EFFECT OF INTRA-ROW SPACING ON GROWTH PERFORMANCE AND YIELD OF ONION (*Allium cepa* L.) VARIETIES AT MIZAN-AMAN, SOUTHWESTERN ETHIOPIA

MSc THESIS

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HAWASSA UNIVERSITY
COLLEGE OF AGRICULTURE

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SCHOOL OF PLANT AND HORTICULTURAL SCIENCE
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We, the undersigned, members of the Board of Examiners of the final open defense by

DIRO BUZAYO TOLESSA have read and evaluated his thesis entitled "Effect of Intra-row Spacing on Growth Performance and Yield of Onion (*Allium cepa* L.) Varieties at Mizan-Aman, Southwestern, Ethiopia", and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements for the degree of **Master of Science in Agronomy**.

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As members of the Board of Examiners of the final MSc open defense, we certify that we have read and evaluated his thesis prepared by ***DIRO BUZAYO TOLESSA*** under the title "Effect of Intra-row Spacing on Growth Performance and Yield of Onion (*Allium cepa* L.) Varieties at Mizan-Aman, Southwestern, Ethiopia", and recommend that it be accepted as fulfilling the thesis requirement for the degree of Master of Science with specialization in **Agronomy**.

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I hereby certify that all the corrections and recommendations suggested by the Board of Examiners are incorporated into the final Thesis "Effect of Intra-row Spacing on Growth Performance and Yield of Onion (*Allium cepa* L.) Varieties at Mizan-Aman, Southwestern, Ethiopia"

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DEDICATION

I dedicate this thesis manuscript to my beloved wife, Bayise Adugna and my best friend, Tadesse Lamessa; thank you for encouragement that you gave me during my study and your support is overwhelming in the success of my life.

STATEMENT OF THE AUTHOUR

First of all, I declare that this thesis is my work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Msc. degree at the Hawassa University College of Agriculture and is deposited in the University's Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma or certificate.

Name: Diro Buzayo **Signature:** ________________

Place: Hawassa University, Hawassa

Date of Submission: ________________________

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
ATVET	Agricultural technical, vocational, educational and training
BD	Bulb diameter
BL	Bulb length
BMZARD	Bench Maji zonal agriculture and rural development
BNT	Bulb neck thickness
DAT	Days after transplanting
DM	Days to maturity
BDM	Bulb dry matter
FAO	Food and agricultural organization
LAI	Leaf area index
LL	Leaf length
LN	Leaf number per plant
MBY	Marketable bulb yield
MoA	Ministry of agriculture
NH	Neck height
Ph	Plant height
RCBD	Randomized complete block design
SAS	Statistical analysis software
SNNPRs	South Nation Nationalities and People Regional state
TBY	Total bulb yield
UMBY	Unmarketable bulb yield

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EFFECT OF INTRA-ROW SPACING ON GROWTH PERFORMANCE AND YIELD OF ONION (*Allium cepa* L.) VARIETIES AT MIZAN-AMAN, SOUTHWESTERN ETHIOPIA

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ABSTRACT

Onion is among the most important vegetable crops produced in Mizan-Aman for home consumption and as income sources. However, lack of site based varieties and inappropriate planting density have been the major bottlenecks of onion production and productivity in the area, since there are no recommended spacing and variety for that area specifically. Rather farmers use to practice non-uniform plant spacing. This study was thus conducted at Mizan ATVET College in 2015/2016 with the objective of investigating the effect of intra-row spacing on growth performance and yield components of onion varieties. Three varieties (Adama Red, Bombay Red and Melkam) were evaluated under four different intra-row spacings (6, 10, 14 and 18 cm) and constant inter-row spacing of 20 cm by using randomized complete block design replicated three times. Data on days to maturity, growth performance and yield were recorded and subjected to analysis of variance using SAS version-9 software. Results of the study indicated that, intra-row spacing and variety had significant effect on plant height, leaf number per plant, leaf length, days to maturity, bulb diameter and length, bulb dry matter, total bulb yield as well as, marketable and unmarketable bulb yield. Closer intra-row spacings enhanced early maturity, while wider spacing delayed maturity. The maximum plant height, leaf length and leaf number were recorded in 10 cm intra-row spacing. Bombay Red variety was early maturing with the highest mean value for growth and yield parameters. It had the highest total bulb and marketable bulb yield than Melkam and Adama Red onion varieties specially when planted at 10 cm intra-row spacing. Bombay Red with 10 cm intra-row spacing also gave highest total bulb and marketable bulb yield. The correlation values also confirmed the significant and positive association between growth parameters and bulb yield. Based on the result of this study, higher onion yield with better quality was attained when Bombay Red variety was planted with 10 cm intra-row spacing under Mizan-Aman condition, for recommendation, although additional verification trial is needed to substantiate the result.

Key words: bulb size, growth, intra-row spacing, onion varieties, yield

1. INTRODUCTION

Onion (*Allium cepa* L.) is an important bulb crop of tropical and subtropical part of the world. It is the second most important horticultural crop in the world after tomatoes (Ketter and Randle, 1998) and is consumed worldwide for its unique flavor and health related properties (Grffiths *et al.*, 2002). Onion is also a vital vegetable crop whose distinctive flavour is appreciated by people throughout the world (Ibrahim, 2010) and is cultivated for ultimate uses as green and bulb. Additionally, it has medicinal properties in the treatment and prevention of a number of serious diseases (cardiovascular, blood clots and stomach cancer) that attributed with onion biochemical constituents (Mohamed *et al.*, 2012). In Ethiopia, onion is one of the most important vegetable crops produced mainly as a source of cash income and for flavoring the local stew 'wot'. It also occupies economically important place among vegetables in the country (Lemma and Shemelis, 2003).

Research indicated that onion performs best in altitude ranging between 700-1800 masl (Aklilu, 1997). Thus, Onions are spread throughout Ethiopia being cultivated under both irrigated as well as rainfed conditions in different agro-climatic regions (Lemma and Herath, 1994). Consequently, the total area covered by onion is increasing from time to time mainly due to its high profitability per unit area, ease of production and intensification of small scale irrigation system. Despite the increase in cultivated areas, the productivity of onion is much lower which is about 10.13 t ha^{-1} (CSA, 2015) as compared to the world average 19.30 t ha^{-1} (FAOSTAT, 2011).

The low yield of onion in Ethiopia is reported to be mainly associated with low soil fertility, inappropriate fertilizer (Geremew *et al*., 2010), lack of improved varieties (Yemane *et al*., 2013) and poor management practices (Lemma and Shimeles, 2003). Although productivity of an onion variety depends on the interaction between variety and the environment (Jilani and Ghaffoor, 2003), agronomic practices such as; sowing date, fertilization, irrigation and plant spacing among others, have also an effect on its growth, and bulbs yield (Brewster, 2008). Especially plant spacing is an important factor in determining onion bulb yield, which varies from place to place and from variety to variety (Lemma and Shimeles, 2003).

The agricultural research system of Ethiopia has made tremendous effort to improve onion production and productivity. In this regard, it has generated improved onion varieties among others such as Red Creole, Bombay Red, Melkam, Dereselegn and Adama Red, out of which Bombay Red and Adama Red varieties are widely grown in Ethiopia (EARO, 2004). However, these varieties are not distributed to most onion growing areas of the country and tested in different agro-ecologies. Thus it would be very difficult to recommend similar production technologies that can be applicable to the diverse agroecological zones of the country, since full package of information is required to optimize onion productivity (Lemma and Shimeles, 2003). Accordingly, plant population needs to be optimized, since optimum plant population has dual advantages, as it avoids strong competition among plants for growth resources such as water, nutrient and light, as well as enables plants to efficiently use the available crop land without wastage (Geremew *et al.,* 2010).

Consequently maintaining optimum spacing for onion production ensures the optimal yield (Mesbaul, 2007) through proper harvesting of the required solar radiation and plant nutrients which are essential for higher yield. Moreover, appropriate spacing reduces competition among plants which is positively correlated with higher yield up to a certain level (Badaruddin and Haque, 2000). Currently the national recommended intra and inter-row spacing for onion production in all onion producing potential areas is 10 and 20 cm, respectively (Lemma and Shimelis, 2003).

In Mizan-Aman area, has suitable agro climatology for onion production and it is one of the most important vegetable crops. However, the crop is not extensively produced by farmers due to different problems. According to the survey reports of Mizan ATVET College in 2015 the problems are associated with some agronomic practices like plant spacing, fertilizer application, weeding practice, and the variety being used for production. The farmers randomly grow onion without considering appropriate agronomic practices including intra-row spacing for their locality. Many onion producers of Mizan-Aman were using intra-row spacing narrower than 10 cm expecting to achieve high yield per unit area. They also randomly grow onion without specified variety with similar agronomic practices including intra-row spacing for all varieties. However, narrower intra-row spacing not only increases production costs but also influence bulb size and yield. It is also clear that, using the same spacing for different varieties would have an impact on the yield and yield components. Thus, recommending area and variety specific plant spacing is to be imperative to achieve better onion yield in quantity and quality. In view of this, the present study was initiated to investigate the effect of different intra-row spacing on the growth performance and yield of onion varieties with the following specific objectives:

- ✓ To evaluate the effect of intra-row spacing on growth performance and yield of onion varieties
- ✓ To determine appropriate intra-row spacing for higher yield and quality of onion in the study area
- ✓ To identify best performing onion variety with proper intra-row spacing in the area

2. LITERATURE REVIEW

2.1. Origin and distribution of onions

Alliums belong to the genus Allium the family Alliaceae, which is originated in southwest Asia and the Mediterranean regions. It has been cultivated since ancient times in the Middle East and India. It made its way to Egypt through trade, where they became a popular food in ancient Egypt, where it is depicted on tombs as early as 3200 BC and has been found in mummies (Golani *et al.*, 2006). During the fourth century B.C., Alexander the Great transported onions from Egypt to Greece, where they spread to other parts of Europe following Alexander's conquest. By the fifteenth century, Europeans began introducing different cultivars and landraces to parts of the New World. Christopher Columbus' crews planted onions in Hispaniola as early as 1494, and the vegetable was mentioned as cultivated in the present day United States as early as 1629. By the nineteenth century, various types of onion were growing all across the U.S.(Fritsch and Friesen, 2012). Then it was introduced into the new world shortly after its discovery, and was cultivated there as early as 1629. It is now distributed throughout the world including Europe, Asia, North America and Africa (Khare, 2012).

2.2. Onion production

The cultivated onion (*Allium cepa* L.) is one of the important condiments widely used in all households. The total world production of onion was about 86.34 million tons (FAOSTAT, 2011). Leading onion producing countries in production were China, India, USA, Iran, Egypt, Turkey, Russian Federation and Pakistan.

Onion is considerably important in the daily Ethiopian diet. The bulbs and lower stem sections are the most popular as seasonings or as vegetables in stews (MoARD, 2009). Estimates of area in hectare, and total production of onion in Ethiopia for all seasons and all holdings that is both rural and urban is 20,443.92 and 2,572,052.63, respectively in which Oromia is the most important production region contributing 64%, followed by Amhara 30% (CSA, 2008/09).Yield potential of properly cured dry bulbs at research centers in the country ranges between 25 and 35 t ha^{-1}, whereas in the farmers field it ranges between 9 and 15 t ha^{-1} (Lemma and Shimeles, 2003).

Generally, onion production and productivity has been limited due to inappropriate agronomic practices such as plant population, planting date, harvesting date and fertilizer application for varying environment and cultivar. Higher yield with better bulb size could be obtained if plants are grown at optimum spacing (Weldemariam *et al.,* 2013; Yemane *et al.*, 2013). The research conducted at Adami Tulu indicated that marketable bulb yield was significantly affected by difference in intra-row spacing. That is, varieties planted with wider intra-row spacing of 10 and 8 cm produced the least marketable yield of about 16.98 and 15.82 t ha^{-1}, respectively (Geremew *et al*., 2010). However, Yemane *et al*. (2013) reported that 7.5cm intra-row spacing as suitable for Adama Red, Bombay Red, Melkam and Nasik Red at Aksum, Northern Ethiopia. On the other hand, from onion varieties, Nasik Red performs better followed by Bombay Red at Adami Tulu (Geremew et al., 2010), while Melkam and Bombay Red varieties were found to be superior in yield at Aksum, Northern Ethiopia (Yemane *et al.*, 2013), Nafis variety at Humbo, Southern Ethiopia (Tibebu *et al*., 2014) and Melkam Variety at Kobo, Amhara region (Tesfalegn, 2015).

2.3. Onion varieties in Ethiopia

Different types of onion cultivars are available in Ethiopia which varies in terms of vegetative characteristics such as foliage length, leaf arrangement (erect, pending) and leaf color. They also differ in bulb characteristics, internal structure (single, double, multiple) bulb shape (flat to cylindrical to spindle), color (red, yellow, white), flavor rate (sweet, mid pungent and pungent) (Weldemariam *et al.*, 2013).

The five common onion varieties available in Ethiopia are: Adama Red, Bombay Red, Nasik Red (Dereselgn), Red Creole and Melkam to farmers. Adama Red is a dark red colored, firm, very pungent, and flat globe shaped. Melkam variety is a high yielder but light red in bulb color than Adama Red, whereas Red Creole is red color, firm, very pungent, not easily bolting, and relatively tolerant to purple blotch disease. Bombay Red is thick flat shaped, light red, light pungent, susceptible to purple blotch disease and it has a high proportion of split bulbs and has short shelf life compared to Adama Red. Dereselgn, early maturing, medium red, large bulb sizes and fits to short growing season. Yemane *et al*. (2013) reported that Adama Red and Nasik Red had higher BDM (%) than Melkam and Bombay Red. Adama Red variety was found to be superior for bulb quality as measured by BDM and storability. According to EARO (2004) Bombay Red and Adama Red varieties are widely grown in Ethiopia.

2.4. Onion Growth

Onion is usually grown from seed, although sets (tiny bulb onions) are sometimes produced specially to maximize the production period. During growth, cell division occurs at the base of each leaf sheath around the central meristem region, located just below ground level (Brice *et al.*, 1997). The number of leaves produced before bulbing is also regarded as key to the process of bulb growth since they are the main suppliers of assimilates for bulb expansion (Mettananda and Fordham, 1999). The final bulb size depends on the physiological process regulating the development of bulbs before their formation (Lancaster *et al.*, 1996). Report from Geremew *et al*., (2010) indicated that higher bulb growth attained by Bombay Red variety planted with 10cm intra-row spacing followed by Adama red planted with similar intra-row spacing, while the lowest bulb was from Adama Red variety with 4cm intra-row spacing. Similarly, Yemane *et al*., (2013) conducted field trials on four onion varieties (Bombay red, Adama red, Melkam and Nasik red) and three intra-row spacing (5, 7.5 and 10 cm) and reported that, intra-row spacing of 10 cm showed the largest bulb, followed by 7.5 intra-row spacing, whereas the smallest bulb was from closer spacing (5 cm).

The field trial conducted by Gessesew *et al*., (2015) on six rates of N fertilizer (0, 46, 69, 92, 115 and 138kg ha^{-1}) and four levels of intra-row spacing (7.5, 10, 12.5 and 15 cm) at Gode, South-Eastern Ethiopia indicated that, nitrogen fertilizer at the rate of 138 kg ha^{-1} and intra-row spacing of 15 cm produced largest bulb, while smallest bulbs were produced from null nitrogen fertilizer and at 7.5 cm intra-row spacing. Similarly, research conducted on different nitrogen levels (0, 50, 100 and 150 kg N ha^{-1}) and intra-row spacing (10, 15, 20 and 25 cm) on the growth and yield of onion at Sokoto, Nigeria reported the highest bulb from 25cm spacing and 100kg N/ha, while the smallest from 10cm and with no nitrogen application (Aliyu *et al*., 2008).

2.5. Variety and intra-row spacing effect on growth and yield of onion

2.5.1. Effect of variety on growth and yield potential of onion varieties

Report from Yemane *et al*., (2014) indicated that different varieties significantly vary in growth and yield parameters. Bombay Red followed by Melkam varieties were the earliest, which matured 123 and 118 days, respectively, whereas, Adama Red variety was late maturing. Tesfalegn (2015) also reported that Bombay Red followed by Melkam varieties were the earliest, which matured 100.4 and 110.5 days, respectively, while Adama Red variety was late maturing. Taller plant height was recorded for Adama Red, longest leaf for Adama Red and Nasik Red, whereas the minimum plant height and leaf length were observed for Bombay Red.

Tibebu *et al*., (2014) showed that growth and yield parameters of varieties had significant differences in plant height, bulb diameter, total bulb yield, marketable yield, and bulb dry matter contents. Maximum plant height (37.3 cm) and number of leaves (10.6) were obtained from Nafis variety, whereas minimum plant height (31.5 cm) was observed from Adama Red and number of leaves (9.69) from Bombay Red. Nafis scored the highest mean bulb diameter (3.9 cm); however the lowest mean bulb diameter of 3.2 cm was recorded for Adama Red. The research conducted on performance of common onion varieties indicated the existence of differences among onion varieties in terms of plant height and number of leaves per plant (Mohanty and Prusti, 2001).

Tibebu *et al.,* (2014) indicated the existence of significant variation among varieties in marketable yield which varied from 9.17 to 15.94 t ha^{-1}. Higher total bulb and marketable yield were recorded from Bombay Red and Nafis, while the minimum total bulb and marketable bulb yield were recorded from Adama Red. Yemane *et al.,* (2014) and Tesfalegn (2015) reported highest total bulb yield and marketable yield for variety Melkam, while the lowest total yield and marketable yield were obtained from Adama Red. Another research also showed that significant difference among onion varieties in total bulb and marketable bulb yield (Muhammad *et al.*, 2004). Mohanty and Prusti (2001) reported the existence of difference among onion varieties in bulb yield.

Geremew *et al*. (2010) reported that Adama red gives the least bulb diameter than Bombay Red and Nasik Red onion varieties in Adami Tulu area. Similarly, Tibebu *et al.,* (2014) showed the existence of significant difference among onion varieties in bulb diameter. Yemane *et al.*, (2014) reported that Adama Red having BDM (%) of 17.67 showed higher and significant difference from Melkam and Bombay Red which had BDM (%) of 15.23 and 14.41, respectively. Nafis scored the highest bulb dry matter content (38.97) which was, however, statistically similar to the bulb dry matter content (38.66) of Bombay Red (Yemane *et al.,* 2014).

2.6.2. Effect of intra-row spacing on growth and yield potential of onion varieties

Dellacecca and Lovato (2000) reported selection of plant population as an important management decision since onion yield could be influenced by plant population. It is critical to know the optimum plant population to achieve higher yield with good quality. Space arrangement could allow crops to fully exploit light and soil resources and give high yields (Lesly, 2010). The yield attained at specific plant spacing is also influenced by growing conditions, in particular soil conditions and water availability (Dellacecca and Lovato, 2000). Wider intra-row spacing resulted in significant increases in number of leaves/plant, plant height and single bulb weight. The diameter of the bulb was also significantly increased by wider intra-row spacing (Mesbaul, 2007).

Ali *et al.,* (2005) reported that as intra-row spacing increased, total bulb and marketable bulb yield decreased, whereas bulb diameter increased. According to Yemane *et al*. (2013); Tesfalegn (2015) and Mesbaul (2007) an intra-row spacing has significant effect on leaf length, number of leaves per plant, plant height, bulb diameter, bulb length, total bulb yield, marketable bulb yield and unmarketable bulb yield. Yemane *et al.,* (2014) showed a statistically similar result among intra-row spacing of 5 and 7.5 cm which scored the highest marketable yield in tons per hectare, while intra-row spacing of 10 cm showed the lowest marketable bulb and total bulb yield.

Mesbaul (2007) reported the maximum bulb dry matter from narrower spacing and lowest from wider spacing.

In the report of Mahadeen (2008) and Sikder *et al.,* (2010) intra-row spacing had significant effect on bulb diameter, bulb neck thickness, and bulb yields per hectare. They further indicated that wider intra-row spacing produce the highest bulb diameter, thicker bulb neck and reduced bulb yield per ha. The highest yield was recorded at 10 cm intra-row spacing, whereas the lowest yield was recorded at 20 and 25 cm spacing (Mahadeen, 2008). According to Rizk *et al.* (1991); Lesly (2010); Nasir *et al.,* (2007) and Muhammad *et al*., (2009) marketable, unmarketable and total bulb yields were lower at wider intra-row spacing. Moreover Farooq *et al.,* (1990); Mike and Martin (2009); Gagopale (2012) reported that bulb diameter decreased as plant density increased, while at low plant densities, individual onions were larger. Gagopale (2012); Mahadeen, (2008) and Sikder *et al*., (2010) further indicated that as plant population decreased, bulb neck thickness increased. The thickest necks were produced by plants with lower population, followed by the medium plant population, while the thinnest necks were at the highest plant population (Muhammad *et al*., 2009) and Attallah *et al.,* 2012). The highest bulb neck thickness was observed at intra-row spacing of 10 cm, while the least at 5 intra-row spacing (Yemane *et al*., 2013). Additionally, some authors (Nasir *et al.,* 2007; Muhammad *et al*., 2009 and Attallah *et al.,* 2012) showed the maximum number of leaves per plant at the lower planting density, while minimum number of leaves per plant at the higher planting density. Harun and Rashid (1998) showed that the highest plant height and the highest bulb dry matter produced in closer intra-row spacing.

3. MATERIALS AND METHODS

3.1. Description of the study site

The study was conducted in 2015/2016 at Bench-Maji zone of the Southern Nation, Nationalities and People's Region state (SNNPRs), Mizan Agricultural Technical, Vocational, Educational and Training (ATVET) College, which is located at 561 and 836 km Southwest of Addis and Hawassa, respectively. It lies about $6^{o}59^{'}$N, $35^{o}35$'E and at an altitude of 1350 masl. The mean annual rainfall in the study area is 1546 mm, while the annual temperature ranges from 20^{o}C to 40^{o}C with mean minimum and maximum temperature of 22^{o}C and 29^{o}C, respectively (BMZARD, 2015). The soil is characterized as clay loam with textural classes of 44% clay, 30% sand and 26% silt content and 5.7 pH value (Appendix Table 1).

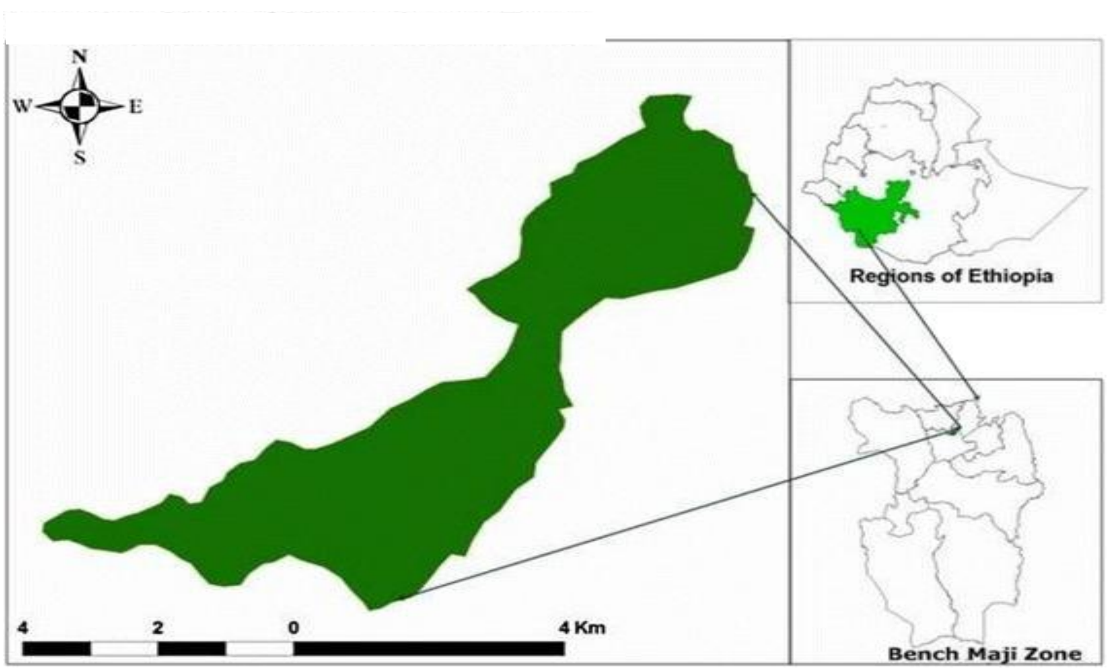

Figure 1. Location Map of the experimental site, Mizan Aman, Southern Region in Ethiopia

3.2. Treatments and experimental design

The study was a factor experiment that consisted three onion varieties (Adama Red, Bombay Red, and Melkam) and four intra-rows spacing (6, 10, 14 and 18 cm). The factors were arranged in RCBD design with three replications.

Table 1. Treatment combinations of the study conducted in 2015/16 at Mizan-Aman

Onion Variety	Intra-row spacing (cm)	N^{o} of plants per plot	N^{o} of plants per hectare
Adama Red	6	198	825,000
	10	120	500,000
	14	84	350,000
	18	66	275,000
Bombay Red	6	198	825,000
	10	120	500,000
	14	84	350,000
	18	66	275,000
Melkam	6	198	825,000
	10	120	500,000
	14	84	350,000
	18	66	275,000

The seeds for planting were obtained from Melkassa Agricultural Research Center from where they were released for production.

Table 2. Description of onion varieties used in the study conducted in 2015/16 at Mizan-Aman

Character	**Adama Red**	**Bombay Red**	**Melkam**
Leaf color	Medium green	Dark green	Dark green
Leaf arrangement	Erect	Medium	Erect
Bulb size	60 – 80	85 - 100	70 - 90
Bulb shape	Flat globe	Flat globe	High globe
Bulb skin color	Dark red	Light red	Medium red
Bulb flesh color	Reddish white	Reddish white	Reddish white
Year of release	1980	1980	1998
Maturity days	110 – 130	< 120	110 - 130
Bulb yield (kg/ha)	350	300	400

Source: Adapted from EARO (2004)

Each plot had 2.0 m length and 1.2 m width, having six rows per plot with inter-row spacing of 20 cm, while the intra-row spacing varied as per the treatment. Yield data were taken from the four internal rows in each plot. The spaces between plots and blocks were 0.5 and 1.0 m respectively, and the total experimental area was 163.2 m^2.

3.3. Experimental procedure and management

The experimental field was well prepared by using oxen driven local plow *(Maresha)* in accordance with conventional farming practices in the study area. Raised seed bed was then prepared with 1.0 m width and 5.0 m length, after which seeds were sown in the rows at a rate of 4 kg/ha. Dry grass was used as mulching material for 15 days soon after sowing. The seedlings were then transplanted to the experimental field in single row at 50 days after sowing as the recommended by EARO (2004).

Phosphorus fertilizer was applied in the form of DAP with the rate of 46 P_2O_5kg/ha at planting, while 87Nkg/ha in the form of UREA and DAP was applied in a split pattern, in which the first 50% at transplanting and the remaining, 45 days after transplanting. Ridomil fungicide was applied at the rate of 2.5 kg/ha against leaf purple blotch, while weeds were controlled manually by hand weeding (EARO, 2004).

3.4. Data collection

In this study, the effect of intra-row spacing on growth performance and yield of onion varieties at Mizan-Aman was assessed for vegetative growth and yield components of onion. Days to maturity was registered on plot basis. Growth data were collected from five randomly selected plants and most yield components data were collected from four central rows. The two external rows in each plot and plants at both ends of each row were considered as borders and excluded from data collection. The procedure applied to collect the data is presented as follows.

3.4.1. Days to maturity

Days to maturity: was recorded as the actual number of days from the date of transplanting to when about 75% of the leaves fell down and 2/3 leaves had turned yellow (EARO, 2004).

3.4.2. Growth Parameters

Plant height (cm): Plant height was measured from the ground level up to the tip of the longest leaf using ruler. Plant height of five randomly selected plants was measured in the central rows of each plot at maturity stage of the crop and the average was computed.

Leaf length (cm) was measured from the leaf base up to the tip of the highest leaf using a standard ruler from five randomly selected plants in each plot at maturity by using ruler and the average leaf length was taken.

Leaf number per plant: refers to the mean number of leaves produced by sampled plants. The number of fully developed leaves of five randomly selected plants was counted at the active green leaf stages and the average was computed to obtain number of leaves per plant.

Leaf area index (LAI) was calculated by dividing the total leaf area obtained per unit area occupied by the sampled plants.

$$\text{Leaf area index} = \frac{\text{Leaf area/plant}}{\text{Land area/plant}}$$

$$A = -93.1 + 1.83L + 38.6\ C_{25}$$

Where A= leaf area, L=Leaf length and C_{25}= Leaf circumference at 25% distance from the leaf base of the first emerged leaf (Gamiely *et al*, 1991).

3.4.3. Yield and Yield Components

Total bulb yield (t ha^{-1}): Total bulb yield was recorded from the four central rows of each plot at harvest. The harvested bulbs were weighed and it was converted into t ha^{-1}.

Marketable bulb yield (t ha^{-1}): This referred to the weight of healthy and marketable bulbs that range from 20 g to 160 g in weight. Bulbs below 20 g in weight were considered too small to be marketed whereas those above 160 g were considered oversized according to Lemma and Shimeles (2003). This parameter was determined from total bulb yield at final harvest time after discarding bulbs smaller than 20 g, splitted, diseased and decayed bulbs, from the four central rows of each plot and expressed as t ha^{-1}.

Unmarketable bulb yield (t ha^{-1}): The total weight of unmarketable bulbs that are under sized (< 20 g), diseased, decayed and split bulbs was measured from the four harvestable central rows at final harvest and expressed in t ha^{-1}.

Bulb dry matter of yield (t ha^{-1}) was calculated by multiplying bulb dry matter calculated in percent with the total yield in t ha^{-1} and divided by one hundred.

3.4.4. Quality parameter

Bulb diameter (cm) was measured by caliper at the middle portion of five selected bulbs at the widest circumference and the average was taken as the diameter of bulb.

Bulb length (cm) was measured from the neck of bulb to the bottom of the five selected bulbs and then their average was taken as the length of bulb.

Bulb dry matter (%): the average dry matter weight of matured bulb was expressed in percent. For determination of bulb dry matter, a homogenate was prepared from sampled plant bulbs from each plot and those samples were chopped down, from which 100 gram of the homogenate sample was taken and oven dried at temperature of 70 ^{o}C to constant weight, the weight was measured using sensitive balance and percent of bulb dry matter was calculated as the ratio of weight of oven dried sample to the weight of fresh sample multiplying by 100.

Bulb neck thickness (cm): The average neck thicknesses of five randomly selected plants in each plot were obtained by measuring the neck of bulbs at the narrowest point at the junction of bulb and leaf sheath using a caliper.

3.5 Data analysis

The data were subjected to analysis of variance (ANOVA) using SAS version 9.0 procedures. The mean separation was done using (LSD) test at 5% probability level. And simple correlation was made in determining association of parameters by using Pearson analysis.

4. RESULTS AND DISCUSSIONS

4.1. Growth parameters

4.1.1. Plant Height (cm)

The results of this study revealed a highly significant ($p \leq 0.001$) differences in terms of plant height among the onion varieties; as well as intra-row spacing had significant ($p \leq 0.05$) effect on the parameter. However, variety and intra-row spacing did not significantly interact to influence plant height (Appendix Table 2).

The maximum plant height (63.5 cm) was recorded from Bombay Red, while the shortest (45.3 cm) was attained by Adama Red (Table 3). These differences could be due to the specific genetic makeup of the varieties. This result was similar to the findings of Mohanty and Prusti (2001); Islam *et al.,* (2007); Tibebu *et al.,* (2014); Yemane *et al.,* (2014) and Tesfalegn (2015) who indicated the presence of significant differences among onion varieties in terms of plant height.

The highest plant height (59.6 cm) was also attained in plants spaced at10 cm intra-row was statistically at par with the plant height (55.2 cm) obtained under 6 cm intra-row spacing. Even if there is no significant difference statistically among intra-row spacing of 6cm, 14 cm and 18cm in terms of plant height, numerical value differences were observed (Table 3). Height of plant can be considered as one of the indices of plant vigor and it depends upon vigor and growth habit of the plant. The result showed that the plants in 10 cm intra-row spacing attained the higher height. The maximum plant height at 10 cm intra- row spacing might be due to appropriate space availability for growth of the plants. The finding of Khan *et al*., (2003) had confirmed that 10 cm intra-row spacing produced significantly the highest plant height. In agreement with the current finding, Yemane *et al.*, (2014) and Tesfalegn (2015); also reported maximum plant height recorded in plants with 10 cm intra-row spacing. Sara *et al.*, (2015) also reported that maximum height was produced from spaced 10 cm followed by 7.5 cm and 5 cm intra-row spacing. In conformity with this finding Derajew (2014) reported maximum plant height when plants were spaced at 7.5 cm distance, followed by plants spaced at 10 and 12.5 cm without significant difference among them, while the lowest height was recorded at spacing of 15 cm which was also at par with the two intermediate intra-raw spacings.

4.1.2. Leaf length (cm)

In the current study, leaf length highly significantly ($p \leq 0.001$) differed among varieties, it was also significantly ($p \leq 0.05$) affected by intra-row spacing. However, the two factors did not interact to significantly influence leaf length (Appendix Table 2).

Irrespective of the intra-row spacing the maximum leaf length (53.6 cm) was attained from Bombay Red which was significantly different from Melkam (48.3 cm) and Adama Red (40.19 cm). The leaf length of variety Melkam was also significantly different from Adama Red (Table 3). The differences in leaf length among onion varieties might be due to their genetic differences. In agreement with the current result, Tesfalegn (2015) also reported that, Adama Red had higher leaf length than Melkam and Bombay Red. In contrary, Yemane *et al.*, (2014) reported higher leaf length for Adama Red compared to Bombay Red and Melkam varieties.

In this study, the longest leaf (51.3 cm) was observed in plants spaced with 10 cm followed by plants at spacing of 6 cm (48.1 cm) with no significant difference between them. Even though no significant difference statistically among intra-row spacing of 6 cm, 14 cm and 18 cm in terms of leaf length, numerical value differences were observed (Table 3). The longer leaves produced at 10 cm intra-row spacing might be due to proper utilization available growing space. On the other hand, closer and wider intra-row spacing influenced leaf length in the same manner. Similar results were reported by Ghafoor *et al*., (2003) and Khan *et al*., (2003) in which that 10 cm intra-row spacing produced higher leaf length in various onion varieties. Yemane *et al*., (2014) and Sara *et al.*, (2015) also reported that maximum leaf length was produced from 10 cm intra-row spacing.

4.1.3. Leaf number per plant

The leaf number per plant was highly significantly ($p \leq 0.001$) different among onion varieties, as well as significantly ($p \leq 0.01$) affected by intra-row spacing. However, the interaction effect of the two factors had no significant effect on leaf number per plant (Appendix Table 2).

Independent of the intra-row spacing, maximum number of leaves per plant (13) was obtained from Bombay Red which was significantly different from Melkam (11.8) and Adama Red (9.9)

(Table 3). The difference of onion varieties in leaf number per plant could relate to their inherent genetic differences. Similarly, some authors such as Muhammad and Abdul (2003); Islam *et al.*, (2007); Muhammad *et al.*, (2009); Smaranika and Joydip (2014); Tibebu *et al.*, (2014) and Abo *et al*., (2016) confirmed the existence of significant difference among onion varieties in terms of number of leaves per plant.

Without considering the varietal differences, the maximum number of onion leaves per plant (12.3) was recorded from onion plants planted at 10 cm intra-row spacing which was statistically in par with 6 cm intra-row spacing. However, it was significantly different from the 14 cm (11.6) and 18 cm (10.7) intra-row spacing (Table 3). This result is in agreement with that of Yemane *et al.*, (2014) who reported higher leaf number produced from the plant spaced at 10 cm intra-row spacing. Similarly, Mesbaul (2007); Muhammad *et al*., (2009) and Derajew (2014) reported the existence of significant difference among intra-row spacing in leaf number per plant of onion.

4.1.4. Leaf area index (LAI)

The analysis of variance revealed that there was highly significant ($P \leq 0.001$) difference among onion varieties in leaf area index as well as significantly ($p \leq 0.01$) influenced by intra-row spacing. However, the two factors do not interact to influence this (Appendix Table 2).

The highest leaf area index was obtained from Bombay Red and Melkam onion varieties whereas the lowest from Adama Red (Table 3). This is in agreement with Nasir (2007) and Sara (2015) who observed a significant variation of LAI among onion varieties. They further indicated that any factor decreasing the leaf area such as diseases, pests and low plant population contribute to a lower yield of poor quality bulbs.

In the current study, the maximum leaf area index was obtained from 6 and 10 cm intra-row spacing, while the minimum was from 14 and 18 cm intra-row spacing (Table 3). The increase in LAI at the closer (6 and 10 cm) intra-row spacing could be due to more coverage of onion canopy at the closer than wider spacing. Rana and Rana, (2013) showed the increase in LAI at the narrower spacing than wider spacing and consequently the increase in rate of dry matter accumulation, to be proportional to rate of dry matter accumulation per unit leaf area. Further they explained during the phase of development, an increase in leaf area leads to an increase in rate of dry matter accumulation and an increase in dry matter accumulation leads to an increase in leaf area.

Table 3. Effect of intra-row spacing and onion varieties on growth parameters of the study conducted in 2015/16 at Mizan-Aman

Treatment	Plant height (cm)	Leaf length (cm)	Leaf number per plant	LAI
Variety				
Adama Red	45.3^{c}	40.2^{c}	9.9^{c}	0.6^{b}
Bombay Red	63.5^{a}	53.6^{a}	13.0^{a}	1.0^{a}
Melkam	56.1^{b}	48.3^{b}	11.8^{b}	0.9^{a}
LSD ($_{0.05}$)	4.2	3.98	0.55	0.17
Intra-row spacing (cm)				
6	55.2^{ab}	48.1^{ab}	11.8^{ab}	1.0^{a}
10	59.6^{a}	51.3^{a}	12.3^{a}	0.9^{a}
14	54.4^{b}	45.6^{b}	11.6^{b}	0.7^{b}
18	50.8^{b}	44.2^{b}	10.7^{c}	0.6^{b}
LSD ($_{0.05}$)	4.9	4.6	0.6	0.19
CV (%)	9.11	9.94	5.62	7.8

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% level of significance.

4.2. Days to maturity

The main factors of variety and intra-row spacing significantly ($p \leq 0.001$) influenced days to maturity. However, the interaction effect of the two factors was not significant to influence this parameter (Appendix Table 2). Bombay Red matured significantly earlier (107.8 days) than Adama Red (115.6 days), while Melkam matured even later (123.4 days) than both varieties

(Table 4). The result indicated that Bombay Red was the earliest variety, which matured at about 16 and 8 days earlier than Melkam and Adama Red respectively. The variation of days to maturity among the onion varieties is likely to be due to the differences in their inherent genetic makeup. The current finding was in agreement with results of Yemane *et al.,* (2014) and Tesfalegn (2015) who reported that Bombay Red was the earliest matured variety than Adama Red and Melkam onion varieties. Similarly, the finding is inconformity with EARO (2004) that reported Bombay Red matured within less than 120 days, Adama Red and Melkam were matured between 110 to 130 days which was recommended nationally. Abdur *et al.,* (2015) also reported that there was significant difference among onion varieties in days to maturity.

In the current study, time to maturity increased with the increasing in intra-row spacing, in which plants grown at wider spacing (18 cm) took more days to mature than closer intra-row spacing (6 cm) (Table 4). This might be due to less competition among plants for growth resources at wider intra-row spacing which increases the period of vegetative growth, whereas the closer spacing between plants may intensify the competition and force plants to mature earlier. Moreover, growth resource demand is usually higher in densely populated plant, mainly due to high competition for nutrient, light and water, resulting in faster growth than sparsely populated plants. Some authors (Derajew, 2014; Guesh, 2015; Tesfalegn, 2015 and Weldemariam *et al*., 2015) also indicated that, maturity days of onion plant were delayed in wider intra-row than narrower intra-row spacing. Similarly, Sara *et al.,* (2015) also reported that the closer intra-row spacing enhanced maturity by about 112.6 days, while the wider intra-row spacing showed slightly delayed maturity of 121 days.

Table 4. Effect of intra-row spacing and onion varieties on days to maturity of the study conducted in 2015/16 at Mizan-Aman

Treatment	Days to maturity
Variety	
Adama Red	115.6^{b}
Bombay Red	107.8^{c}
Melkam	123.4^{a}
LSD (0.05)	1.3
Intra-row spacing (cm)	
6	112.9^{d}
10	114.4^{c}
14	116.4^{b}
18	118.6^{a}
LSD (0.05)	1.5
CV (%)	1.32

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% level of significance.

4.3. Yield and Yield Components

4.3.1. Total bulb yield (t ha^{-1})

The main effect of variety and intra-row plant spacing as well as interaction significantly (P≤0.001) influenced the onion bulb yield (Appendix Table 3). This might be due to different onion varieties vary in their yielding potential, because of their genetic makeup.

The highest total bulb yield (29.75 t ha^{-1}) was produced, when Bombay Red variety was planted at 10 cm followed by 6 cm intra-row spacing (26.45 t ha^{-1}) while Adama Red planted at 18 cm intra-row spacing produced the least (17.01 t ha^{-1}) bulb yield (Table 5). Additionally, the differences in onion varieties responses to different intra-row spacings could be in differential ability to transform accumulated biomass to bulb production under different intensities of interplant competition. Similarly, Khan *et al*., (2002) and Ehizogie *et al*., (2015 indicated that different cultivars of onion were responded to different intra-row spacing in terms of total bulb yield per hectare. This is also in agreement with the findings of Geremew *et al*., (2010) who reported maximum total bulb yield from variety Bombay Red when planted at 4 cm intra-row spacing followed by 10 cm spacing, while the lowest bulb yield was from Adama Red variety when planted at 10 cm and 8 cm intra-row spacing. According to Attallah *et al*., (2012) the highest total bulb yield was obtained when onion crops were grown under closer spacing, whereas the lowest was from wider spacing.

4.3.3. Unmarketable bulb yield (t ha^{-1})

The main effect of intra-row spacing, and variety on unmarketable bulb yield showed very significant ($p \leq 0.001$) difference, similarly the interaction of the two factors significantly ($p \leq 0.05$) influenced the unmarketable bulb yield (Appendix Table 3). This result is in line with the study report of Muhammed *et al*., (2009) which revealed that unmarketable bulb yield could be affected by both varietal differences and intra-row spacing.

In the current study, higher unmarketable bulb yields were produced, from variety Adama Red (1.5 t ha^{-1}) followed by Melkam (1.42 t ha^{-1}), both planted with 6 cm intra-row spacing, while the lowest unmarketable bulb yield was recorded when Bombay Red was planted at all the four spacing (Table 5). High unmarketable yield in Adama Red and Melkam at closely (6 cm) spaced plants could be due to inter-plant competition resulted in a fewer large sized bulbs than wider spacings that favored the production of small sized bulbs which are unmarketable. In the study area, Adama Red and Melkam were appeared relatively less tolerant to narrower intra-row spacing. Results of the current study are in agreement with the finding of Geremew *et al.*, (2010) who reported that unmarketable bulb yield of onion is affected by the interaction between variety and intra-row spacing. They further indicated highest unmarketable bulb yield from variety Adama Red planted at 5 cm intra-row spacing. Similarly, Yemane *et al*., (2013) reported there was higher unmarketable bulb yield of Adama Red at closer spaced plants. This result is also in agreement with Tendaj (2005) who reported that an increase in intra-row spacing of onion from 5 to 20 cm resulted in reduction of total yield from 36.0 t ha^{-1} to 23.9 t ha^{-1} but the majority of the bulbs are undersized and then unmarketable in case of 5 cm intra-row spacing.

Table 5. Interaction effects of intra-row spacing and onion varieties on bulb yield in 2015/16 at Mizan-Aman

Treatment		Total bulb yield (t ha^{-1})	Unmarketable bulb yield (t ha^{-1})
Variety	***Intra-row spacing (cm)***		
Adama Red	6	18.70^{i}	1.50^{a}
	10	18.00^{j}	0.97^{bc}
	14	17.48^{k}	1.02^{b}
	18	17.01^{l}	0.67^{c}
Bombay Red	6	26.45^{b}	0.32^{d}
	10	29.75^{a}	0.18^{d}
	14	21.62^{g}	0.12^{d}
	18	20.75^{h}	0.08^{d}
Melkam	6	25.45^{c}	1.42^{a}
	10	24.88^{d}	0.88b^{c}
	14	23.74^{e}	0.17^{d}
	18	22.86^{f}	0.16^{d}
LSD ($_{0.05}$)		0.07	0.04
CV (%)		7.46	19.9

LSD (5%) = Least significant difference at P = 0.05, Means with the same letter(s) within a column are not significantly different at 5% level of significance.

4.3.4. Bulb dry matter (t ha^{-1})

Bulb dry matter in this study was significantly ($p \leq 0.001$) different among onion varieties, while intra-row spacing and the interaction of the two factors showed insignificant difference on the parameter (Appendix Table 3).

The maximum bulb dry matter (4.3 t ha^{-1}) was attained from variety Bombay Red followed by Melkam (3.3 t ha^{-1}) and Adama Red (2.1 t ha^{-1}) all significantly differing from each other (Table 6). This could be due to the existence of genetic variability among onion varieties. In agreement to the current finding Geremew *et al*., (2010) showed that the highest bulb dry matter was obtained from Bombay Red, while the minimum was from Adama Red. Similarly, Dereje (2012) also reported that onion varieties are significantly different from each other in terms of bulb dry matter per hectare. Onion dry matter content is a function of genetic makeup of varieties (Islam *et al*., 2007). Tibebu *et al*., (2014) reported the lowest mean bulb dry matter was obtained from Adama Red which was significantly lower than Bombay Red.

Table 6. Effect of intra-row spacing and onion varieties on bulb dry matter of the study conducted in 2015/16 at Mizan-Aman

Treatment	**Bulb dry matter (t ha^{-1})**
Variety	
Adama Red	2.1^{c}
Bombay Red	4.3^{a}
Melkam	3.3^{b}
LSD (0.05)	0.1
Intra-row spacing (cm)	
6	3.2
10	3.3
14	3.2
18	3.2
LSD (0.05)	Ns
CV (%)	3.8

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% level of significance.

4.4. Bulb Quality parameter

4.4.1. Marketable bulb yield (t ha^{-1})

In this study the main effect of variety and intra-row spacing as well as interaction of the two factors very significantly ($p \leq 0.001$) influenced marketable onion bulb yield (Appendix Table 3). The highest marketable bulb yield (29.57 t ha^{-1}) was produced, when Bombay Red variety was planted with 10 cm followed by 6 cm intra-row spacing (26.13 t ha^{-1}) (Table 7). The increase in marketable bulb yield of Bombay Red at narrower (6 and 10 cm) intra-row spacing might be due to maximum plant height and more leaf number per plant. Moreover, the plants grown under narrower intra-row spacing produced more bulb yield which could be due to the higher number of plant per unit land area and photosynthetic active radiation capture ratio could be increased as population density increases and play important role in marketable bulb yield increment. Thus, the marketable bulb yield of onion does not only dependent on the performance of individual plants, but also related with the total number of plants per unit area. The study report of Mattera *et al.,* (2013) also showed that, at closer spacing, photosynthetic active radiation capture ratio increased which ultimately increased marketable bulb yield. That is why as bulbing begins, the photosynthetic efficiency of the larger leaves produced at narrower spacing increased to meet their own demand as well as the growing bulbs which resulted higher yield. Similar results were reported by Geremew *et al.,* (2010) in which marketable yield was significantly affected by both varietal difference and plant density, where the maximum marketable bulb yield was obtained from Bombay Red planted with 4 cm followed by 6 cm intra-row spacing, while the least from Adama Red planted with 8 cm and 10 cm spacing. In the study of Attallah *et al*., (2012) the highest marketable yield was also obtained from onion grown at closer intra-row spacing.

4.4.2. Percentage of marketable bulb yield

In this study the percentage of marketable bulb yield was differently obtained among onion varieties as well as among intra-row spacing. The maximum percentage of marketable bulb yield was attained by Bombay Red than Adama Red and Melkam (Fig. 2). This is likely to be due to the highest growth performance of Bombay Red in the study area which result the highest percentage of marketable bulb. The highest percentage of marketable bulb yield was attained at 10 cm intra-row spacing while the lowest was from 6 cm intra-row spacing (Fig. 3). This could be due to 10cm intra-row spacing superiority over the rest intra-row spacing.

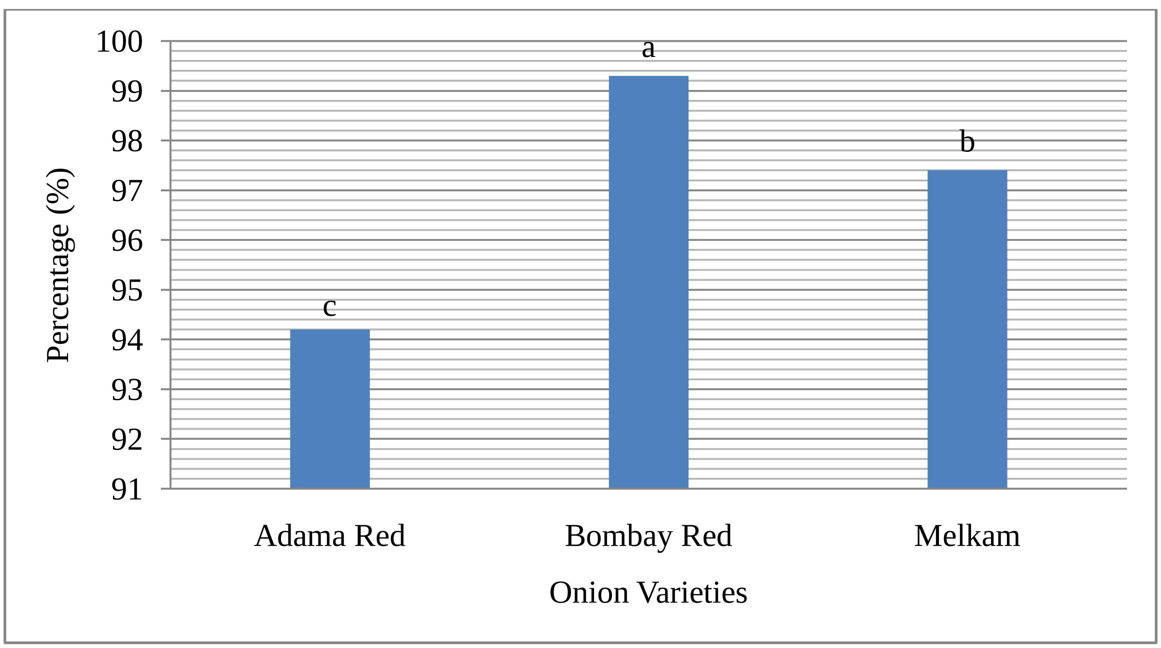

Figure 2. Percentage of marketable bulb yield due to onion varieties

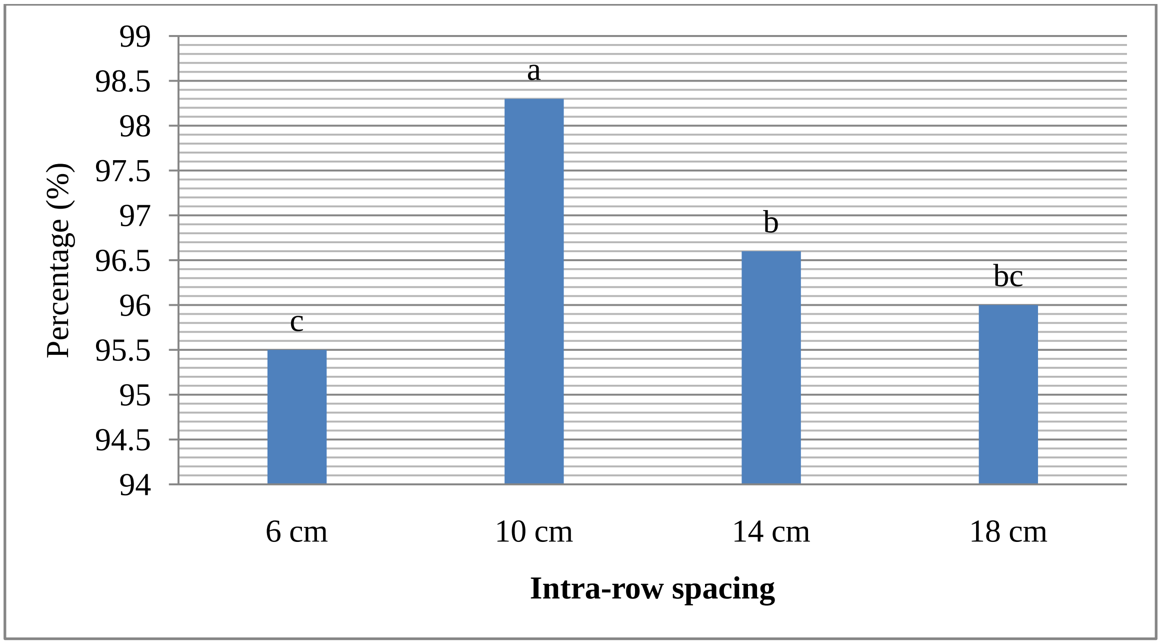

Figure 3. Percentage of marketable bulb yield due to intra-row spacing

4.4.3. Bulb diameter (cm)

The data analysis of this study revealed that, both variety and intra-row spacing had very significant ($P \leq 0.001$) effect on bulb diameter. Similarly, variety and intra-row spacing interacted significantly ($p \leq 0.01$) to influence this parameter (Appendix Table 4).

The highest bulb diameter (7.6 cm) was produced when Bombay Red planted at 18 cm intra-row spacing followed by the same variety at 14 cm and Melkam (6.5 cm) planted at 18 cm intra-row spacing (Table 7). This could be due to the differences in intra-row spacing enhanced plant-plant variation in terms of accumulated biomass and this event affected the stability of dry matter partitioning to bulbs. This is also likely due to the existence of less competition for nutrients and moisture at wider intra-row spacing that resulted in bulbs with bigger diameter. It could also be the availability of nutrient in wider intra-row spacing which stimulates plant growth and thus increases bulb diameter. Especially, competition for moisture is greater in narrower intra-row spacing and reduces bulb puffiness. Similarly, Geremew *et al*., (2010) reported highest bulb diameter from Bombay Red followed by Adama Red varieties both planted with wider intra-row spacing, while the least bulb diameter when Adama Red was planted with narrower intra-row spacing. Attallah *et al*., (2012) indicated an increase in bulb diameter along with increasing plant spacing in which, densely planted onions gave the smallest bulb diameter, whereas onions that grow at low density gave the highest bulb diameter. A significant decrease in bulb diameter was observed with increased plant population (Muhammad *et al*., 2009). Similar results were reported by Mohanty *et al*., (2002); Sarada *et al*., (2009) and Dwivedi *et al*., (2012) under different climatic conditions with different onion varieties.

Table 7. Interaction effects of intra-row spacing and onion varieties on marketable bulb yield and bulb diameter in 2015/16 at Mizan-Aman

Treatment		**Bulb diameter (cm)**	**Marketable bulb yield (t ha^{-1})**
Variety	***Intra-row spacing (cm)***		
Adama Red	6	3.9^{f}	17.2^{h}
	10	4.5^{ef}	17.03^{h}
	14	4.5^{e}	16.46^{i}
	18	4.8^{de}	16.33^{i}
Bombay Red	6	5.1^{d}	26.13^{b}
	10	5.9^{c}	29.57^{a}
	14	6.5^{b}	21.5^{f}
	18	7.6^{a}	20.67^{g}
Melkam	6	4.5^{de}	24.03^{c}
	10	5.9^{c}	24.0^{c}
	14	6.1^{bc}	23.57^{d}
	18	6.5^{b}	22.7^{f}
LSD($_{0.05}$)		0.113	0.06
CV (%)		6.13	8.09

LSD (5%) = Least significant difference at P = 0.05, Means with the same letter(s) within a column are not significantly different at 5% level of significance.

4.4.4. Bulb length (cm)

In the current study, bulb length was significantly ($P \leq 0.001$) affected by intra-row spacing and variety independently but not by the interaction of the two factors (Appendix 4).

In the current study, the maximum bulb length (5.6 cm) was also obtained from Bombay Red variety followed by Melkam (4.8 cm) and Adama Red (4.1 cm) which were significantly different from each other (Table 8). This might be due to vigours vegetative growth of Bombay Red which resulted in longer bulbs. Moreover, the differences among onion varieties in bulb length could be due to their genetic difference. However, Kahsay *et al.,* (2013) reported significantly highest bulb length from Melkam variety although, not statistically different from Adama Red variety, while Bombay Red variety recorded the lowest bulb length. The difference in the result of current finding and Kahsay *et al*., (2013) could be due to environmental difference in which the crop was grown. Similarly, Islam *et al.*, (2007) indicated that there was significant difference among onion cultivars in bulb length.

Bulb length increased as intra-row spacing increased from 6 to 18 cm, and thus the longest bulb was attained from 18 cm intra-row spacing. The increase in bulb length as the intra-row spacing increased from 6 to 18 cm that the increased bulb length was ranged from about 4 to 22% (Table 8). In this study, as intra-row spacing decreased so did the onion bulb length. This might be due to the competition of plants for nutrients, light and moisture at narrow spacing which did not allow the bulbs to have more assimilates available for storage and thus resulted in smaller bulb length. Accordingly, lack of available space and competition for light could account for the decrease in bulb length from denser population. Tesfalegn (2015) also reported significantly (18%) longer bulbs from plants with 10 cm spacing, as compared with the smallest recorded from plants spaced with 4 cm. Yemane *et al.,* (2013) and Derajew, (2014) also indicated the highest bulb length from the wider intra-row spacing and the lowest from narrower intra-row spacing.

4.4.5. Bulb dry matter (%)

Bulb dry matter in this study was significantly ($p \leq 0.001$) different among onion varieties, while intra-row spacing and the interaction of the two factors showed insignificant difference on the parameter (Appendix Table 4).

The maximum bulb dry matter (15.6%) was attained from variety Bombay Red followed by Melkam (13.7%) and Adama Red (11.5%) all significantly differing from each other (Table 8). This could be due to the existence of genetic variability among onion varieties. In contrary, Yemane *et al.,* (2013) recorded the lowest percentage of bulb dry matter from Bombay Red variety and the highest from Adama Red that significantly differs from Melkam and Bombay varieties. This could be associated with the differential performance of cultivars under different agro-climatic conditions (Jilani and Ghaffoor, 2003).

4.4.6. Bulb neck thickness (cm)

A significant ($p \leq 0.01$) variation in bulb neck thickness (cm) was observed among different onion varieties, whereas the differences among intra-rows and the interaction of the two factors were insignificant (Appendix Table 4).

The maximum neck thickness (1.8 cm) was measured from Bombay Red variety which was significantly different from Melkam and Adama Red which had statistically similar (1.6 cm) neck length (Table 8). The variation in bulb neck thickness could be due to differences in genetic makeup of the varieties. This result is in conformity with the findings of Yemane *et al.,* (2013) and Tesfalegn (2015) who reported that onion varieties significantly different from one another in bulb neck thickness. Similarly, Mohanty and Prusti (2001) and Muhammad *et al*., (2004) also reported that significant bulb neck thickness difference among onion varieties.

Table 8. Effect of intra-row spacing and onion varieties on some bulb quality parameters in 2015/16 at Mizan-Aman

Treatment	**Bulb length (cm)**	**Bulb neck thickness (cm)**	**Bulb dry matter (%)**
Variety			
Adama Red	4.1^{c}	1.6^{b}	11.5^{c}
Bombay Red	5.6^{a}	1.8^{a}	15.6^{a}
Melkam	4.8^{b}	1.6^{b}	13.7^{b}
LSD ($_{0.05}$)	0.29	0.07	0.31
Intra-row spacing (cm)			
6	4.2^{c}	1.7	13.4
10	4.8^{b}	1.8	13.7
14	5.0^{b}	1.7	13.6
18	5.4^{a}	1.6	13.7
LSD ($_{0.05}$)	0.34	NS	Ns
CV (%)	7.11	5.05	2.71

Ns = non-significant at 0.05 probability level, 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% level of significance.

4.5. Correlation analysis

In the current study, correlation coefficient (r) values calculated to determine the association between growth parameters and bulb yield evidently indicated the magnitude and directions of the relationships (Table 9). The result shows that total bulb yield was significantly ($p \leq 0.001$) and positively correlated with plant height, leaf number per plant, leaf length, and bulb dry matter. This indicates that, an increase in plant height, leaf number per plant, leaf length and leaf area index (LAI) of onion, increase the total bulb yield, because as leaf number per plant increases the photosynthetic capacity is also enhanced and increases crop yield. In agreement to this finding, some authors such as; Islam *et al*., (2007); Negash *et al*., (2009); Derajew (2014) and Kushal *et al*., (2015) reported positive and significant correlation of yield to plant height, leaf number per plant, leaf length and bulb dry matter

Table 9. Simple correlation between onion growth parameters and bulb yield in the study conducted in 2015/16 at Mizan-Aman

Variables	LN	PH	LL	BD	BL	MBY	TBY
LN	1						
PH	0.77***	1					
LL	0.73***	0.97***	1				
BD	0.46**	0.44**	0.38*	1			
BL	0.51**	0.44**	0.38*	0.94***	1		
MBY	0.81***	0.73***	0.71***	0.39*	0.41*	1	
TBY	79***	0.71***	0.69***	0.3^{Ns}	0.32^{Ns}	0.99***	1

*, ** and *** Indicates that significant, highly significant and very highly significant difference at probability levels of 5%,1% and 0.1% respectively, Ns = non significant and LN =Leaf number, PH = Plant height (cm), LL = Leaf length (cm), BD = Bulb diameter (cm), BL= Bulb length (cm), MBY = Marketable bulb yield and TBY = Total bulb yield

The result also indicated that, leaf number was significantly and positively correlated with total yield (r=0.79***), plant height (r=0.77***), bulb length (r=0.51**), bulb diameter (r = 0.46**), and leaf length (r= 0.73***) (Table 9). This association shows that, an increase photosynthetic leaves in relation to variety and intra-row spacing had clearly contributed for an increase in onion bulb yield.

5. SUMMARY AND CONCLUSION

Onion is one of the widely cultivated crops in Ethiopia and is popular vegetable crop by producers and consumers. Although onion is produced for home consumption and as a cash crop in Mizan-Aman area its production constrained by lack of improved varieties and inappropriate production practices are. This study was therefore conducted at farm site of Mizan ATVET College to investigate the effect of intra-row spacing on growth performance and yield of three onion varieties. The experiment was laid out in randomized complete block design with three replications in factorial arrangement maintaining constant inter-row spacing of 20cm. All agronomic practices were carried out as recommended for onion production.

Data were collected and analyzed for days to maturity, growth parameters, yield and yield components. The results of the study showed the existence of significant effect of variety on all the parameters considered and intra-row spacing on all parameters except bulb dry matter. The interaction of variety and intra-row spacing indicated significant effect on bulb diameter, total bulb yield, marketable and unmarketable bulb yield.

From the three onion varieties Bombay Red matured earlier with 107 days than Adama Red and Melkam onion varieties. Days to maturity also increased as the intra-row spacing increased, in which plants spaced at 6 cm matured earlier by about six days than plants spaced at 18 cm. Larger bulb diameter was measured from variety Bombay Red followed by Melkam when both were planted with 18 cm intra-row spacing, while the smallest from Adama Red variety planted with 6 cm intra-row spacing. Bombay Red had also higher bulb dry matter than Melkam and

Adama Red varieties. Moreover, when intra-row spacing increased from 6 cm to 18 cm, plant height and leaf length decreased by 7.9% and 8% respectively. Higher bulb length (5.4 cm) was also recorded from 18 cm intra-row spacing, while lower bulb length (4.2 cm) in 6 cm. Most of these parameters had positive and significant correlations with total and marketable bulb yields except bulb diameter and bulb length which were positively correlated, but not significant. The highest total and marketable bulb yield (t/ha) was attained when Bombay Red variety was planted at 10 cm followed by Bombay Red planted at 6 cm intra-row spacing, whereas the highest unmarketable bulb yield was scored from Adama Red planted at 6 cm intra-row spacing.

The result of this study revealed that, Bombay Red performed better and gave the highest marketable bulb yield than the other varieties in the study area. Therefore, onion variety Bombay Red with 10 cm intra-row spacing has been found to be potential candidate for recommendation for Mizan-Aman condition to attain higher yield with better quality. However, the experiment has to be further verified with additional agricultural inputs and agronomic practices for final recommendation.

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7. APPENDICES

Appendix Table 1. Physical and chemical properties of soil of the experimental site at Mizan-Aman in 2015/16

Soil properties	**Value**
Physical properties	
Clay (%)	44
Sand (%)	30
Silt (%)	26
Chemical properties	
OC (%)	2.27
PH	5.7
EC (ms/Cm)	0.10
CEC (meq/100g)	37.50

OC – Organic carbon, EC – Electrical conductivity and CEC – Cation exchange capacity

Appendix Table 2. Mean squares from ANOVA for days to maturity and growth parameter of onion of the study conducted in 2015/16 at Mizan-Aman

Source of variation	DF	Mean square values				
		DM	PH	LL	LN	LAI
Variety (A)	2	736.33***	1005.47***	545.44***	29.08***	0.47***
Intra-row spacing (B)	3	54.4***	117.3*	87.15*	4.32**	0.3**
AXB	6	3.48^{ns}	22.71^{ns}	11.53^{ns}	0.27^{ns}	0.01
Error	22	2.36	25.12	22.13	0.42	0.04
CV (%)		1.33	9.11	9.94	5.62	7.8

*, ** and ***, significant at P< 5%, P< 1% and p< 0.1% respectively and ns = non significant, DF = degree of freedom, CV (%) = coefficient of variation in percent, DM = days to maturity, PH= Plant height (cm), LL= Leaf length (cm), LN = Leaf number/plant and LAI = Leaf area index.

Appendix Table 3. Mean squares from ANOVA for yield and yield component of onion of the study conducted in 2015/16 at Mizan-Aman

Source of variation	**Mean square values**				
	DF	**TBY**	**MBY**	**UMBY**	**BDM (t ha^{-1})**
Variety (A)	2	176.81***	213.36***	2.26***	14.99***
Intra-row spacing (B)	3	34.102***	25.64***	1.04***	0.03^{ns}
AXB	6	12.58***	14.04***	0.23**	0.03^{ns}
Error	22	0.065	0.06	0.04	0.02
CV (%)		7.46	8.09	19.9	3.8

*, ** and ***, significant at P< 5%, P< 1% and p< 0.1% respectively and ns = non significant, DF = degree of freedom, CV (%) = coefficient of variation in percent, TBY= Total bulb yield (t/ha), MBY = Marketable bulb yield (t/ha), UMBY = Unmarketable bulb yield (t/ha) and BDM = Bulb dry matter (%)

Appendix Table 4. Mean squares from ANOVA for bulb quality parameter of the study conducted in 2015/16 at Mizan-Aman

		Mean square values			
Source of variation	DF	BD	BL	BDM (%)	BNT
Variety (A)	2	11.052***	6.895***	50.46***	0.053**
Intra-row spacing (B)	3	4.953***	2.224***	0.14^{ns}	0.02^{ns}
AXB	6	0.512**	0.187^{ns}	0.09^{ns}	0.013^{ns}
Error	22	0.113	0.118	0.14	0.007
CV (%)		6.13	7.11	2.71	5.05

*, ** and ***, significant at P< 5%, P< 1% and p< 0.1% respectively and ns = non significant, DF = degree of freedom, CV (%) = coefficient of variation in percent, BD= bulb diameter (cm), BL = Bulb length (cm) and BNT=Bulb neck thickness (cm).

8. SKETCH OF BIOGRAPHY

Diro Buzayo Tolessa was born on August 7, 1990 in Gindeberet, West Shewa zone of Oromia region. He attended his elementary school at Haro, secondary and preparatory at Gindeberet High School and preparatory school.

After passing the Ethiopian Higher Education Entrance (EHEE), the author joined Wollega University, College of Agriculture in 2009 and graduated with Bsc. degree in Plant Science on June 25/2011. Right after graduation, he was employed by Ministry of Agriculture (MoA), Agricultural Technical Vocational Educational Training (ATVET) coordination at Mizan ATVET College as junior instructor. After two year of service in the College he joined Hawassa University, School of Graduate Studies in 2014 to pursue his MSc. degree studies in Agronomy.