

Full Length Research Paper

Effect of intra-row spacing on yield and quality of some onion varieties (*Allium cepa* L.) at Aksum, Northern Ethiopia

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Lack of improved varieties and production practices have been the major bottlenecks of onion production and productivity in Tigray, particularly at Aksum area. There have been no recommended intra-row spacing and variety for that area specifically; rather farmers used to practice non-uniform plant spacing. Thus, a field experiment was conducted to investigate the influence of intra-row spacing, variety and their interactions on yield, shelf life and bulb quality of onion, thereby recommend the optimum practices to farmers in the study area. The study was conducted between August 2010 and April 2011 at Aksum area (L/maichew district). Three different intra-row spacings (5, 7.5 and 10 cm) were evaluated using four varieties of onion ('Adama' Red, 'Bombay' Red, 'Melkam' and 'Nasik' Red) using RCBD replicated four times. Data on yield and quality parameters were recorded and subjected to ANOVA. Results indicate that intra-row spacing of 10 cm was superior in plant height, leaf number per plant, leaf biomass yield, leaf dry matter content and percentage of bolters. Highest total bulb yield was recorded at the closest intra-row spacing (5 cm) followed by 7.5 cm. 'Melkam' variety was the highest yielder, while 'Adama' Red was the lowest yielder. Average bulb weight increased with increasing intra row spacing. 'Melkam' variety followed by 'Bombay' Red variety was superior in average bulb weight. 'Adama' Red recorded the highest unmarketable yield.

Key words: Intra-row spacing, yield, quality, onion varieties, spacing.

INTRODUCTION

Onion (*Allium cepa* L.) belongs to the genus *Allium* of the family Alliaceae (Hanelt, 1990). Onion is by far the most important of the bulb crops cultivated commercially in most parts of the world. The crop is grown for consumption both in the green state as well as in mature bulbs. Onions exhibit particular diversity in the eastern Mediterranean countries, through Turkmenistan, Tajikistan to Pakistan and India, which are the most important sources of genetic diversity and believed to be center of

origin (Astley et al., 1982; Brewster, 2008). *Alliums* are typically plants of open, sunny, dry sites in fairly arid climates, however many species are also found in the steppes, dry mountain slopes, rocky or stony open sites, or summer dry, open, scrubby vegetation (Hanelt, 1990).

Onion is considerably important in the daily Ethiopian diet, mostly used as seasonings or as vegetables in stews (MoARD, 2009). It is one of the richest sources of flavonoids in the human diet and flavonoid consumption

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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 anti-inflammatory potential. One onion quality parameter, the percentage of single-center bulbs, has become important to meet demands of both processing and fresh market buyers (Brewster and Rabinowitch, 1990).

Yield and quality of dry bulbs can be influenced by cultural practices and growing environments. So far, research in the country was mainly focused on the identification of superior cultivars of onions and adopting improved management practices for better yield. The control of plant spacing is one of the cultural practices to control bulb size, shape and yield (Geremew et al., 2010).

The higher yield and better control of over or under bulb size could be obtained if plants are grown at optimum density. Bulb neck diameter, mean bulb weight and plant height decreased as population density increased.

Total bulb yield can be increased as population density increases (Kantona et al., 2003). Aksum-Adwa area is one of the potential areas for onion production in Ethiopia (EHDA, 2011). Market problem and poor cropping pattern are major problems in the study areas due to lack of proper agronomic practice used by farmers (AxARC, 2009). This is because there had been no agronomic or varietal trial done for onion so far at the area especially oriented to quality bulb production.

According to Fekadu and Dandena (2006), one of the major constraints of the vegetable sector in the country include: Lack of proper post harvest handling, suitable marketing and transportation systems, sufficient quantity of seed supply and good orientation of people to make them aware of the nutritive and economic advantages of these crops.

The present study was therefore undertaken to investigate the effects of different intra-row spacing on the yield and quality of onion varieties.

MATERIALS AND METHODS

Description of the study site

The study was conducted in 2010/11 from August 2010 to April 2011 at Aksum area (L/maichew district), Central Zone of Tigray National Regional State, 245 km away from Mekelle towards the North West. The experimental site lies between latitude of 14° 07' 00" and 14° 09' 20" N, and 38° 38' 00" and 38° 49' 09" E longitude, and elevation of 2080 m above sea level. The soil is classified as loamy clay vertisol. The rainy season of the area is monomial and receives 700 mm average rainfall per annum. The annual minimum and maximum monthly temperature ranges from 11 to 15.1°C respectively.

Experimental treatment and design

The experiment consisted of factorial combination of two factors of:

intra-row spacing (5, 7.5 and 10 cm) having plant population of 100, 75 and 50 per m² respectively and variety (Adama Red, Bombay Red, Melkam and Nasik Red). The row spacing was 20 cm. The field experiment was laid out in 3 x 4 factorial randomized complete block design (RCBD) replicated four times.

Experimental management

Cultural management practices other than intra-row spacing were done according to the national recommendations. During maturity when 2/3 of the leaves become yellow in color, bulb was harvested and cured for 5 days (EIAR, 2007). Five sample bulbs were taken from each plot for data collection at one time.

Data collection and analysis

Data were collected using the standard procedures described by IPGRI (2001). Total bulb yield, unmarketable bulb yield (UMY), marketable bulb yield (MBY), size category of bulbs (%), average bulb weight (ABW), bulb length (BL), bulb diameter (BD), neck diameter (ND), bulb dry matter content and total soluble solids (%) were measured and the mean values subjected to the Analysis of Variance (ANOVA) using SAS version 9.2 Computer software (SAS Institute Inc., 2008). Whenever the treatment was significant, least significance differences (LSD) was used for mean separation at $p=0.05$.

RESULTS AND DISCUSSION

Total bulb yield (t/ha)

Results indicated that there was no significant interaction effect between the intra-row and variety, while main effects of intra-row spacing ($p<0.0001$) and varieties ($p<0.01$) significantly influenced total bulb yield of onion. As intra-row spacing increased from 5 to 10 cm, total bulb yield in tons/hectare decreased. Significantly, the highest total bulb yields of 36.14 and 33.82 t/ha were recorded at 5 and 7.5 cm intra-row spacing, respectively. An intra-row spacing of 10 cm showed the lowest total bulb yield (28.51 t/ha) (Table 1). This is due to the reality that as intra-row spacing decreases, total plant population increases and this in turn contributes to increase in total bulb yield, but the bulb dimension and weight decrease. The current result is in agreement with works of different authors. Jan et al. (2003) recorded the highest yield (40.44 t/ha) at spacing of 17 x 4.5 cm, and the lowest yield (19.95 t/ha) at 27 x 14.5 cm spacing. Hassan (1978), Mohamedali (1988) and Russo (2008) also found similar results. Rekowska and Skupien (2007) also reported significantly higher yield of bulbs and green leaves of garlic in closer intra-row spacing.

Moreover, Kantona et al. (2003) noticed that onion yield increased from 17.4 to 39.5 t/ha as plant population per square meter increased from 50 to 150. Carlson et al. (2009) reported influence of plant density on the yield of two potato varieties, in which both varieties produced highest total yields at the closest plant spacing of 17.75 cm. Hemphill (1987) also reported that a fourfold increase

Table 1. Effect of intra-row spacing and variety on total bulb yield (TBY), marketable bulb yield (MBY) and average bulb weight (ABW) of onion.

Treatment	TBY (T/ha)	MBY (T/ha)	ABW(g)
Intra-row spacing (cm)			
5	36.14 ^a	34.49 ^a	49.86 ^c
7.5	33.82 ^a	32.97 ^a	69.69 ^b
10	28.51 ^b	28.10 ^b	81.31 ^a
LSD _(0.05)	3.10	3.10	4.76
CV (%)	12.90	13.63	9.90
Variety			
Adama Red	29.86 ^c	28.45 ^c	61.03 ^c
Bombay Red	34.68 ^{ab}	34.00 ^{ab}	67.29 ^b
Melkam	35.20 ^a	34.36 ^a	75.77 ^a
NasikRed	31.57 ^{bc}	30.60 ^{bc}	63.74 ^{bc}
LSD _(0.05)	3.53	3.60	5.50
CV (%)	12.90	13.63	9.90

Means within a column followed by the same letter(s) are not significantly different at $p \leq 5\%$ according to LSD test.

in planting density doubled the yield of shallot. The author further stated that yield per unit area did not increase proportionally to the increase in planting density since bulb weight per plant decreased at higher densities, but low planting density and small planting stock size favored production of large bulbs required for some markets, but with greatly reduced total yield.

Results also indicated that '*Melkam*' and '*Bombay*' Red varieties had the highest total bulb yield (35.20 and 34.68 t/ha), but '*Bombay*' Red fell into the second group with '*Nasik*' Red (31.57 t/ha), besides the second group '*Nasik*' Red also fell into the lowest group with '*Adama*' Red (Table 1). Significantly, the least total bulb yield (29.86 and 31.57 t/ha) was recorded for '*Adama*' Red but statistically similar with '*Nasik*' Red. The present finding is supported by different investigations previously done. Jilani and Ghaffoor (2003) and Jilani et al. (2009) suggested that varieties could have different yield potential in different agro-ecologies due to their genetic potential and genetic environment interaction effect.

Marketable bulb yield

A highly significant ($p < 0.001$) differences were observed among the levels of intra-row spacing and onion varieties on the marketable bulb yield (t/ha). As intra-row spacing increased from 5 to 10 cm, marketable bulb yield in tons/hectare decreased from 34.49 to 28.10. Among the intra-row spacing, a statistically similar result was obtained from 5 and 7.5 cm intra-row spacing, which scored the highest marketable yield in tons per hectare, 34.49 and 32.97, respectively (Table 1). Intra-row spacing of 10 cm showed the lowest (28.1 t/ha). Generally, a trend of increasing gross marketable yield

together with plant density was observed. Plant density has an impact on marketable bulb size and the higher the plant density the smaller the marketable size (Seck and Baldeh, 2009). Kantona et al. (2003) also reported that as plant density increased number of marketable bulbs increased significantly.

The highest marketable bulb yield (34.36 t/ha) was recorded by '*Melkam*' Variety. However, it was not significantly different from '*Bombay*' Red variety. The lowest marketable yield (28.45 t/ha) was recorded on '*Adama*' Red variety, but not significantly different from '*Nasik*' Red (Table 1). In agreement with the present results, Jilani et al. (2009) reported similar observation. A cultivar performs differently under different agro-climatic conditions and various cultivars of the same species grown even at the same environment often yield differently. Thus, performance of a cultivar mainly depends on the interaction of genetic makeup and environment (Jilani and Ghaffoor, 2003).

Average bulb weight (g)

Main effects of intra-row spacing and variety highly significantly ($p < 0.0001$) influenced average bulb weight, but the interaction was not statistically significant. As intra-row spacing increased from 5 to 10 cm, average bulb weight increased from 49.86 to 81.31 g (Table 1). The results are in line with the findings of Rashid and Rashid (1978) who noticed that onion bulb size and weight increases with increasing inter, and intra-row spacing, but recorded lower total bulb yield that increases with closer spacing. Densely populated plants produced lower bulb weight as compared to thinly populated plants. Increasing plant spacing resulted in heavier onion bulbs

Table 2. Effect of intra-row spacing and variety interactions on unmarketable yield of onion.

Intra-row spacing(cm)	Variety	Unmarketable bulb yield (t/ha)
5	Adama Red	2.67 ^a
5	Bombay Red	1.16 ^c
5	Melkam	1.07 ^c
5	Nasik Red	1.68 ^b
7.5	Adama Red	1.01 ^c
7.5	Bombay Red	0.63 ^{def}
7.5	Melkam	0.93 ^{cd}
7.5	Nasik Red	0.88 ^{cde}
10	Adama Red	0.54 ^{ef}
10	Bombay Red	0.32 ^f
10	Melkam	0.53 ^{ef}
10	Nasik Red	0.29 ^f
LSD(0.05)		0.37
CV (%)		26.10

Means in the same column connected with the same letter(s) are not significantly different $p \leq 5\%$ as established by LSD-test.

(Jilani et al., 2009). Mean bulb weight and plant height decreased as population density increased (Mohamedali, 1988). Jan et al. (2003) also found minimum bulb weight at narrower spacing (17 x 4.5 cm).

In the same way, Kantona et al. (2003) reported a decrease in bulb weight as the plant population per square meter increased from 50 to 200 plants likely due to competition associated with closely spaced plants that resulted in lower bulb weight per plant. Abubaker (2008) also reported that the highest yield per plant of bean was obtained from 20 x 30 and 30 x 30 cm planting densities as compared to higher planting densities of 10 x 30 cm. When onions are planted at wider spacing, the emerged shoots get a better microenvironment that resulted in healthy and larger bulbs and high bulb weight per plant. Moreover, better air circulation reduces disease occurrence, which contributes to higher yield per plant. Palada and Crossman (1998) also reported an increase in okra fresh weight per plant from 38 to 70 g with the increase in plant spacing from 31 to 41 cm due to increase in the number of stem and wider leaf area per plant at wider spacing.

'Melkam' variety showed significantly high average bulb weight (75.77 g). The least value was observed on 'Adama' Red (63.74 g), it was not significantly different from 'Nasik' Red (63.74 g) (Table 1). The lowest average bulb weight (61.03 g) was recorded by 'Adama' Red variety. Difference in average bulb weight within varieties was due to their genetic variability. This finding is in concurrence with the findings of Jilani and Ghaffoor (2003) and Jilani et al. (2009) who reported the variation among onion cultivars in average bulb weight. Kimani et al. (1993) also reported significant bulb weight variation among eight onion cultivars. According the EARO (2004),

'Melkam' variety is characterized by large bulb weight.

Unmarketable bulb yield

The main effect of intra-row spacing, variety and their interaction on unmarketable bulb yield (t/ha) and percentage of unmarketable bulb yield from the total bulb yield showed highly significant ($p < 0.01$) difference. The highest unmarketable bulb yield was produced, by the treatment combination of 5 cm intra-row spacing and 'Adama' Red (2.67 t/ha) followed by treatment combination of 5 cm intra-row spacing and 'Nasik' Red (Table 2). High unmarketable yield in closely spaced plants could be due to inter-plant competition resulting in a fewer large sized bulbs than wider spacing that negatively affected the marketable yield and favored the production of small sized bulbs which are unmarketable. This finding is in agreement with other related reports. Seck and Baldeh (2009) concluded that plant density has an impact on marketable bulb size.

The result further revealed that 'Adama' Red and 'Nasik' Red varieties are relatively less tolerant to narrower intra-row spacing in the study area. In support of the present result, some authors (Rumpel and Felczynski, 1997; Russo, 2008; Jilani et al., 2009; Geremew et al., 2010) also reported similar results that marketable bulb yield and unmarketable bulb yield could be affected by both varietal differences and plant density.

Bulb yield of different size category

Small size bulbs (%)

Highly significant difference was observed for the main

Table 3. Effect of intra-row spacing and variety interactions on percentage of small size and medium size bulbs of onion.

Intra-row spacing (cm)	Variety	Percentage of small size bulbs	Percentage of medium size bulbs
5	Adama Red	23.755 ^a	69.980 ^{cd}
5	Bombay Red	15.449 ^b	75.943 ^{abc}
5	Melkam	10.828 ^{bcd}	77.022 ^{abc}
5	Nasik Red	13.421 ^{bc}	80.514 ^a
7.5	Adama Red	15.112 ^b	75.73 ^{abc}
7.5	Bombay Red	8.626 ^{cde}	75.865 ^{abc}
7.5	Melkam	9.359 ^{cde}	70.328 ^{cd}
7.5	Nasik Red	12.482 ^{bc}	72.974 ^{bcd}
10	Adama Red	6.905 ^e	75.964 ^{abc}
10	Bombay Red	7.203 ^{de}	71.899 ^{cd}
10	Melkam	4.433 ^e	67.897 ^d
10	Nasik Red	7.167 ^{de}	79.388 ^{ab}
LSD(0.05)		5.084	7.45
CV (%)		25.3	6.95

Means with the same letter are not significantly different at $P \leq 5\%$ as established by LSD- test.

effects, intra-row spacing and variety ($p < 0.0001$) and their interaction ($P < 0.01$) on percentage of small size bulb yield. The highest percentage of small size bulbs yield (23.76 2.755) was scored at a combination of intra-row spacing of 5 cm and 'Adama' Red variety (Table 3). It is factual that yield of small bulbs increases with density opposite to the yield of large bulbs, which can be highest at lowest density (Rumpel and Felczynski, 2000). Castellanos et al. (2004) cited in Broome (2009) also reported that super garlic cloves were largest at less dense plantings, while yield of smaller cloves (40 to 45 mm) increased at a higher density. Brewster and Rabinowitch (1990) found that high plant-population density (170 plants/m²), percentage of small bulbs was higher and rates of double bulbs were lower than at low plant density (90 plants/m²).

Medium size bulbs (%)

The interaction effect of intra-row spacing and variety on percentage of medium size bulbs yield showed statistically significant difference ($p < 0.05$). Although, the main effect of variety and intra-row spacing did not show statistically significant difference. The highest medium size bulbs percentage (80.51 80.514) was recorded at a combination of 5 cm intra-row spacing and 'Nasik' Red variety. However, it was not significantly different from 'Melkam' (77.02), 'Bombay' Red (75.94) at 5 cm intra-row spacing, and also 'Bombay' Red (75.87) and 'Adama' Red (75.73) at intra-row spacing of 7.5 cm, and 'Adama' Red (75.96) at 10 cm intra-row spacing.

The lowest medium size bulb percentage was observed at the combination of 10 cm intra-row spacing with 'Melkam' (67.9). However, it was statistically on par with

'Adama' Red (69.98) at intra-row spacing of 5 cm, 'Bombay' Red (71.9) at intra-row spacing of 10 cm, 'Melkam' (70.33) and 'Nasik' Red (72.94) at intra-row spacing of 7.5 cm (Table 3). Nasir et al. (2007) reported maximum weight of medium bulbs (958.50 g/plot) produced at higher planting density of 80 plants/m² and there was parietal difference.

Large size bulbs (%)

The interaction effect of intra-row spacing and variety did not show statistically significant difference, while the main effect of intra-row spacing and variety on percentage of large size bulbs yield showed statistically very high significant ($p < 0.0001$) difference. There was statistically significant difference among all spacing levels.

As the intra-row spacing increased from 5 to 10 cm, the percentage of large size bulbs increased from 9.3 to 20.3 (Figure 1). Likewise, Jilani et al. (2009) reported significant variations for different plant spacing, as the widest spacing showed its superiority over all the other spacing.

Among the varieties, it was revealed that 'Melkam' recorded significantly the highest large size bulbs (20.71), followed by 'Bombay' Red variety. The lowest percentage of large size bulbs was recorded by 'Nasik' Red (11.1) and 'Adama' Red (11.5) (Figure 1). In agreement with this finding, Mallor et al. (2011) reported the difference among onion lines on average bulb size ranging from 150 to 190 g.

Bulb length (cm)

Results (Table 4) show that the effect of the intra-row

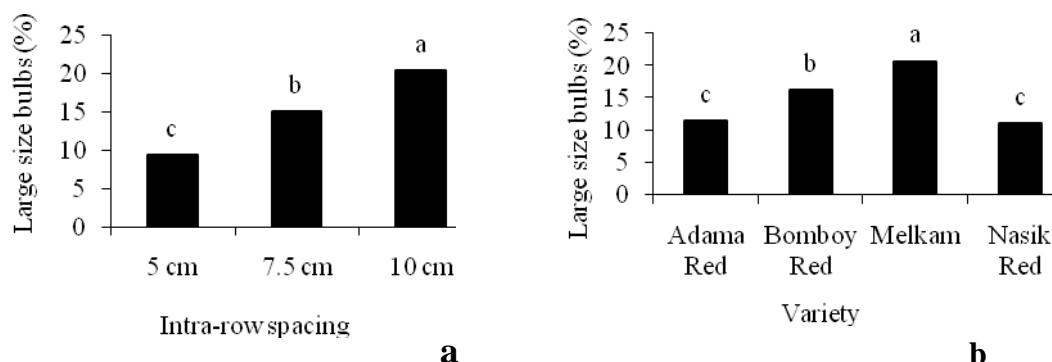


Figure 1. Effect of intra-row spacing (a) and variety (b) on large size bulb percentage of onion. Means followed by the same letter are not significantly different at $p \leq 5\%$ as established by LSD-test (LSD=3.69).

Table 4. Effect of intra-row spacing and variety on bulb length, bulb diameter and bulb neck diameter of onion.

Treatment	Bulb length (cm)	Bulb diameter (cm)	Bulb neck diameter (cm)
Intra-row spacing (cm)			
5	4.11 ^b	4.66 ^c	1.48 ^b
7.5	4.43 ^a	5.23 ^b	1.57 ^b
10	4.54 ^a	5.63 ^a	1.74 ^a
LSD _(0.05)	0.13	0.22	0.12
CV (%)	4.16	6	10.2
Variety			
Adama Red	4.44 ^{ab}	5.07 ^{ns}	1.57 ^b
Bombay Red	4.18 ^c	5.21 ^{ns}	1.54 ^b
Melkam	4.51 ^a	5.2 ^{ns}	1.77 ^a
NasikRed	4.33 ^{bc}	5.11 ^{ns}	1.49 ^b
LSD _(0.05)	0.15	NS	0.14
CV(%)	4.16	6	10.2

NS= Non-significant. Means within a column followed by the same letter(s) are not significantly different according to LSD test.

spacing and variety interaction did not show statistically significant difference, while the intra-row spacing and varieties affected the bulb length of onion significantly ($p < 0.001$). The highest bulb length (4.54 cm) was recorded at the intra-row spacing (10 cm) and intra-row spacing of 7.5 cm (4.43). The narrowest intra-row spacing (5 cm) showed the lowest (4.11 cm) bulb length. As intra-row spacing increased from 5 to 10 cm, bulb length increased from 4.1 to 4.6 cm. The present result is in agreement with those reported by Kantona et al. (2003). Hyder et al. (2007) and Hosmani et al. (2010) also elaborated that there is strong association of bulb length with bulb diameter, and plant height, which were increased as intra-spacing increased.

Significantly highest bulb length (4.51 cm) was obtained from 'Melkam' variety. However, it was not statistically different from 'Adama' Red variety (4.44 cm) (Table 4). In contrast, 'Bombay' Red variety recorded the lowest (4.18 cm), but it was on par with 'Nasik' Red

variety (4.33). This is due to the reality that varieties can have different characteristics like bulb shape and color as suggested by Lemma (2004). Jilani et al. (2009) also found difference among cultivars in bulb length due to genetic inheritance.

Bulb diameter (cm)

There was no statistically significant difference of interaction of variety and intra-row spacing on bulb neck diameter. Meanwhile, the main effect of intra-row spacing showed statistically very highly significant ($p < 0.0001$) difference in bulb diameter. Intra-row spacing of 10 cm showed the highest bulb diameter (5.63 cm), followed by 7.5 (5.23 cm) and 5 cm (4.66 cm) intra-row spacing (Table 4). The increase in bulb diameter at wider intra-row spacing could be probably attributed to more nutrients space and moisture availability. Bulb diameter

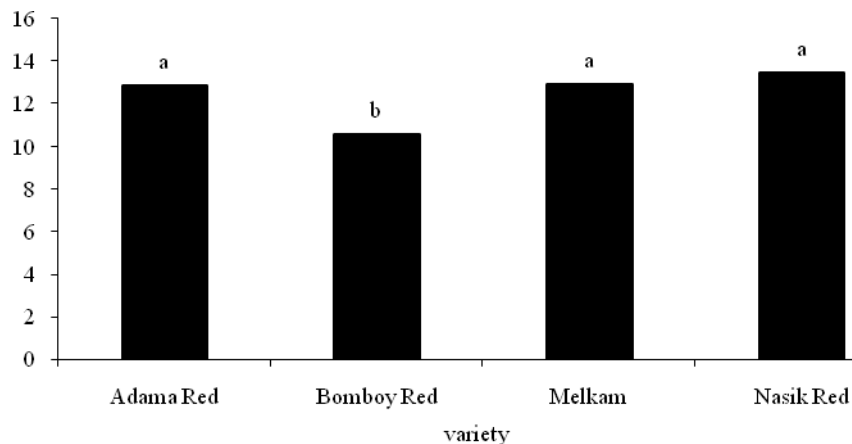


Figure 2. Differences in the percentage of bulb dry matter content (%) of onion varieties. Means followed by the same letter are not significantly different at $p \leq 5\%$ as established by LSD-test (LSD=1.46).

contributes significantly to yield component of a crop (Cheema et al., 2003; Jilani and Ghaffoor, 2003). The present findings are in line with those reported by Rashid and Rashid (1978), Quadir and Boulton (2000), Jan et al. (2003), Kantona et al. (2003), Akoun (2005), Hyder et al. (2007) and Jilani et al. (2009). Mohammedali (1988) also reported wider intra-row spacing gave larger bulbs of onion. Tendaj (2005) reported an increase in intra-row spacing of shallot from 5 to 20 cm, resulting in increment of percent share of bulbs having greater than 25 mm diameter from 13.70 to 47.20%.

Bulb neck diameter (cm)

Thickness of neck is an important parameter that determines the storability qualities of onion varieties. The results indicated that the main effect of both intra-row spacing and variety on bulb neck diameter (cm) showed significant ($p < 0.001$) difference; the interaction had no significant effect on bulb neck diameter. The highest bulb neck diameter (1.74 cm) was observed at the intra-row spacing of 10 cm (Table 4). The least bulb neck diameter (1.48 and 1.57 cm) was recorded at intra-row spacing of 5 and at 7.5 cm intra-row spacing, respectively. The current finding complies with the work of Brewster and Rabinowitch (1990). In agreement with this result, Jilani and Ghaffoor (2003), Kantona et al. (2003), Jilani et al. (2009) and Khalid (2009) reported similar results.

'Melkam' showed significantly the highest bulb neck diameter (1.77 cm), while there was similar results in the rest varieties (Table 4). The presence of variation in bulb neck diameter among onion cultivars is also reported by Mar (1994), Kalb (2001), Jilani and Ghaffoor (2003) and Jilani et al. (2009). According to Currah and Proctor (1990), thick neck in onion is caused by the onion growth actively in that the neck did not become dormant and

resulted to undifferentiated scales with high thickness at wider inter plant spacing. This indicated that thick neck in onion causes delay in bulbing and has a negative impact on bulb yield, especially when water stress might be encountered lately. Other workers such as Brewster and Rabinowitch (1990) as well as Lemma and Shimeles (2003) explained that the cause of thick neck in onion is generally due to defective nutrition prolonged cool time and lack of interplant competition in addition to genetic inheritance.

Bulb dry matter content (%)

Intra-row spacing effect and interaction effect did not show significant difference. However, varieties had significant ($p < 0.01$) effect on bulb dry matter content. In conformity with this result, Mohamodali (1988) and Abubaker (2008) reported that different in-row spacing seems to have no effect on the dry matter content. The lowest percentage of dry matter content (10.6) was recorded by 'Bombay' Red variety, while there is statistically high and similar results shown on the other three varieties (Figure 2). The result is consistent with the findings of Islam et al. (2007), Magdi et al. (2009), Mousa and Mohamed (2009) who reported significant difference among onion genotypes in dry matter content. Varieties known as 'storage onions' have high dry matter content (15 to 20%) and relatively high amounts of fructans, but have lower levels of reducing sugars, besides relatively high rates of organosulfur compounds (Mallor et al., 2011).

Kimani et al. (1993) additionally reported a dry matter content variation from low levels of 7 to 10% to high levels of 15 to 20% in onion varieties. The authors suggested that onions with high dry matter are preferred for processing. They further showed that onions with high

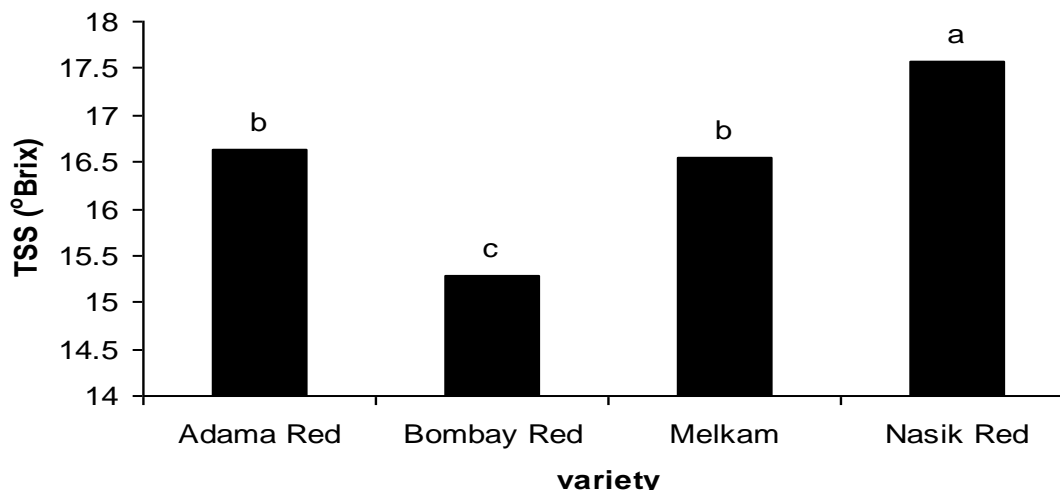


Figure 3. Differences in the TSS content (°Brix) of onion varieties. Means followed by the same letter are not significantly different at $p \leq 5\%$ as established by LSD-test (LSD=0.55).

dry matter content tend to low yield than those with low dry matter content and the latter exhibit rapid bulbing that contradicts the high dry matter content found in '*Melkam*' variety while having high yield. The range of dry matter content of the varieties is similar to previous studies done in Ethiopia, which stated that dry matter content in bulb onion varies in according to cultivars. It varied from low level of 7 to 10% to high level of 15 to 20% and average 11 to 15% (Lemma and Shimeles, 2003). The authors further explained that the lower levels are usually rapidly bulbing, becoming soft texture and usually with low keeping qualities. The higher levels of dry matter in onion found in selected cultivars are important for dehydration.

Total soluble sugars content (TSS)

Effect of intra-row spacing and interaction did not show statistically significant difference on TSS content of onion while varieties had significant ($p < 0.0001$) effect on total soluble sugar (TSS) content of onion bulb.

In this experiment, '*Nasik*' Red gave significantly the maximum TSS content (17.6 °Brix), followed by '*Adama*' Red and '*Melkam*' varieties (Figure 3). However, there was no significant difference between the latter two varieties. '*Bombay*' Red showed significantly the minimum TSS content (15.3 °Brix) (Figure 3). High total soluble solids (TSS) have been proved to be associated with long storage life (AVRDC, 2000). Cultivars with high bulb yields may have lower total soluble solids content as compared to the cultivars with lowest yields. This observation is also in line with the report of EARO (2004) which described '*Bombay*' Red variety with low TSS in °Brix than the other varieties of onion released and being cultivated in Ethiopia. Varieties used for storage have high and intense, pungent flavour and are desirable

characteristics for cooking or for industrial processing (Mallor et al., 2011). Hosmani et al. (2010) suggested that there could be less influence of environments for these traits.

Rajcumar (1997) also reported that a total soluble solid variation of about 4.0 to 16.3% could exist among different cultivars of onion. The author further explained his findings that cultivars with high bulb yields have lower total soluble solids content as compared to the cultivars with lowest yields and a negative correlation ($r = -0.85$) between bulb yield and soluble solids content was found, suggestive of a strong association between these two characters.

Mallor et al. (2011) also reported significant negative correlation between bulb weight and soluble solids content. They elaborated that these results indicate a trend in larger onions which contain lower rates of both organo-sulfur derivatives and carbohydrates; therefore, suggesting that bulb size increase was because of higher water content. Cultivars with high bulb yields have lower total soluble solids content as compared to the cultivars with lowest yields (AVRDC, 1990, 2008).

Summary and conclusion

Onion is one of the popular and the most cultivated vegetables in Ethiopia in general and in Tigray region in particular. Farmers in the study area produce onion as a cash crop using non-uniform plant spacing based on the existing indigenous knowledge.

The study was conducted to investigate best plant spacing for highest yield and better quality of onion varieties and to recommend best variety adaptable to the specific area and best plant spacing that give best yield and bulb quality.

The experiment was conducted from August 2010 to April 2011 under irrigated condition at Aksum area, L/maichew district, Central Zone of Tigray National Regional State. The experiment was done at three intra-row spacings (Factor 1): S1 (5 x 20), S2 (7.5 x 20) and S3 (10 x 20) cm equivalent to densities of 90, 67 and 45 plants/m²; respectively, and four onion varieties (Factor 2): 'Adama' Red, 'Bombay' Red, 'Melkam', 'Nasik' Red. A 3 x 4 factorial experiment was laid out in RCBD with four replications. Data were collected on yield and quality parameters.

Results of the study show that main effects of intra-row spacing, varieties as well as their interactions had considerable influence on different parameters. The highest total bulb yield (36.14 t/ha) was recorded at intra-row spacing of 5 and by 7.5 cm (33.82 t/ha).

Highest total bulb yield (35.2 t/ha) was also recorded on 'Melkam' variety, while the lowest yield (29.86 t/ha) was recorded on 'Adama' Red variety. Intra-row spacings of 5 and 7.5 cm also had higher marketable yield than 10 cm. As intra-row spacing increased from 5 to 10 cm average bulb weight in grams increased from 49.86 to 81.31 g.

The highest average bulb weight (75.77 g) was recorded on 'Melkam' variety followed by 'Bombay' Red (67.29), while the lowest average bulb weight (61.03 gm) was recorded by 'Adama' Red variety. The highest unmarketable yield was produced, at the combination of 5 cm intra-row spacing and 'Adama' Red variety (2.67 ton/ha). The highest percentage of small size bulbs (23.76 and 15.45%) was produced by the treatment combination of 'Adama' Red at 5 cm spacing and 'Bombay' Red at 5 cm spacing, respectively.

While the minimum percentage of small size bulbs (4.4 and 6.9) was found in the combination of 'Melkam' at 10 cm and 'Adama' Red at 10 cm spacing, respectively. The highest percentage of large size bulbs (20.71) was recorded in 'Melkam' variety, while the lowest percentage of large bulbs (11.1) was obtained in 'Nasik' Red variety. The finding suggested that it is better to use intra-row spacing greater than 5 cm to minimize more small bulbs as this is not mostly preferred for market.

Besides, the ultimate goal of onion production is profitability through yield enhancement; the result revealed that 'Melkam' and 'Bombay' Red varieties appeared to be superior for yield and earliness at the study area although it needs repeated research for complete recommendation.

The highest percentage of bulb dry matter content (13.47) was recorded on 'Nasik' Red variety, while the lowest percentage (10.6) was recorded on 'Bombay' Red variety. The highest TSS in °Brix, was found at the late matured varieties 'Nasik' Red (17.57), while the lowest TSS in °Brix was found at the early varieties 'Bombay' Red (15.29) followed by 'Melkam' (16.54).

Hence, for fresh consumption, the milder ones with lesser TSS in °Brix value are better for use since they

have better yield and adaptability advantages at the dryland condition of Tigray in general and Aksum area in particular.

REFERENCES

- Abubaker S (2008). Effect of plant density on flowering date, yield and quality attribute of Bush Beans (*Phaseolus Vulgaris* L.) under Center Pivot Irrigation System. Am. J. Agric. Biol. Sci. 3(4):666-668.
- Akoun J (2005). Effect of plant density and manure on the yield and yield components of the common onion (*Allium cepa* L.) var. Nsukka red. Nigerian J. Hortic. Sci. 9:43-48
- AVRDC (2000). AVRDC Report 1999. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan. 7:152.
- AVRDC (2008). AVRDC Publication Number 08-702. Shanhua, Taiwan: AVRDC-The World Vegetable Center. 8:196.
- AVRDC (1990). Vegetable production training manual. Asian Vegetable Research and Development Centre. ShanTainan. p. 447.
- Axum Agricultural Research Center (AXaRC) (2009). Problem appraisal report. Aksum, Ethiopia. Unpublished document.
- Brewster JL (2008). Onions and other Vegetable *Alliums*. 2nd ed. CAB International. North America.
- Brewster JL, Rabinowitch HD (1990). Onion and allied crops: Biochemistry, Food science and minor crop VIII CRC press, Inc, USA
- Broome AL (2009). Biomass and photosynthetic efficiency of *Allium* species grown in Elevated carbon dioxide levels, with differing plant densities and Harvest schemes. A Dissertation in Agronomy submitted to the graduate faculty of Texas Technology University. p. 112.
- Carlson LH, Kirby D, Kliewer B, Thompson C (2009). Evaluation of cultural practices to control hollow heart in premier russet. University of California Intermountain Research & Extension Center, Research progress No 121.
- Cheema KL, Saeed HA, Habib AS (2003). Performance of Exotic Onion Cultivars in Spring Season Under Faisalabad (Pakistan) Condition. Int. J. Agri. Biol. 5:4.
- Currah L, Proctor F (1990). Onion in Tropical regions. Natural Resources, Institute Bulletin No.35.
- Ethiopian agricultural research organization (EARO) (2004). Directory of released crop varieties and their management. Addis Ababa. Ethiopia.
- Ethiopian Horticultural Development Agency (EHDA) (2011). Assessment of development potentials and investment options in the export-oriented fruit and vegetable sector.
- Ethiopian Institute of Agricultural Research (EIAR) (2007). Crop technologies guidelines. Amharic version. Addis Ababa.
- Fekadu M, Dandena G (2006). Review of the status of vegetable crops production and marketing in Ethiopia. Uganda J. Agric. Sci. 12(2):26-30.
- Geremew A, Teshome A, Kasaye T, Amenti C (2010). Effect of intra-row spacing on yield of three onion (*Allium cepa* L.) varieties at Adami Tulu agricultural research center (mid rift valley of Ethiopia). J. Hortic. For. 2(1):007-011, January, 2010 <http://www.academicjournals.org/jhf>
- Hanelt P (1990). "Taxonomy, Evolution, and History." In Onions and Allied Crops, edited by Haim D. Rabinowitch and James L. Brewster, 1-26. Boca Raton, Fla.: CRC Press,
- Hassan MS (1978). Effect of plant population densities on yield of onion in the Sudan Gezira. Acta Hort. (ISHS) 84:85-90 http://www.actahort.org/books/84/84_10.htm
- Hemphill D (1987). Over wintering onions and other *Allium* in the Willamette Valley. On-line version of Oregon Agricultural Experiment Station Special Report 794. p. 44.
- Hyder H, Sharker N, Ahmed MB, Hannan MM, Razvy MA, Hossain M, Hoque A, Karim R (2007). Genetic variability, and interrelationship in onion (*Allium cepa* L.). Middle-East J. Sci. Res. 2(3-4):132-134.
- Hosmani RM, Patil BC, Ajjappalvara PS (2010). Genetic variability and character association studies in onion (*Allium cepa* L.). Karnataka J. Agric. Sci. 23(2):302-305.
- IPGRI (2001). Descriptors for *Allium* (*Allium* spp.). International Plant

- Genetic Resources Institute, Rome, Italy; European Cooperative Programme for Crop Genetic Resources Networks (ECP/GR), Asian Vegetable Research and Development Center, Taiwan. p. 52.
- Islam MK, Alam MF, Islam AK (2007). Growth and yield response of onion (*Allium cepa* L.) genotypes to different levels of fertilizers. *Bangladesh J. Bot.* 36(1):33-38.
- Jan NE, Wazir FK, Ibrar M, Mohammed H, Ali AR (2003). Effect of different inter and intra-row spacing on the growth and yield of different Cultivars of Onion. *Sarhad J. Agric.* 19:4.
- Jilani MS, Ghaffoor A (2003). Screening of Local Varieties of Onion for Bulb Formation. *Int. J. Agri. Biol.* 5:2. Pakistan <http://www.ijab.org>
- Jilani MS, Khan MQ, Rahman S (2009). Planting densities effect on yield and yield components of onion (*Allium cepa* L.). *J. Agric. Res.* 47(4):397-404.
- Kalb T (2001). Onion Cultivation and Seed Production: Training Guide AVRDC.
- Kantona RAL, Abbeys L, Hillac RG, Tabil MA, Jane ND (2003). Density affects plant development and yield of bulb onion (*Allium cepa* L.) in Northern Ghana. *J. Veg. Crop Prod.* 8(2):15-25.
- Khalid MK (2009). Effect of set-size and storage temperature on bolting, bulbing and seed yield in two onion cultivars. *Pakistan. Scientia Horticulturae* 122(2):187-194
- Kimani PM, Karinki JW, Peters R, Rabinowitch HD (1993). Influence of environment on the performance of some onion cultivars in Kenya. *Afri. Crop Sci. J.* 1(1):15-23.
- Lemma D (2004). Onion production pamphlet (Amharic version). EARO, Melkassa Research Center.
- Lemma D, Shimeles A (2003). Research experiences in onion production. Research report No. 55, EARO, Addis Ababa Ethiopia, pp. 52.
- Magdi AA, Mohamed MF (2009). Enhanced yield and quality of onion (*Allium cepa* L. CV(%) Giza 6) produced using organic fertilization. *Ass. Univ. Bull. Environ. Res.* 12:1.
- Mallor C, Balcells M, Sales E (2011). Genetic variation for bulb size, soluble solids content and pungency in the Spanish sweet onion variety Fuentes de Ebro. Response to selection for low pungency. *Plant Breed.* 130:55-59. doi: 10.1111/j.1439-0523.2009.01737.x
- Mar C (1994). Onions for the Home Garden, Kansas State University. Ministry of Agriculture and Rural Development (MoARD). Animal and Plant Health Regulatory Directorate: Crop Variety Register. Issue No. 12 June, 2009 Addis Ababa, Ethiopia
- Mohamedali GH (1988). Effect of Plant Population Densities on Yield and Quality of White Dehydration Onion in the Northern Sudan. <http://www.arcsudan.sd/>
- Mousa MA, Mohamed MF (2009). Enhanced Yield and Quality of Onion (*Allium cepa* L. CV(%) GIZA 6) Produced Using Organic Fertilization. *Ass. Univ. Bull. Environ. Res.* 12:1.
- Nasir MD, Wazir FK, Dawar MD, Dawar SH (2007). Effect of planting density on growth and yield of onion varieties under climatic conditions of Peshawar. *Sarhad J. Agric.* 23:4.
- Palada CM, Crossman MA (1998). Planting density affects growth and yield of Okra. *Proceedings of the 34th Annual Meeting 1998-Carrabean Food Crop Society.* pp. 52-57.
- Quadir MA, Boulton A (2000). Plant spacing effect on bulb yield of mild onion. National Vegetable Industry Centre, NSW Agriculture, Yanco, Australia. *Farmers' Newsletter, Hort.* 184:50-51.
- Rajcumar R (1997). Selection of onion cultivars for yield, early maturity and storage potential in Mauritius. *Food and Agricultural Research Council, Reduit, Mauritius.* pp. 153-159.
- Rashid MA, Rashid MM (1978). The effect of spacing on the yield of onion. *Hort. Abst.*, 48:481.
- Rekowska E, Skupien K (2007). Influence of flat covers and sowing density on yield and chemical composition of garlic cultivated for bundle-harvest. pp. 17-24. In: Kosson R., Szwejdka J., and Górecka K. (eds). *Vegetable Crops Research Bulletin Vol. 66/2007.* Research Institute of Vegetable Crops. Skierniewice, Poland.
- Rumpel J, Felczynski A (1997). Effect of plant density on yield and bulb size of direct sown onion. *ISHS Acta Horticulturae* 533: VIII International Symposium on Timing Field Production in Vegetable Crops.
- Russo VM (2008). Plant density and nitrogen fertilizerRate on yield and nutrient content of onion Developed from Greenhouse-grown Transplants. *Hortsci.* 43(6):1759-1764.
- Seck A, Baldeh A (2009). Studies on onion bulb yield and quality as influenced by plant density in organic and intensive cropping systems in The Gambia (West Africa). *African Crop Science Conference Proceedings*, 9:69- 173, Printed in Uganda.
- Tendaj M (2005). Shallot production and research in Poland. pp. 55-60. In: R. Kosson, J. Szwejdka, and K. Górecka (eds). *Vegetable Crops Research Bulletin Vol. 62/2005.* Research institute of vegetable crops Skierniewice, Poland.