

*Full Length Research Paper*

# Effects of intra-row spacing on plant growth and yield of 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. Since there have been no recommended intra-row spacing, 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 growth and yield of onion, thereby to 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) laid out in randomized complete block design replicated four times. Data on growth and yield parameters were recorded and subjected to analysis of variance (ANOVA). Results indicated 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, variety, growth and yield.

## INTRODUCTION

Onion (*Allium cepa* L.) belongs to the family Alliaceae (Hanelt, 1990). Onion is by far the most important of the bulb crops cultivated commercially in nearly 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 Turkmenia, Tajikstan to Pakistan and India, which are the most important sources of genetic diversity and believed to be center of origin of onion (Astley et al., 1982 cited in Brewster, 2008). *Alliums* are typically plants of open, sunny, dry sites in fairly arid climates (Hanelt, 1990).

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Onion is considerably important in the daily Ethiopian diet. All the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews (MoARD, 2009). It is one of the richest sources of flavonoids in the human diet which is relevant given that the flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. Flavonoids are not only anti-cancer, but also are known to be anti bacterial, antiviral, anti-allergenic and anti-inflammatory.

Different cultural practices and growing environments are known to influence growth and yield of onion. So far, research in the country was mainly focused on the identification of superior cultivars of onions and adopting improved management practices. The control of plant spacing is a way of ruling bulb yield. Spacing has effect on different varieties as their root and leaf growth habits. Geremew et al. (2010) recommended intra row spacing of 4 cm for 'Nasik' Red and 'Adama' Red varieties, and 6 cm for 'Bombay' Red variety, at which highest marketable yield was gained and reduced unmarketable bulb yield in central rift valley areas of Ethiopia. Higher yield could be obtained if plants are grown at optimum density. Varieties as well as planting densities significantly affected the onion bulb yield. Plant height decreased as population density increased. Total bulb yield increases significantly as population density increases. Number of marketable bulbs increases significantly with higher planting density (Kantona et al., 2003).

To improve onion production, the agricultural research system of the country has made efforts to generate improved varieties. 'Bombay' Red and 'Adama' Red varieties are widely grown in Ethiopia (EARO, 2004). However, these varieties are not distributed to all or most growing areas of the country and are not tested in different agro-ecologies, particularly in the study area. Although some production technologies are developed in the country, it is very difficult to give general recommendation that can be applicable to the different agro-ecological zones. To optimize onion productivity, full package of information is required (Gupta et al., 1994; Lemma and Shimeles, 2003). Plant population needs to be optimized. The optimum use of spacing or plant population has dual advantages (Geremew et al., 2010). It avoids strong competition between plants for growth factors such as water, nutrient and light. In addition optimum plant population enables efficient use of available cropland without wastage.

Aksu-Adwa area is one of the potential areas for onion production in Ethiopia (EHDA, 2011). However, there are no packages of recommendation with regard to crop management practices. Market problem and poor cropping pattern are also major problems in the study areas. Onion is the first in area coverage, but the yield is 107 q/ha which is very less compared to the national average (187 q/ha) (Mintesnot et al., 2005). Lack of proper agronomic practice used by farmers is one of the

major problems in onion production (AxARC, 2009). This is because there had been no agronomic or varietal trial done for onion so far. The nationally recommended spacing between plants of onion has been 10 cm, which was based on the research done in central rift valley of the country some years back. Nevertheless, in the real situation, the practice, which is adopted by farmers, is a bit far (narrower or wider) from the recommendation. There is no recommendation made even in the region with regard to onion plant spacing. The present study was therefore, undertaken to investigate the effects of different intra-row spacing on the growth and yield of onion varieties with the following specific objectives: To determine the best plant spacing for optimum growth and yield of some onion varieties and to study the interaction effect of intra-row spacing and varieties on onion's growth and yield

## MATERIALS AND METHODS

### Description of the study site

The study was conducted in 2010/11 from August 2010 to April 2011 under irrigated condition 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- 15.1°C, respectively.

### Experimental treatment and design

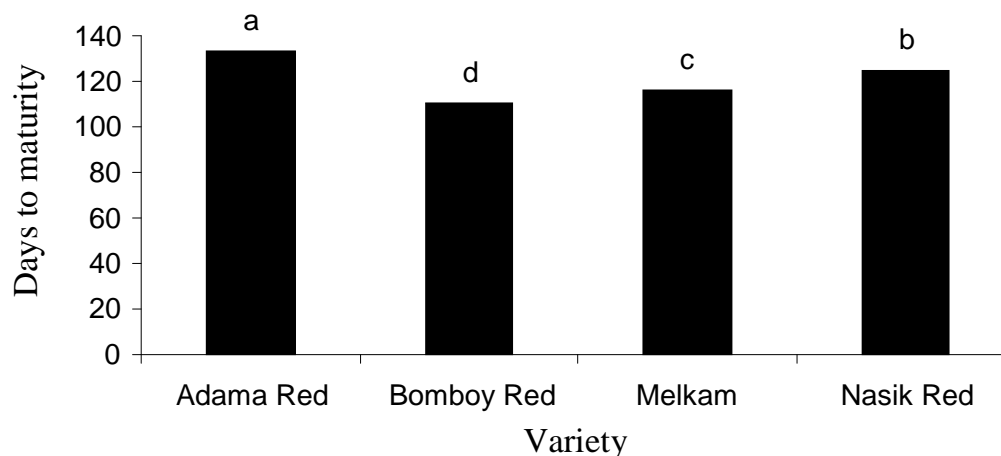
The experiment consisted of factorial combination of two factors viz; intra-row spacing (5 , 7.5 and 10 cm) and variety (Adama Red, Bombay Red, Melkam and Nasik Red) laid out in 3x4 factorial randomized complete block design (RCBD) replicated four times.

### Experimental management

Cultural management practices other than intra-row spacing were done according to the national recommendations. Seeds were sown for nursery rising and transplanted after 50 days from sowing. DAP fertilizer was applied during the last land preparation and Nitrogen in the form of urea was split applied during planting and 6 weeks after transplanting. Weeds were controlled mechanically (by hand weeding). The plots were irrigated at intervals of 7-10 days until maturity. During maturity when 2/3 of the leaves become yellow in color, bulb was harvested and cured for 5 days (EIAR, 2007). Sample bulbs were taken from each plot for data collection.

### Data collection and analysis

Data were collected on vegetative growth parameters (plant height, leaf length, leaf diameter, leaf number/plant, percentage of bolters and days to maturity), biomass parameters (leaf biomass, dry leaf



**Figure 1.** Average days to maturity of onion varieties, means followed by the same letter are not significantly different at  $p=0.05$  as established by LSD-test ( $LSD=1.36$ ), CV, Coefficient of variation; CV (%) = 1.35.

weight and harvest index) and yield parameters (total bulb yield, unmarketable bulb yield, marketable bulb yield and average bulb weight) using the standard procedures described by IPGRI (2001). The mean values of the above response parameters were 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

### The average days to physiological maturity

The main effect of intra-row spacing and interaction effect of intra-row spacing and varieties did not show significant difference. A very highly significant difference ( $p<0.0001$ ) was observed among the varieties on days to maturity. 'Bombay' Red followed by 'Melkam' varieties were the earliest, which matured 123 and 118 days, respectively, while 'Adama' Red variety was late maturing (Figure 1). This result is consistent with the onion varieties characteristics defined in EARO (2004) that 'Bombay' Red can mature in 110 days. Kimani et al. (1993) reported variations in days to maturity among onion cultivars. The varietal difference could be due to the inherent genetic variability of the crop in days to maturity.

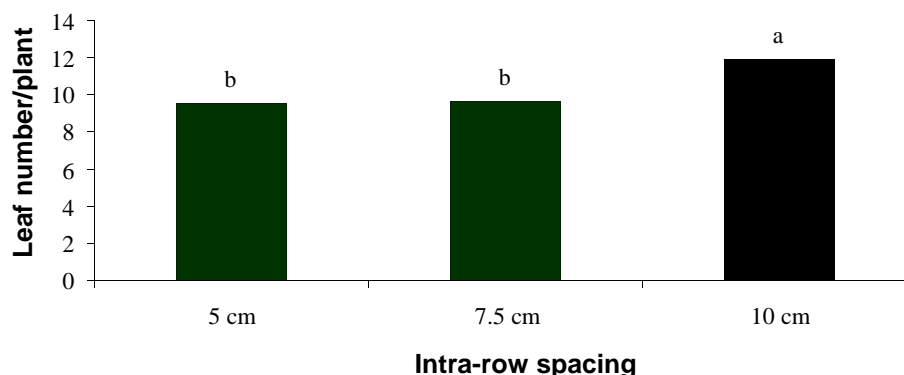
### Leaf number per plant

The main effect of variety and interaction effect of variety and intra row spacing did not show any significant difference on leaf number per plant at maturity, while there was highly significant difference among the intra-row spacing levels at  $p=0.0001$ . Onion planted at 10 cm intra-row spacing produced significantly higher leaf

number of leaves than bulbs planted at 5 and 7.5 cm, but there was no significant difference between spacing 5 and 7.5 cm. As intra-row spacing increased from 5 to 10 cm, the number of leaves per plant increased from 9.5 to 11.94 at maturity stage (Figure 2). It is apparent that when and intra-row spacing increases the number of plants per unit area; more mineral nutrients, light, moisture and space become available leading to vigorous growth possible that increase in planting density resulted in reduction in number of leaves because of shortage of more mineral nutrient, light, moisture and space. Jan et al. (2003), Akoun (2005), Aliyu, et al. (2008), Ahmed et al. (2010) and Jilani et al. (2010) reported that increase in planting density resulted in reduction in number of leaves. Karaye and Yakubu (2006) also reported that garlic planted at 15 and 20 cm intra-row spacing produced significantly higher number of leaves per plant than the 10 cm intra-row spacing. Ibrahim (1994) and Bodnar et al. (1998) also observed widely spaced garlic plants tend to grow more vegetatively and bear more leaves per plant.

### Plant height (cm)

The interaction effect of intra-row spacing and variety on plant height at maturity was not significant. Intra-row spacing and variety significantly affected plant height at maturity at  $p=0.05$  and  $p=0.0001$ , respectively). Intra-row spacing of 10 cm had significantly the tallest plants (Table 1). In agreement to current finding, Jan et al. (2003) reported that maximum plant height (61.4 cm) in plants having 22 x 9.5 cm spacing and minimum plant height (58.18 cm) was observed at 17 x 4.5 cm spacing. Aliyu et al. (2008) also found superior plant height at 25 cm intra-row spacing than at 15 cm intra-row spacing



**Figure 2.** Effect of intra-row spacing on leaf number per plant, Means followed by the same letter are not significantly different at  $p=0.05$  as established by LSD-test (LSD=0.77). CV, Coefficient of variation; CV (%) = 10.31.

**Table 1.** Effect of intra-row spacing and variety on plant height, leaf diameter and leaf length of onion.

Treatment	Plant height (cm)	Leaf diameter (cm)	Leaf length (cm)
Intra-row spacing (cm)			
5	48.58 <sup>b</sup>	0.97 <sup>b</sup>	37.56 <sup>b</sup>
7.5	49.55 <sup>b</sup>	1.08 <sup>a</sup>	38.3 <sup>b</sup>
10	51.31 <sup>a</sup>	1.20 <sup>a</sup>	40.44 <sup>a</sup>
LSD <sub>(0.05)</sub>	1.43	0.10	2.32
CV (%)	3.98	13.00	7.20
Variety			
'Adama' Red	51.90 <sup>a</sup>	1.11 <sup>a</sup>	40.75 <sup>a</sup>
'Bombay' Red	46.80 <sup>c</sup>	0.90 <sup>b</sup>	35.17 <sup>c</sup>
'Melkam'	49.17 <sup>b</sup>	1.09 <sup>a</sup>	37.83 <sup>b</sup>
'Nasik' Red	51.58 <sup>a</sup>	1.18 <sup>a</sup>	41.25 <sup>a</sup>
LSD <sub>(0.05)</sub>	3.98	0.12	2
CV (%)	1.69	13	7.2

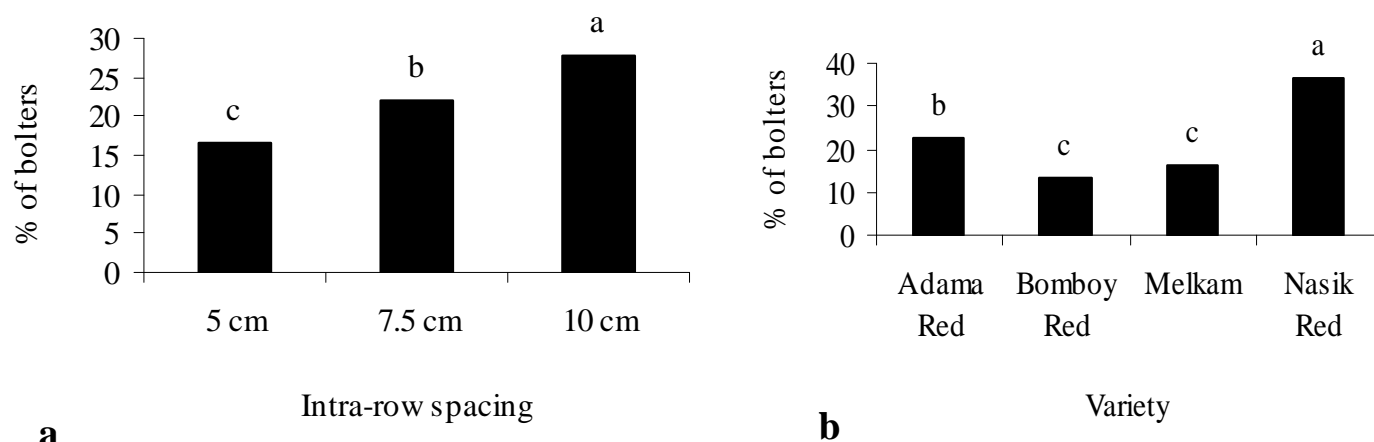
Means within a column followed by the same letter(s) are not significantly different at  $p=0.05$  at LSD-test.

(51.78 cm and 47.35 cm, respectively). The reduction in plant height at increased plant density might be attributed to the possible competition for soil moisture and nutrients as it was the case in Ibrahim (1994), Bodnar et al. (1998), Karaye and Yakubu (2006). Moreover, results are also in agreement with the findings of Zamir et al. (1999) on maize, Kantona et al. (2003) and Khan et al. (2003) on onion, Agele et al. (2007) on sunflower, and Woldemariam (2009) on ginger. 'Adama' Red and 'Nasik' Red varieties produced significantly higher plant height from the others (Table 1). In concurrent to the present findings, Jilani and Ghafoor (2003), Islam et al. (2007) and Jilani et al. (2010) found significant genotypic variation among onion varieties in plant height. Perez et al. (2004) recorded significantly different and highest plant height on radish of 72.2 cm at 15 cm spacing and 66.7 cm at 10 cm spacing.

#### Leaf diameter (cm)

The various intra-row spacing showed significant difference ( $p=0.01$ ) in terms of leaf diameter. Among the intra-row spacing, the closest (5 cm) caused the lowest leaf diameter and significant difference to both treatments (7.5 and 10 cm) (Table 1). This result is supported by the findings of Broome (2009) who reported that leaf diameter of different *Allium* species plants grown at 20 cm was larger than plants grown at 15 cm which in turn were larger than plants grown at 10 cm. Palada and Crossman (1998) reported that leaf area of okra increased with increase in plant spacing linearly.

'Nasik' Red variety recorded the highest leaf diameter (1.2 cm), but not significantly different from 'Adama' Red and 'Melkam' varieties (Table 1). 'Bombay' Red variety showed significantly the lowest leaf diameter (0.9 cm).



**Figure 3.** Effect of intra-row spacing (a) and variety (b) on percentage of bolters, Means followed by the same letter are not significantly different at  $p=0.05$  as established by LSD-test (LSD=5.42 and 5.8, respectively), CV, Coefficient of variation. CV (%) =28.8.

Jilani et al. (2009) also reported that onion cultivars varied significantly with respect to leaf diameter due to genetic inheritance.

### Leaf length (cm)

A significant variation ( $p=0.05$ ) in the leaf length (cm) was observed at the different intra-row spacing treatments (Table 1). The effect of varieties on leaf length at maturity was also very significant ( $p=0.0001$ ). Intra-row spacing of 10 cm showed higher leaf length and significant differences with both treatments (5 and 7.5 cm). Nevertheless, there was no significant difference between spacing of 5 and 7.5 cm. Onion bulbs planted at 10 cm intra-row spacing produced the tallest (40.4 cm) leaf length whereas onion bulbs planted at 5 cm produced the shortest (37.6 cm) leaf length. Jilani and Ghaffor (2003) suggested that plant densities could affect length of leaf. Lowest plant density can give highest leaf length. Jilani, et al. (2010) also reported the highest leaf length at wider spacing whereas shortest leaves correspond to the closest plant spacing. This is probably, attributed to increased competition for nutrients and moisture at higher plant density.

'Adama' Red and 'Nasik' Red showed higher leaf length compared to other varieties. There was significant difference on 'Bombay' Red from 'Melkam' variety. The result is in agreement with Jilani and Ghaffor (2003), Jilani et al. (2009), and Smittle (1993) who reported that cultivars varied significantly from each other with respect to leaf length.

### Percentage of bolters

The interaction effect failed to show any influence on

percentage of bolted plants, but was very significantly ( $p=0.0001$ ) affected by intra-row spacing and varieties. All intra-row spacing showed significant ( $p=0.05$ ) difference among each other (Figure 3a). As intra-row spacing increased from 5 to 10 cm, the percentage of bolters increased from 16.49 to 27.8. This may be due to the availability of more nutrients, space and light in wider spacing, which contribute to luxurious growth leading to flower stalk development. In support of the current result Hassen (1978), Mohamodali (1988) and Khalid (2009) elucidated that at closer spacing, small bulbs are produced which are less susceptible to incidence of bolting.

'Nasik' Red variety showed higher percentage of bolters (36.36) compared to other varieties. While there was no significant difference between 'Bombay' Red (15.98) and 'Melkam' (13.19) they showed significant difference from 'Nasik' Red and 'Adama' Red (Figure 3b). Similarly, EARO (2004) reported differences among varieties in terms of bolting and seed setting. Khalid (2009) also observed variation in time of inflorescence in two onion cultivars. Bolting may be also a problem of physiological nature and is undesirable for better bulb production and onion varieties can differ in percentage of bolting. Jilani and Ghaffor (2003) also reported that bolting percentage was affected by varieties. Similarly Salunkhe (1998) also suggested that bolting may vary due to genetic factors.

### Fresh leaf weight (g) per plant

The interaction effect of intra-row spacing and variety significantly ( $p<0.001$ ) affected average fresh leaf biomass (Table 2). The highest fresh leaf biomass weight per plant (20.55 g) was recorded at intra-row spacing of 10 cm, followed by 7.5 cm (13.5 g) and 5 cm (11.79 g)

**Table 2.** Effect of intra-row spacing and variety on fresh leaf biomass, leaf dry weight and harvest index of onion.

Treatment	Fresh leaf biomass /plant (g)	Leaf dry weight/plant (g)	Harvest index
Intra-row spacing (cm)			
5	11.79 <sup>b</sup>	1.48 <sup>b</sup>	0.79 <sup>b</sup>
7.5	13.5 <sup>b</sup>	2.28 <sup>a</sup>	0.83 <sup>a</sup>
10	20.55 <sup>a</sup>	2.63 <sup>a</sup>	0.79 <sup>b</sup>
LSD <sub>(0.05)</sub>	3.06	0.37	0.03
CV (%)	27.81	23.1	4.64
<b>Variety</b>			
'Adama' Red	17.42 <sup>a</sup>	2.28 <sup>ab</sup>	0.77 <sup>c</sup>
'Bombay' Red	11.82 <sup>b</sup>	1.9 <sup>b</sup>	0.83 <sup>a</sup>
'Melkam'	18.42 <sup>a</sup>	2.67 <sup>a</sup>	0.81 <sup>ab</sup>
'Nasik' Red	13.55 <sup>b</sup>	2.11 <sup>b</sup>	0.8 <sup>bc</sup>
LSD <sub>(0.05)</sub>	3.54	0.43	0.03
CV (%)	27.81	23.1	4.64

Means within a column followed by the same letter(s) are not significantly different at  $p=0.05$  established by LSD-test.

intra-row spacing. This revealed that as intra-row spacing increased from 5 to 10 cm, average fresh leaf biomass per plant increased by 74%. The investigations of Jilani et al. (2009) support this result. In addition, Perez et al. (2004) reported that minimum total biomass per plant of Radish was obtained from 5 cm spacing while, maximum total biomass per plant was observed at 15 cm spacing followed by 10 cm spacing. Biomass is directly proportional to number of leaves, length of leaves, root length, root diameter, fresh root weight and weight of fresh leaves per plant. The positive correlation result of leaf biomass with plant height ( $r=0.55^{**}$ ), leaf number ( $r=0.55^{***}$ ), leaf diameter ( $r=0.41^{**}$ ) can supported the above conclusion. Varieties 'Melkam' and 'Adama' Red recorded the highest average fresh leaf biomass weight per plant (18.42 and 17.42 g, respectively) (Table 2). This might be because onion varieties may have different morphological and biochemical characteristics that affect the biomass accumulation among different storage and vegetative parts, as reported by Jilani and Ghaffoor (2003) and Jilani et al. (2009).

### Leaf dry weight per plant (g)

Leaf dry weight per plant was significantly ( $p<0.001$ ) affected by both intra-row spacing and variety. Significantly, the highest leaf dry weight (2.63 g) was recorded at intra-row spacing of 10 cm than at intra-row spacing of 5 cm (Table 2). However, it was not significantly different from that recorded at 7.5 cm intra-row spacing (2.28 g). Intra-row spacing of 5 cm showed significantly lower leaf dry weight (1.48 g). Results showed that dry weight of plant shoots decreased with increase in plant density. Differences in intra-row spacing enhanced plant-to-plant variation in terms of accumulated

biomass and this phenomenon affected bulb yield and the stability of dry matter partitioning to bulbs. Large plants in wide in-row spacing have competitive advantage and this can be associated with high capacity for resource capture, which enhances vigorous vegetative growth. Shamsi and Kobraee (2009) reported an increase in dry matter accumulation of soybean parallel to increase of intra-row spacing.

Varieties 'Melkam' and 'Adama' Red showed significantly higher leaf dry weight (2.67 g and 2.28 g, respectively) (Table 2). The variety 'Bombay' Red recorded the lowest leaf dry weight (1.9 g). Differences in onion varieties responses to different intra-row spacings and they are manifested in differential ability to transform accumulated biomass to bulb production under different intensities of interplant competition. In case of 'Bombay' Red variety presence of shorter leaf diameter might have reduced the above ground biomass and resulted in higher harvest index. This result is elucidated by Izaadkhan et al. (2010) who reported that varieties of onion differed in leaf dry weight.

### Harvest index

The interaction effect of intra-row spacing and variety showed significant ( $p<0.05$  and  $p<0.01$ , respectively) effect on harvest index. Intra-row spacing of 7.5 cm showed the highest harvest index (0.83), followed by 5 and 10 cm intra-row spacing, both of which recorded the same harvest index (0.79) (Table 2). The lower harvest index at the wider spacing might be due to the production of more vegetative parts including flower stalks, which might have diverted assimilate away from the economically important bulbs. Kabir and Sarkar (2008) also reported a significant interaction effect on harvest

**Table 3.** 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 <sup>a</sup>	34.49 <sup>a</sup>	49.86 <sup>c</sup>
7.5	33.82 <sup>a</sup>	32.97 <sup>a</sup>	69.69 <sup>b</sup>
10	28.51 <sup>b</sup>	28.10 <sup>b</sup>	81.31 <sup>a</sup>
LSD <sub>(0.05)</sub>	3.1	3.1	4.76
CV (%)	12.9	13.63	9.9
Variety			
Adama Red	29.86 <sup>c</sup>	28.45 <sup>c</sup>	61.03 <sup>c</sup>
Bombay Red	34.68 <sup>ab</sup>	34.00 <sup>ab</sup>	67.29 <sup>b</sup>
Melkam	35.20 <sup>a</sup>	34.36 <sup>a</sup>	75.77 <sup>a</sup>
NasikRed	31.57 <sup>bc</sup>	30.60 <sup>bc</sup>	63.74 <sup>bc</sup>
LSD <sub>(0.05)</sub>	3.53	3.6	5.5
CV (%)	12.9	13.63	9.9

Means within a column followed by the same letter(s) are not significantly different at  $p=0.05$  according to LSD test.

index of mungbean and the highest value recorded from varieties at closer spacing probably due to the reduced vegetative biomass.

The highest harvest index (0.83) was recorded by 'Bombay' Red variety. The lowest harvest index (0.77) was recorded by 'Adama' Red variety (Table 2). Similarly, Naim et al. (2010) observed differences in harvest index on cowpea varieties. The authors further stated that some varieties gave the highest value of vegetative growth during growth stages and the highest seed and biological yield at the end of growth season. Fasika et al. (2008) also reported highly significant genetic differences among Ethiopian shallot genotypes for harvest index. This means that there can be variation in movement of food among the consumable parts and vegetative parts.

### 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. The highest total bulb yield (36.14 t/ha) was recorded at 5 cm intra-row spacing. However, it was not significantly different from the total bulb yield obtained at intra-row spacing of 7 cm (33.82 t/ha). An intra-row spacing of 10 cm showed the lowest total bulb yield (28.51 t/ha) (Table 3). 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, while

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 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 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 (Ademe et al., 2012).

Results also indicated that 'Melkam' variety had the highest total bulb yield (35.20 t/ha). The least total bulb yield (29.86 t/ha) was recorded by 'Adama' Red varieties. The present finding is supported by different investigations previously done. Jilani and Ghaffor (2003) and Jilani et al. (2009) suggested that varieties could have different yield potential in different agro-ecologies due to their genetic potential as well as genetic and environment interaction effect.

### Marketable bulb yield

Marketable bulb was bulbs which are greater than 25 g in weight according the assessment of the local market. A highly significant ( $p=0.05$ ) 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 per hectare decreased from 34.49 to 28.1 (Table 3). Among the intra-row spacing, a statistically similar result was obtained from 5 and 7.5 cm intra-row spacing (34.49 and 32.97, respectively) while 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 bulb size (Seck and Baldeh, 2009). Kantona et al. (2003) also reported that as plant density can increase number of marketable bulbs significantly.

The highest marketable bulb yield (34.36 t/ha) was recorded in '*Melkam*' and the lowest (28.45 t/ha) in '*Adama*' Red variety (Table 3). In agreement to the present results, Jilani et al. (2009) reported similar observation. A cultivar performs differently under diverse 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 3). 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 (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 cm 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 that an increase in okra fresh weight per plant from 38 to 70 g with the increasing in plant spacing from 31 to 41 cm due to increasing in the number of stem and wider leaf area per plant at wider spacing (Ademe et al., 2012).

'*Melkam*' variety showed significantly high average bulb weight (75.77 g), followed by '*Bombay*' Red (67.29 g) and '*Nasik*' Red (63.74 g) (Table 3). 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, which is consistent with the finding of Jilani and Ghaffoor (2003) and Jilani et al. (2009). Kimani et al. (1993) also reported significant bulb weight variation among eight onion cultivars. According to the EARO (2004), '*Melkam*' variety is characterized by large bulb weight. The current result is also supported by reports of various workers (Mohamedali, 1988; Rumpel and Felcznski, 1997; Kantona, et al., 2003; Hyder et al., 2007; Russo, 2008) who found similar results.

#### 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 (2.26 t/ha) (Table 4). 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. This finding is in agreement with related report of Seck and Baldeh (2009) who concluded that plant density had 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 Felcznski, 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.

#### CONCLUSION AND RECOMMENDATION

Onion is extremely popular and the most cultivated vegetables in Ethiopia, especially in Tigray region. 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 growth, yield, better quality and shelf life of onion varieties and to recommend superior variety adaptable to the specific



**Table 4.** 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 <sup>a</sup>
	Bombay Red	1.16 <sup>c</sup>
	Melkam	1.07 <sup>c</sup>
	Nasik Red	1.68 <sup>b</sup>
7.5	Adama Red	1.01 <sup>c</sup>
	Bombay Red	0.63 <sup>def</sup>
	Melkam	0.93 <sup>cd</sup>
	Nasik Red	0.88 <sup>cde</sup>
10	Adama Red	0.54 <sup>ef</sup>
	Bombay Red	0.32 <sup>f</sup>
	Melkam	0.53 <sup>ef</sup>
	Nasik Red	0.29 <sup>f</sup>
LSD(0.05)		0.37
CV (%)		26.1

Means connected with the same letter(s) are not significantly different at  $p=0.05$  as established by LSD test.

area and best plant spacing that give prime growth and yield. Results of the study showed that main effects of intra-row spacing, varieties as well as their interactions had considerable influence on different parameters. 'Bombay' Red variety was found to be the earliest which matured 23 days earlier than the latest variety of all and followed by 'Melkam' which is earlier in 18 days than the latest 'Adama' Red. Leaf number was maximum (12) at the 10 cm spacing and minimum (9) at the 5 cm spacing. The highest (51.3 cm) plant was observed at the wider spacing 10 cm and the lowest (48.6 cm) was perceived at the narrow spacing 5 cm. As intra-row spacing increased from 5 to 10 cm the percentage of bolters increased from 16.5 to 27.86%. The percentage of bolters increased with increasing plant spacing especially in 'Nasik' Red and 'Adama' Red varieties.

The highest total bulb yield (36.14 t/ha) was recorded at intra-row spacing of 5 and 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 5 cm intra-row spacing and 'Adama' Red variety (2.67 ton/ha.8). The highest percentage of small size bulbs was produced by the treatment combination of 'Adama' Red at 5 cm spacing and 'Bombay' Red at 5 cm spacing (23.76 and 15.45%, respectively) while the minimum percentage of small size bulbs was found in the combination of 'Melkam' at 10 cm

and 'Adama' Red at 10 cm spacing (4.4 and 6.9, 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 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.

### Conflict of Interests

The author(s) have not declared any conflict of interests.

### 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. Agri. Biol. Sci. 3(4):666-668.
- Ademe D, Derbew D, Getachew T (2012). Influence of bulb topping and intra row spacing on yield and quality of some shallot (*Allium Cepa* Var. *Aggregatum*) varieties at Aneded woreda, western Amhara 27 March. Afr. J. Plant Sci. 6(6):190-202.
- Ahmed MEN, Amgad M, Muatasim HS, Abdalla AE (2010). Effect of Intra-row Spacing on Growth and Yield of Three Cowpea (*Vigna unguiculata* L. Walp.) Varieties under Rainfed. Res. J. Agric. Biol. Sci. 6(5):623-629.
- 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. Horticultural Sci. 9:43-48.
- Aliyu U, Dikko AU, Magaji MD, Sing A (2008). Nitrogen and Intra-row Spacing Effect on Growth and yield of Onion (*Allium cepa* L.,) J. Plant Sci. 3(3):188-193 ISSN 1816-4951.

- AxARC (Axum Agricultural Research Center) (2009). Problem appraisal report. Aksum, Ethiopia. Unpublished document.
- Bodnar JL, Schumacher B, Uyenaka S (1998). Garlic production in Ontario, Omafra Factsheet, Canada. P. 8.
- Brewster JL (2008). Onions and other Vegetable *Alliums*. 2nd ed. CAB International. North America.
- 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, Kliever B, Thompson C (2009). Evaluation of cultural practices to control hollow heart in premier russet. University of California Intermountain Research and Extension Center, Research progress No 121.
- EARO (Ethiopian agricultural research organization) (2004). Directory of released crop varieties and their management. Addis ababa. Ethiopia.
- EHDA (Ethiopian Horticultural Development Agency) (2011). Assessment of development potentials and investment options in the export-oriented fruit and vegetable sector.
- EIAR (Ethiopian Institute of Agricultural Research) (2007). Crop technologies guidelines. Amharic version. Addis Ababa.
- Fasika S, Hailu T, Kebede W (2008). Genetic Variability Studies in Ethiopian Shallot (*Allium cepa* L. var. Ascalonicum Backer) Genotypes. E. Afri. J. Sci. 2(2):130-134.
- 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. Horticulture Forestry 2(1):007-011, January, 2010 <http://www.academicjournals.org/jhf>
- Gupta PK (2000). Soil, Plant, Water and Fertilizer Analysis. Rajasthan Agricultural University. Bikaner, Agrobios India. P. 438.
- 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](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. 44 pages.
- 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.
- Ibrahim AI (1994). Effect of grass mulch and plant spacing on growth and yield of garlic (*Allium sativum* L.) Unpublished B. Sc. Project, Department of Agronomy, ABU Zaria.
- 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. 52 pages.
- 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.
- Izadkhan M, Tajbakhsh M, Zardoshty MR., Goratteph AH (2010). Evaluation Effects of Different Planting Systems on Water Use Efficiency, Relative Water Content and some Plant Growth Parameters in Onion (*Allium cepa* L.). Not Sci. Biol. 2(1):88-93.
- 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, Ahmed P, Waseem K, Kiran M (2010). Effect of plant spacing on growth and yield of two varieties of onion (*Allium cepa* L.) Under the agro-climatic condition of D. I. Khan. Pak. J. Sci. 62:1.
- Jilani MS, Ghaffoor A (2003). Screening of Local Varieties of Onion for Bulb Formation. Int. J. Agri. Biol., Vol. 5, No. 2, 2003. 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.
- Kabir MH, Sarkar MAR (2008). Seed yield of mung bean as affected by variety and plant spacing in Kharif-I season. J. Bangladesh Agric. Univ. 6(2):239-244.
- Kantona RAL, Abbeyb L, Hillac RG, . Tabil MA, Jane ND (2003). Density Affects Plant Development and Yield of Bulb Onion (*Allium cepa* L.) in Northern Ghana. Journal of Vegetable Crop Production, Volume8, Issue2 March, pp.15-25.
- Karaye AK, Yakubu AI (2006). Influence of intra-row spacing and mulching on weed growth and bulb yield of garlic (*Allium sativum* L.) in Sokoto, Nigeria: Afri. J. Biotech. 5(3):260-264.
- Khalid MK (2009). Effect of set-size and storage temperature on bolting, bulbing and seed yield in two onion cultivars, 17 September 2009. *Pakistan. Scientia Horticulturae* 122(2):187-194.
- Khan MK, Hasan MA, Miah M, Alam M, Masum AS (2003). Effect of plant spacing on the growth and yield of different cultivars of onion. *Pakistan J. Biol. Sci.* 6(18):1582-1585.
- Kimani PM, Karinki JW, Peters R, Rabinowitch HD (1993). Influence of environment on the performance of some onion cultivars in Kenya. *Afr. Crop Sci. J.* 1(1):15-23.
- Lemma D, Shimeles A (2003). Research experiences in onion production. Research report No. 55, EARO, Addis Abeba Ethiopia, P. 52.
- Mintesnot B, Abdulkadir A, Atinkut M, Mustefa Y (2005). Community Based Irrigation Management in the Tekeze Basin: Performance Evaluation. Mekelle University, ILRI & EARO March.
- MoARD (2006). Crop Variety Register. Crop Development department, Issue No.9, June 2006, Addis Abeba, 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/>
- Naim HME, Hagelsheep AM, Abdelmuhsin MS, Abdalla AE (2010). Effect of Intra-row Spacing on Growth and Yield of Three Cowpea (*Vigna unguiculata* L. Walp.) Varieties under Rainfed.
- Palada CM, Crossman MA (1998). Planting density affects growth and yield of Okra. Proceedings of the 34th Annual Meeting 1998- Caribbean Food Crop Society. pp. 52-57.
- Perez MA, Ayub CM, Saleem BA, Virk NA, Mahmood N (2004). Effect of Nitrogen Levels and Spacing on Growth and Yield of Radish (*Raphanus sativus* L.). In Int. J. Agric. Biol. 6:3 publishing, UK.
- 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., Szejda J., and Görecka 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 contentof onion Developed from Greenhouse-grown Transplants. Hortscience 43(6):1759-1764.
- Salunkhe DK (1998). Handbook of Vegetable Science and Technology: Production, omposition, Storage, and Processing Food Science and Technology (Marcel Dekker, Inc.) 86. CRC Press.
- 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: 169-173 Printed in Uganda.
- Shamsi K, Kobraee S (2009). Effect of plant density on the growth, yield and yield components of three soybean varieties under climatic conditions of Kermanshah, Iran. Journal of Animal & Plant Sciences, 2009. 2(2):96 -99.
- Smittle D (1993). Onion production in the tropics. United states Agency for International Development (USAID). Washington, D.C.
- Woldemariam W (2009). Effects of set size and spacing on growth and yield of ginger (*Zingiber officinale* rosc.) at Areka, Southern Ethiopia.
- Zamir SI, Maqsood M, Saifi MA, Yousaf N (1999). Effect of plant spacing on yield and yield components of maize. Int. J. Agri. Biol.1(3):152-153.