to perform under the different agro-climatic condition and genetic makeup. In agreement with present result, Simon et al. [16] reported the highest and lowest bulb yield (15.94 t ha^{-1} and 9.17 t ha^{-1}) from variety Nafis and Adama Red respectively. Thus, the performance of varieties mainly depends on the interaction of genetic and environmental conditions.

Treatment	Marketable (t ha^{-1})	Total bulb (t ha^{-1})
Variety		
Adama Red	27.18c	27.57c
Nafis	36.15a	36.29a
Nasik Red	30.32b	30.57b
Melkam	31.77b	31.77b
LSD (5%)	2.60	2.64
Intra-row spacing (cm)		
7	38.93a	39.52a
10	29.92b	29.92b
13	25.21c	25.21c
LSD (5%)	2.25	2.25
CV (%)	8.48	8.44

Table 4: Marketable and total bulb yields of onion as affected by variety and intra-row spacing. LSD (5%)=Least significant difference at P=0.05, CV (%)=Coefficient of variation in percent, means with the same letter(s) within a column are not significantly different at 5% of significance, ns=non-significant.

As an intra-row spacing level increased from 7 to 13 cm the marketable bulb yield decreased. The highest marketable bulb yield (38.93 t ha^{-1}) was obtained from plants grown at 7 cm intra-row spacing. An intra-row spacing 13 cm showed the lowest marketable bulb yield (25.21 t ha^{-1}). However, the weight of individual bulb at 13 cm intra-row spacing was greater than 10 and 7 cm intra-row spacing (Table 4). Plant density has an impact on marketable bulb yield and the higher plant density causes smaller marketable bulb size [25]. The increased marketable yield at the closest intra-row spacing might be due to high plant population thus, plants produced more bulb yields. Hailu et al. [26] found the highest marketable yield (34.49 t ha^{-1}) from the closest (5 cm) intra-row spacing. Russo [27] also reported 97% of marke table onion bulbs from densely populated plant.

Total bulb yield: Variety and intra-row spacing showed highly significant (P<0.0001) effect on total bulb yield however, their interaction were not significant (Table 3). The highest total bulb yield (36.28 t ha^{-1}) was obtained from variety Nafis followed by Melkam (31.77 t ha^{-1}). The lowest total bulb yield (27.58 t ha^{-1}) was recorded from variety Adama Red. The difference in bulb yield of onion varieties depends on variation in genotypes, climate, cultural practices and their interactions. The present result is in agreement with findings of Simon et al. [16] who obtained the highest total bulb yield from variety Nafis than other varieties. Furthermore, the highest total marketable yield (39.52 t ha^{-1}) and the lowest total marketable yield (25.23 t ha^{-1}) were obtained from the closest (7 cm) and widest (13 cm) intra-row spacing, respectively. The increased total bulb yield by high plant population might be due to increased plant stand and consequently, a higher number of bulbs produced per unit area. However, the weight of bulbs reduced due to higher competition among plants for growth factors. This result is in agreement with findings of Nigullie and Biawas [23] who found the highest total bulb yield from densely populated onion plants than sparsely planted ones.

Conclusions

The result of the present study indicated that growth parameters and yield components increased as intra-row spacing extended from 7 to 13 cm. Nevertheless, marketable yield and total yield decreased with increased intra-row spacing (13 cm). In general, variety Nafis gave superior average bulb weight, marketable and total bulb yield compared to others. The closest intra-row spacing (7 cm) was found to be better in giving higher marketable and total bulb yield than the wider intra-row spacing. Thus, growers in the study area can be benefited from closer intra-row spacing however, it is paramount important to test the feasibility the closest intra-row spacing that cannot be included in the present study(e.g., 6 cm, 4 cm) to further increase the bulb yield per hectare in the study area.

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