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Full Length Research Paper

Growth and survival rate of endemic trees of Ethiopia: *Olea africana* and *Hagenia abysinicca* in Lake Haramaya Watershed, Eastern Ethiopia

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The study was conducted to explore the growth and survival rate of the native tree species of Ethiopia, *Olea africana* and *Hagenia abysinicca* in Lake Haramaya Watershed, Eastern Ethiopia. Three sub watersheds of Lake Haramaya Watershed, namely, Bachake, Damota, and Tinike were selected purposefully on the basis of their extreme degradation and nearby vanished Lake Haramaya. In each sub watersheds, a total of about 12 main standard quadrats have been applied and the required data has been recorded. The result of the study indicated that *O. africana* performs well at Damota sub watershed, accounting 38% of survival rate followed by Tinike sub watershed having a survival rate of 37%. Only 29% of the total planted *O. africana* were survived at Bachake sub watershed. Furthermore, it has been revealed via this study that about 55.6% of *H. abysinicca* survived at Damota sub watershed. Comparing the survival rate of the two species, *H. abysinicca* better withstand and grow under an extreme pressure of local peoples intervention at all sub watersheds. Therefore, the study shows that growing and maintaining of these two endemic trees in all sub watersheds were difficult task unless much awareness will be made. Lastly, the study encourages mega projects on growth and survival rate of other native trees species and explores the challenges associated with growing these trees in the study area in specific and in Ethiopia in general.

Key words: Survival rate, endemic trees, sub watershed.

INTRODUCTION

Ethiopia is very known by its heterogeneous higher plant species estimated to be around 6500 to 7000, of which more than 12 to 19% are native (WCMC, 1992; Teketay, 2001; Hurni, 2007; CBD, 2008). This is due to the fact that the country has a wide variety of ecological characteristics associated with ample diversity of plant and animal species (Alemayehu, 2002). However, a number of studies indicated that almost all of the natural vegetation of Ethiopia is under an extreme pressure of anthropogenic threats (Yirdaw, 1996; Million, 2001;

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Tesfaye et al., 2015; Newton and Cantarello, 2015). Given about 85% of the population Ethiopia is living in the rural areas, their livelihood system is either directly or indirectly depended on agriculture, which provides about 52% of the country's GDP (World Bank, 2000; CIA, 2001).

The speedy decline of forest resources in Ethiopia has resulted in reduction of their biodiversity and on the verge of extinction of certain tree species (Tekle and Hedlund, 2000; WRI, 2001; Alemayehu, 2002a). *Olea africana* and *Hagenia abysinicca* are the major endemic tree species mainly found in Ethiopia, basically on the highland areas of the country. Currently, these tree species are under a big threat of human influences. The local name of *O. africana* is *Ejersa* in Afan Oromo and *Weyira* in Amharic. This species is well known by the local people for its traditional medicine preparation, tooth brush and sometimes for charcoal production. Moreover, *Hagenia abysinicca* is locally known as *Muka Heexoo* in Afan Oromo and *Yekoso Zaf* in Amharic and well known for its medicinal value.

The climate of Ethiopia has been changing as a result of global and local effects of vegetation degradation. Loss of forest cover and biodiversity owing to human-induced activities is a growing arena of many parts of the world including our country, Ethiopia (Demissew, 1980). Thus, frequent drought, crop failure and famine are becoming common events in the highlands, like eastern Hararghe which are the symbols of desertification (Demel, 2001).

In line with this, Haramaya University, Ethiopia via Lake Haramaya Watershed project has given deep attention to these endemic trees and grows the seedlings to use them as a main rehabilitation tree of the degraded lands of Lake Haramaya sub watersheds. This is for the sake of maintaining the species into the environment, though it was a challenging task. Therefore, this study was undertaken to explore the growth and survival rate of the endemic tree species of *O. africana* and *H. abysinicca,* so as to put baseline information about the status of the two tree species in the watershed.

MATERIALS AND METHODS

Description of the study area

Lake Haramaya Watershed is located in Haramaya and partly in Kombolcha districts, Eastern Hararghe Zone, Oromia National Region State, and East Ethiopia. The Watershed lies between 9°23´12.27´´- 9°31´9.85´´ N and 41°58´28.02´´- 42°8´h10.26´´ E (UTM Zone 38) (Figure 1) and covers an area of 15,329.96 ha. The elevation ranges from 1800 to 2345 m above sea level.

Information obtained from Ethiopian National Meteorology Agency indicates that the mean annual rainfall and mean maximum and minimum temperatures of Haramaya watershed are 847.9 mm, 24.7°C, and 11.5°C, respectively. The area received bimodal pattern of rainfall (Figure 2).

This study was conducted in particular at Bachake (3 ha), Damota (2.75 ha) and Tinike (3 ha) sub-watersheds, which are among the 28 sub watersheds of Lake Haramaya watershed. The reason for choosing the three of the sub-watersheds were due to their presence under the extreme pressure of anthropogenic factors; local communities were using these lands as a common grazing lands, expansion of agriculture to plant cash crops like *Khat* (*Catha edulis*) and to lesser extent coffee (*Coffee arabica*). Generally, many socio-economic activities were well notified as per the preliminary field observation of this study and key informant informal interview (not presented in this paper). Furthermore, of the 28 sub-watersheds, three of them are very nearby vanished Lake Haramaya, (on average 5 km away from the lake).

Seedlings preparation techniques

Seedling preparation has been conducted at Rare Nursery site, Haramaya University, Ethiopia. In the processes of seedlings preparation, forest soil, compost /farm yard manure, sand, and local top soil were used by mixing all the substrates at different ratios. The most used ratio is 3 local top soils: 2 forest soil/compost/farm yard manure: 1 sand (Figure 3). The mixed up media were added into a pot having a diameter size of 8 cm to support the sown seeds. Most potting mixes were soilless to avoid soil borne diseases and promote good drainage and suitable environment with sufficient water-holding capacity, nutrient content, and aeration for plant growth and development. Therefore, the pot-planted seedlings stayed on nursery site for at least six months begging from their planting time and all the required management were undertaken till plantation time. Then after, the seedlings of both *O. africana* and *H. abysinicca* were taken to the field via tractor-vehicle used for transportation of seedlings. The height of *O. africana* at the time of planting was estimated to be 35 cm and that of *H. abysinicca* was estimated to be about 45 cm, just the height above the ground.

Site preparation techniques for plantation

All the selected sub watersheds have been delineated and to lesser extent area closure has been done accordingly, though not effective. Additionally, physical soil and water conservation structures have been built by the local people with the coordination of Lake Haramaya Watershed Project, early before the main rainy season of Ethiopia (June, July, August, and September). The work of constructing the physical structure was better in Damota sub watershed. Finally, pits having an average depth of 30 cm and width of 40 cm were prepared along the physical structures across the slope within 2 m distance from one another. Majority of the pits were prepared by the respective farmers of the sub watersheds and seedlings plantation campaign was made by the local people in collaboration with Lake Haramaya Watershed Project run under Haramaya University.

Transect establishment, data collection and analysis

For each specific study site (Bachake, Damota, and Tinike), four subplots has been established systematically across the slope, one with its center located at the center of the spoke and the remaining three located at 20.5 m away from the center subplots (Figure 4). Each subplot has a 7.5 m radius. The operation has been multiplied 12 times with same transects size and design for all specific study sites at an interval of 50 m. Therefore, a total of about 12 main quadrats have been laid out for each sub watersheds and the required data has been recorded (Figure 5). Mortality rate and survival rate were calculated for both endemic tree species at all sub watersheds in the study area. The formulas used were (Megan, 2013):

$$\text{Mortality rate} = \frac{\text{Number of samplings recorded dead during a given year}}{\text{Total number of samplings planted in a given year}} \times 100$$

Survival rate = 100 – Mortality rate

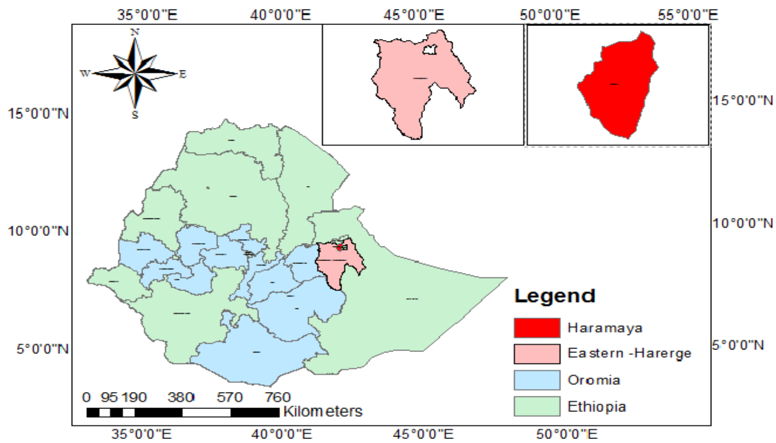

Figure 1. Map of the study area.

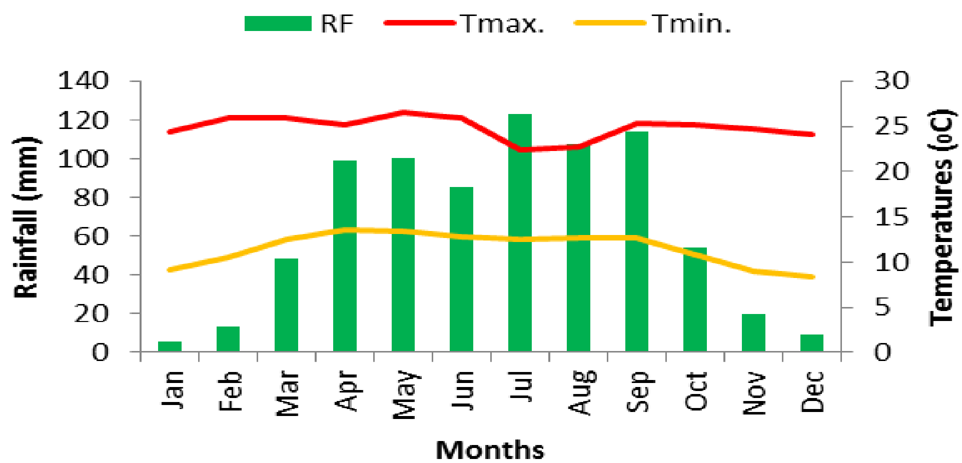

Figure 2. Monthly rainfall and temperature during 1980-2013 in Lake Haramaya Watershed.

Figure 3. Soil types used in pot filling for seedling preparation.

RESULTS AND DISCUSSION

The results of the study depicted that of the transects established at all sub watersheds, *O. africana* performs well at Damota, accounting about 38% of survival rate, followed by Tinike sub watershed having a survival rate of 37%. However, at Bachake sub watershed little survival rate of *O. africana* has been recorded, only 29% (Table 1). The reasons for the variation of survival rate at all sub watersheds were due to high interference of local

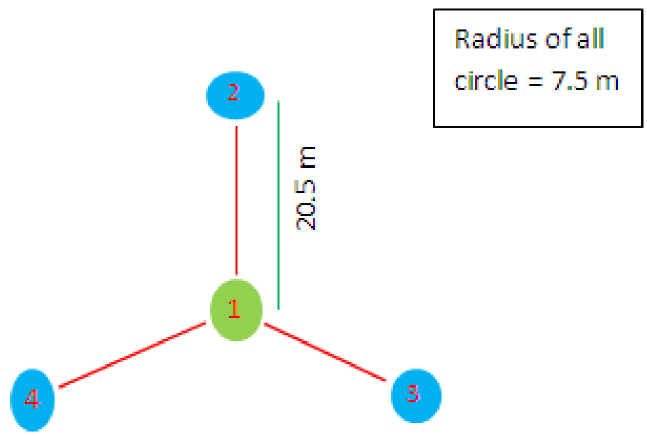

Figure 4. Sample data collection design (USDA Forest Service, 2003; Schulz et al., 2009).

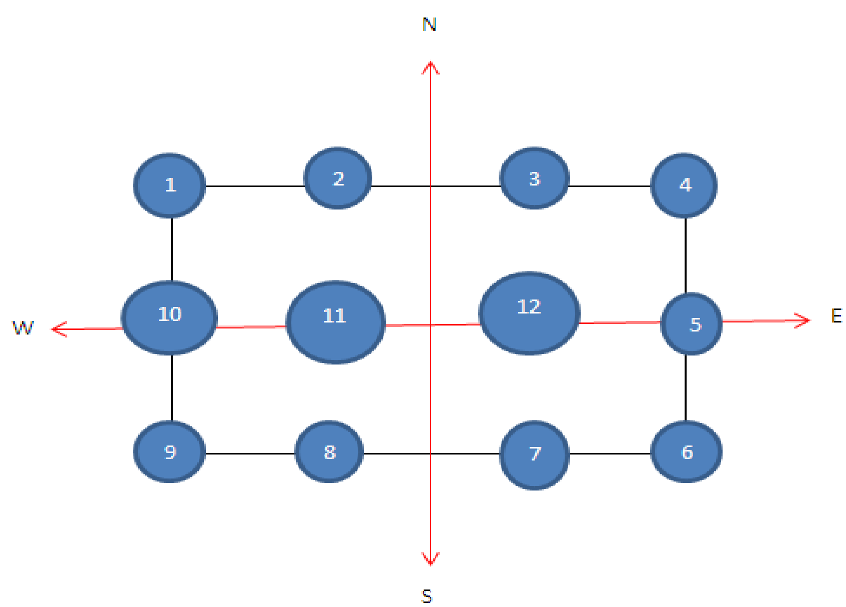

Figure 5. Sampling spot design for each sub watersheds.

Table 1. Total number of seedlings planted, number of saplings dead, mortality and survival rate of *Olea africana* and *Hagenia abysinicca* at Bachake, Damota and Tinike during 2015/2016.

Site	Total tree seedlings planted during 2015/2016	Number of samplings dead	Mortality rate (%)	Survival rate (%)
Olea africana				
Bachake	4500	3200	71.0	29.0
Damota	4700	2900	61.7	38.3
Tinike	4500	2960	63.0	37.0
Hagenia abysinicca				
Bachake	3000	1760	58.7	41.3
Damota	2700	1200	44.4	55.6
Tinike	2500	1320	52.8	47.2

Table 2. Descriptive statistics of number of saplings dead of *Olea africana*.

Site	Qua1	Qua2	Qua3	Qua4	Qua5	Qua6	Qua7	Qua8	Qua9	Qua10	Qua11	Qua12	Mean	Min.	Max.	SDE
Bachake	300	400	266	250	351	240	305	275	294	169	150	200	266.7	150	400	71.90
Damota	277	350	266	230	300	231	235	275	320	169	127	120	241.7	120	350	72.46
Tinike	200	234	342	230	329	231	321	275	248	270	170	110	246.7	110	342	67.53

Table 3. Descriptive statistics of number of saplings dead of *Hagenia abysinicca* at all sub watersheds in all quadrats established.

Site	Qua1	Qua2	Qua3	Qua4	Qua5	Qua6	Qua7	Qua8	Qua9	Qua10	Qua11	Qua12	Mean	Min.	Max.	SDE
Bachake	130	134	218	222	245	17	130	129	190	129	116	100	146.7	17	245	62.9
Damota	100	145	111	100	145	123	123	40	145	100	23	45	100	23	145	42.4
Tinike	200	190	56	100	160	123	90	40	120	100	59	82	110	40	200	51.4

peoples. However, some studies are indicating that conservation and management of plants dominated by farming communities are getting attention nowadays (Garrity and Verchot, 2008; Lemenih and Kassa, 2014). Furthermore, it has been noticed during the study that the perception of local people in all sub watersheds, particularly, in Bachake sub watersheds, towards the growth of considered endemic tree species was so poor though they use these trees for traditional and other purposes (Table 2). Rather, they need to use the lands for free grazing.

Thus, of the total number of seedlings planted during 2015/2016 rainfall season, majority of them have died. Late plantation due to late onset of rainfall and early cessation, poor ways of plantation, little commitment by local people in monitoring after plantation, farmer's preferences of other commercial trees like, *Eucalyptus* species, *Grevillea robust* and fruit trees are also another factor. Soil as a factor of seedlings growth has been kept constant in this particular work. The other negligible challenges of seedlings plantation in this work was those seedlings that died or at risk while transportation for plantation. The aforementioned constraints are similar to those facing the forest development in Ethiopia as noted by Derero et al. (2011) which include: transportation of seedlings, poor seedling quality and inappropriate silviculture, poor research extension linkage and poor coordination in the sector.

On the other hand, the study indicated that of the total *H. abysinicca* planted 3000 seedlings during 2015 rainfall season, about 41% survived at Bachake sub watershed, whereas it was 55.6 and 47.2% for Damota and Tinike sub watersheds, respectively. Comparing the two tree endemic species, *H. abysinicca* performed well at all sub watersheds. This could be due the reason that *H. abysinicca* has a natural ability to withstand and grow under an extreme pressure of human influence. Furthermore, Negash et al. (2012) and Tadesse et al. (2014) suggested that it may be the result of socio-culture, land use and management intensities, and farmers' perceptions on the specified tree in the area that leads the allowance of trees to grow.

Furthermore, Table 2 shows a simple descriptive statistics of number of saplings dead for *O. africana* at all sub watersheds considered for this study. In all quadrats established at all sub watersheds, Bachake sub watershed shows the highest number of samplings dead, about 400 plants. However, the study revealed that the average value for samplings dead at Damota sub watershed was estimated to be lower than the other two sub watersheds, accounting for about 241.7 samplings of the planted 4700 (Table 2). The same pattern has been noticed for *H. abysinicca* where the average samplings dead at Damota sub watershed were less, about 100 samplings followed by Tinike sub watershed which is about 110 samplings (Table 3). The reason for this could be due to a bit commitment of the local people towards the management of the respective sub watersheds.

It has been recognized via this study that of planted samplings of *O. africana* 13700 at all sub watersheds considered in this paper, about 9060 have already died due to many reasons in the areas (Table 4). The average value of dead

Table 4. Descriptive statistics of number of saplings dead at a composite of three sub watersheds of Lake Haramaya watersheds for *Olea africana*.

Site	Qua1	Qua2	Qua3	Qua4	Qua5	Qua6	Qua7	Qua8	Qua9	Qua10	Qua11	Qua12	Total
Bachake	300	400	266	250	351	240	305	275	294	169	150	200	3200
Damota	277	350	266	230	300	231	235	275	320	169	127	120	2900
Tinike	200	234	342	230	329	231	321	275	248	270	170	110	2960
Mean	259	328	291	237	327	234	287	275	287	203	149	143	3020
Min.	200	234	266	230	300	231	235	275	248	169	127	110	2900
Max.	300	400	342	250	351	240	321	275	320	270	170	200	3200
SDE	52.4	85.2	43.9	11.6	25.6	5.2	45.7	0	36.5	58.3	21.5	49.3	158.7
Sum	777	984	874	710	980	702	861	825	862	608	447	430	9060

Table 5. Descriptive statistics of number of saplings dead at a composite of three sub watersheds of Lake Haramaya watersheds for *Hagenia abysinicca*.

Site	Qua1	Qua2	Qua3	Qua4	Qua5	Qua6	Qua7	Qua8	Qua9	Qua10	Qua11	Qua12	Total
Bachake	130	134	218	222	245	17	130	129	190	129	116	100	1760
Damota	100	145	111	100	145	123	123	40	145	100	23	45	1200
Tinike	200	190	56	100	160	123	90	40	120	100	59	82	1320
Mean	143	156	128	141	183	87.7	114	70	152	110	66	76	1427
Min.	100	134	56	100	145	17	90	40	120	100	23	45	1200
Max.	200	190	218	222	245	123	130	129	190	129	116	100	1760
SDE	51	30	82.4	70.4	54	61	21.4	51.4	36	16.7	47	28	294
Sum	430	469	385	422	550	263	343	209	455	329	198	227	4280

samplings of *O. africana* at all sub watersheds has been estimated to be 3020 (Table 4).

Moreover, of the total of the planted samplings at all sub watersheds of *H. abysinicca* 8200, about 4280 samplings were dead. The dead samplings at all sub watersheds considered ranges from 1200 to 1760 to have the mean value of 1427 samplings (Table 5).

CONCLUSION AND RECOMMENDATIONS

It could be generalized from the results of the study that the growth and survival of endemic tree species, *O. africana* and *H. abysinicca* have been widely intervened by the human activities at all sub watersheds. Of three sub watersheds, both trees perform well at Damota, survival about 38 and 55.6% for *O. africana* and *H. abysinicca*, respectively. In contrast, little survival rate for both tree species have been observed at Bachake sub watershed. In line with this, much has to be done on the local communities' awareness creation about the importance of these endemic trees. Training and participatory nursery developments are proven methods of building farmers awareness, leadership and technical skills (Carandang et al., 2006). Efforts by Haramaya University via Lake Haramaya Watershed project to rehabilitate these degraded watershed using endemic trees has been done, however, little attention has been given by Woreda administrative. Therefore, the study encourages strong linkage between the Woreda administrative and University, one to rehabilitate the degraded watersheds, two to maintain such an endemic tree species with the watershed in specific and with the country in general.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Farmyard manure and intra-row spacing on yield and yield components of Adama Red onion (*Allium cepa* L.) cultivar under irrigation in Gewane District, Afar Region, Ethiopia

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A field experiment was conducted at Gewane Agricultural Technical and Vocational Education and Training College in 2012/2013 to assess effect of farmyard manure and intra-row spacing on yield and yield components of Adama Red onion (*Allium cepa* L.) cultivar under irrigation. Factorial combination of four rates of farmyard manure (0, 10, 20 and 30 t ha^{-1}) and four levels of intra-row spacing (7.5, 10, 12.5 and 15 cm) were arranged in randomized complete block design with three replications. Significant effect of intra-row spacing on most of plant growth, bulb yield and bulb characters studied was noticed. Similarly, farmyard manure showed significant effect on mean bulb weight, weight loss, and bulb rotting. The interaction effects of intra-row spacing and farmyard manure rates showed significant influence on biological, total, marketable and unmarketable bulb yields. Highest total bulb yield, 58.74 t ha^{-1} and marketable bulb yields 57.77 t ha^{-1} were obtained from plants spaced at 7.5 cm and plots received 30 t ha^{-1} farm yard manure. The highest weight loss and bulb rotting were observed at wider intra-row spacing (15 cm) and highest farmyard manure application, which was 30 t ha^{-1}. Intra-row spacing of 7.5 cm and 20 t ha^{-1} farmyard manure rate gave good marketable bulb yield and better storage life under the study area.

Key words: Bulb yield; farmyard manure; intra-row spacing; storage life.

INTRODUCTION

Onion (*Allium cepa* L.) is the most common member of the family Alliaceae and the widely grown herbaceous biennial vegetable crop. It is grown mainly for its bulb, which is used in every home, almost daily. As a constituent of a meal, both the green leaves and bulbs can be eaten raw, cooked or in soups and salads (Sani and Jaliya, 1987).

In Ethiopia, the *Alliums* (onion, garlic and shallot) are

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important bulb crops produced for home consumption and are sources of income to many peasant farmers in many parts of the country. Onions have a wide range of climatic and soil adaptation and they are cultivated both under irrigation and rain fed conditions (Tabor and Zeleke, 2000; Rabinowitch and Currah, 2002). The crop is known to be heavy feeder of nutrients mostly supplied from chemical fertilizer which requires high expense and is potentially harmful to human health and environment (Thamburaj, 1991). Therefore, it is imperative to look for cheaper and environment friendly methods of soil fertilization. In this regard, the use of organic fertilizer, as farm yard manure, has currently attracted considerable attention to supply various nutrients to crops. Farm yard manure improves soil permeability to air and water as well as nutrient uptake. This type of fertilizer also supply nutrients, enhance moisture holding capacity and cation exchange capacity (CEC) of the soil and moderates soil pH. They also improve soil bulk density and are beneficial to micro-organism activities (Subedi, 1998). As the source of farm yard manures varied, its contents of plant nutrition also differ as per the types of livestock (cattle, poultry etc).

Plant population is important in onion production since it has an influence on growth, yield and quality of onion bulbs (Brewster, 1994). Optimum inter-row and intra-row spacing (which reduces competition between plants and enables efficient use of available crop land) varies with soil fertility status, soil moisture, the nature of the crop and degree of weed infestation (Singh et al., 1997).

The Upper and Middle Awash Valley Regions of Ethiopia is highly suitable for cash crop such as onion production and marketing (CACC, 2002). However, due to low soil fertility, salinity effect and inappropriate cultural practice the yield is low in the area (MARC, 2004). Farmers adopted spacing of 40 cm wide bed, having two rows in each bed and each row spaced 20 cm apart between rows in a bed and 10 cm between plants in a row. Application of manure rate for different reasons, they did not also adopt recommendations employed elsewhere. There is also lack of site based recommendation on plant spacing and organic fertilizer rate that can help to increase onion production and soil fertility in sustainable way. Therefore, this study was conducted with the objective of assessing the effects of farmyard manure rates and intra-row spacing on yield and yield components of Adama Red onion cultivar.

MATERIALS AND METHODS

An experiment was conducted at Gewane Agricultural Technical and Vocational Training (ATVET) College Demonstration Farm, located in Gewane Woreda (10°10' N and 40°32' E), Afar National Regional State, about 350 km East of the capital city, Addis Ababa at an altitude of about 626 m above sea level (ESRDF, 2003). The experimental area was characterized as semi-arid climatic zone with average annual rainfall of about 400 mm which is erratic and unreliable. The soil was silt clay loam in texture with pH of 8.28 and mean annual temperature of about 32°C with ranges of 44°C, maximum to 17°C, minimum (DPPC, 2000). Adama Red cultivar and well decomposed, aged and dried FYM obtained from cattle was used. The national recommended dose of mineral fertilizer was also being applied to meet the crop demand for optimum yield. Accordingly, 100 kg ha^{-1} Diammonium phosphate (DAP) and 150 kg ha^{-1} urea was applied where half of the urea and all DAP were applied at the time of planting and the rest 50% urea applied 45 days after transplanting.

Factorial combinations of four levels of farmyard manure (0, 10, 20 and 30 t ha^{-1}) and four intra-rows spacing of onion (7.5, 10, 12.5 and 15 cm) were used in a Randomized Complete Block Design (RCBD) with three replications. Gross plot size was 2 m × 3 m (6 m^2) accommodating ten rows. The distance between plots and blocks was 1 m and 2 m apart, respectively. The outer single rows at both sides of the plot and one plant at both ends of the rows were considered as border plants. Internal single rows of the outer double row at both sides of the plot were used for destructive samples (bulb dry mass content). The remaining plants in the six center rows were used as net plot area to determine yield per plot.

Seeds of Adama Red cultivar were sown on prepared seed bed to raise seedlings. Seedlings were transplanted in the field on January 6, 2013 on shoulder of ridges adopting the recommended spacing of 40 cm wide ridges or beds and 20 cm between rows in a bed. Seedlings were grown to height of 12 to 15 cm on the nursery area and then transplanted. Other recommended cultural practices were kept uniform for all treatments. Harvesting of onion bulbs were done on May, 2013 when 70% plants show necrosis of foliage and cured for four days. Curing is drying of onion bulbs using sun light to reduce water content present in it for the purpose of reducing decays.

Data were collected on the following parameters by sampling six plants randomly from six central rows of each plot except days to maturity which was collected on plot basis.

Days to maturity

Days to maturity were the actual number of days from the transplanting to the time when 70% of plants' foliage collapses.

Plant height and leaf length (cm)

Plant height was measured by a ruler in centimeters from the soil surface to the tip of the matured leaf; and leaf lengths were taken from three leaves plant^{-1} at maturity.

Leaf number plant^{-1}

This refers to the mean number of leaves produced by sampled plants. The total number of leaves of sampled plants was counted and divided by the number of plants to get mean leaf numbers plant^{-1}.

Neck thickness (cm)

The average neck thickness was measured at the narrowest point at the junction of bulb and leaf sheath by using verner caliper.

Bulb length and bulb diameter (cm)

The average heights of the matured bulb length and bulb diameter at the widest point in the middle portion of the matured bulb were measured by using vernier caliper.

Mean bulb weight (g)

This is the average weight of matured bulb in grams after harvest and curing. It was measured by sensitive balance.

Bulb dry mass content (%)

For determination of mature bulb dry mass content, a homogenate sample was prepared from sampled plant bulbs from each plot and those samples were chopped down, from which 300 g of the homogenate sample was taken and oven dried at temperature of 70°C to constant weight, the weight was measured using electrical balance and percent of dry matter was calculated using the formula:

$$\text{DMC (\%)} = \frac{((DW+CW)-CW))}{((FW+CW)-CW))} \times 100$$

Where, DMC = dry mass content; CW = container weight; FW = fresh weight.

Biological yield (g)

The biological yield was recorded as the sum of above ground parts and bulb at the time of maturity using a digital balance from the central six rows.

Marketable and unmarketable bulb yield (t ha^{-1})

Marketable bulb yield was determined after discarding bulbs smaller than 3 cm in diameter (Morsy et al., 2012), splitted, rotten, damaged, and discolored after topping and curing of onion crop and those bulbs other than normal and size greater than 3 cm diameter were categorized as unmarketable.

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

It was recorded from central six rows per net plot. The harvested both marketable and unmarketable bulbs yield were weighed after curing and the yield was converted into t ha^{-1}.

Bulb storage life

Cumulative loss in weight, extent of rotting, sprouting and firmness in percent was recorded at interval of two weeks for three months, keeping 60 bulbs from each treatment spread on floor at ambient condition. The storage period was from May 11 to August 8, 2013. The following were some of quality parameters of bulb storage life.

Bulb weight loss (%)

Percent weight loss was determined according to Waskar et al. (1999). The weight loss data were calculated from 60 bulbs which were randomly taken per treatment and weighed at the beginning and middle of each month.

$$\text{Percent weight loss} = \frac{\text{Wi} - \text{Wf}}{\text{Wi}} \text{x} 100$$

Where, wi = initial weight, and wf = final weight.

Sprouting and rotting bulbs (%)

Percent of bulb sprouting and rotting was taken based on the number of bulbs sprouted and decayed in two weeks assessment. Data on sprouting and rotting was recorded by counting the number of bulbs that were sprouted and rotted. The sprouted and decayed bulbs were discarded after each count to avoid double counting. Bulbs that sprouted and rotted at the same time were classified as sprouted.

$$\text{Percent sprouted and decayed bulbs} = \frac{\text{Number of sprouted/decayed bulbs}}{\text{Total number of bulbs}} \times 100$$

The data collected were subjected to analysis of variance (ANOVA) using SAS software version 9.0. GLM procedures and least significant difference (LSD) was used to separate means at $p < 0.05$ probability levels of significance.

RESULTS AND DISCUSSION

Days to maturity and leaf number

The influence of intra-row spacing revealed significant variation ($p<0.05$) on maturity of onion and leaf number while farm yard manure (FYM) and their interaction did not show significant differences (Table 1). Closer plant spacing enhanced maturity (116.17 days) while wider plant spacing (15 cm) showed slightly delayed maturity. Maximum leaf number plant^{-1} (13.17) was obtained from plants spaced at 15 cm followed by those spaced at 12.5 cm intra-row spacing. On the other hand, 7.5 cm spaced plants gave the minimum number of leaves plant^{-1} (11.29) that did not vary statistically from plants spaced at 10 cm apart, which gave 11.65 leaves plant^{-1}. Wider spacing that allowed plant to have access to more nitrogen which prolonged maturity and higher number of leaves. While in closer spacing, plant competes for light, nutrient and moisture causing early bulb maturity and reduced leaf number (Brewster, 1990, 1994). Brewster (1994) and Belay et al. (2015) noted that bulb maturity was advanced by higher planting density, which was associated with a high leaf area index and hence high light interception by the leaf canopy that advanced the date of bulb scale initiation.

Plant height, leaf length and neck thickness

Plant height was affected by intra-row spacing ($P<0.05$) but not by farmyard manure and their interaction (Table 1). Maximum plant height (62.41 cm) was recorded when plants were spaced at 7.5 cm distance, followed by plants spaced at 10 and 12.5 cm with no significant difference among them. The lowest plant height (58.58 cm) was recorded at spacing of 15 cm which was also at par with the 10 and 12.5 cm intra-row spacing (Table 1).

In general, as intra-row spacing increased from 7.5 to 15 cm, plant height showed decreasing trend. This might

Table 1. Main effects of intra-row spacing and FYM on plant height, leaf length, leaf number, days to maturity and neck thickness.

Treatments	Plant height (cm)	Leaf length (cm)	Leaf number	Days to maturity (days)	Neck thickness (cm)
Spacing (cm)					
7.5	62.41[a]	51.45	11.29[b]	116.17[b]	1.01
10	60.16[ab]	48.09	11.65[b]	116.92[ab]	1.02
12.5	60.15[ab]	46.78	12.88[a]	117.42[a]	1.02
15	58.58 [b]	45.21	13.17[a]	117.75 [a]	1.03
LSD (5%)	2.36	Ns	0.63	1.15	ns
FYM (tha^{-1})					
0	58.68	46.92	11.95	116.67	1.00
10	60.72	47.80	12.27	116.92	1.00
20	60.81	49.85	12.36	117.33	1.04
30	61.08	46.97	12.42	117.33	1.03
LSD (5%)	ns	ns	ns	ns	ns
SEM±	0.83	0.61	0.21	0.42	0.02
CV (%)	4.70	15.89	6.18	1.18	7.86

LSD = Least significant difference; SEM = standard error of mean; CV = coefficient of variation; FYM = farmyard manure. Means within a column followed by the same letter are not significantly different at P< 0.05; ns= no significant difference at p<0.05.

Table 2. Main effects of intra-row spacing and FYM on bulb length, bulb diameter, mean bulb weight and bulb dry mass content.

Treatments	Bulb length (cm)	Bulb diameter (cm)	Mean bulb weight (g)	Bulb dry mass content (%)
Spacing (cm)				
7.5	5.48[c]	5.26[c]	85.79[c]	16.23[b]
10	5.53[bc]	5.62[b]	92.29[c]	16.71[b]
12.5	5.87[ab]	6.44[a]	110.58 [b]	16.89[ab]
15	6.02 [a]	6.69[a]	119.76[a]	17.99[a]
LSD (5%)	0.36	0.27	9.17	1.16
FYM (tha^{-1})				
0	5.65	5.85	91.91 [b]	16.32
10	5.68	6.09	101.56[a]	16.59
20	5.71	6.12	107.42[a]	17.29
30	5.86	5.94	107.53[a]	17.61
LSD (5%)	ns	Ns	9.1724	ns
SEM±	0.12	0.09	3.19	0.39
CV (%)	7.65	5.35	10.77	8.18

LSD = Least significant difference; SEM = standard error of mean; CV = coefficient of variation; FYM = farmyard manure. Means within a column followed by the same letter are not significantly different at P< 0.05; ns= no significant difference at p<0.05.

be due to less competition for light in wider spacing and higher competition occurred in closer plants. Kitila et al. (2012) reported that closer spacing of 30 cm resulted in better plant height of tomatoes. Khan et al. (2002) also observed higher plant height in plants spaced at 12 cm distance than in plants spaced at 15 cm distance. Similarly, Gedamu (2005) noted that increased plant height and leaf length was observed at narrower row spacing in garlic. On the other hand, leaf length and neck thickness were not affected by intra-row spacing, FYM rate and their interaction (Table 1).

Bulb length, bulb diameter and bulb dry mass

There was significant effect of intra-row spacing (P<0.05) on onion bulb length but FYM and its interaction with intra-row spacing did not significantly influence bulb length, bulb diameter and percent bulb dry mass (Table 2). Higher bulb length (6.02 cm) was observed from plants planted in wider spacing (15 cm) followed by those planted at 12.5 cm while significantly smaller bulb length (5.48 cm) was obtained from closer spacing (7.5 cm), which was also statistically similar to those planted at 10 cm spacing (Table 2). The increase in bulb length by 9% as intra-row spacing increased from 7.5 to 15 cm could be attributed to adequate availability of growth resources at wider spacing that allows the bulbs to have more assimilates available for storage and thus resulted in higher bulb length. Dawar et al. (2007) reported that generally high planting density results in less availability of soil nutrients, water, light, etc; and that due to these, bulbs do not attain their potential sizes.

The highest bulb diameter (6.69 cm) was recorded from intra-row spacing of 15 cm followed by 12.5 cm which resulted in bulb diameter of 6.44 cm while significantly minimum bulb diameter of 5.26 cm was obtained from closer spacing of 7.5 cm (Table 2). The lack of available space for closer intra-row spacing could account for decrease in bulb diameter. Akoun (2004) reported that there was a marked increased in the diameter of onion bulbs as plant population decreased. Wider intra-row spacing of 15 cm resulted in higher bulb dry mass content (17.99%) while closer spacing (7.5 cm) gave the lowest bulb dry mass content (16.23%). This might be due to wider spacing allows the plants to uptake nutrients and accumulates higher dry matter. The result is in agreement with that of Ademe et al. (2012) who reported that shallot bulbs planted at 20 cm intra-row spacing produced greater bulb dry mass content plant^{-1} than those planted at 15 and 10 cm intra-row spacing. Abubaker (2008) also reported that pod dry weight of bean tended to be higher under the lower plant density. In crop plants, dry matter accumulation is a result of nutrient uptake and one of the measures of plant growth (Noggle and Fritz, 1983).

Mean bulb weight

Analysis of variance showed that mean bulb weight was highly affected ($p<0.001$) by intra-row spacing and FYM rates but not by their interaction (Table 2).The highest mean bulb weight (119.76 g) was recorded from 15 cm spaced onion plants followed by 12.5 cm spaced plants which, however, did not vary statistically. On the other hand, the least mean bulb weight (85.79 g) was obtained from the treatment of 7.5 cm intra-row spacing (Table 2).

In general, with increase in plant spacing, from 7.5 to 15 cm, mean bulb weight increased from 85.79 to 119.76 g. This might be due to the fact that closer spacing between plants resulted in competition for nutrients, moisture and light, thus reducing amount of assimilate stored in the bulbs which reduced their bulb weight. This result is similar with Khan et al. (2002) who reported that plants spaced at 9 cm gave the lowest average weight for a single onion bulb while in 15 cm spaced plants, the weight of the bulb was maximum. Similar result was also reported by Ademe et al. (2012) where bulbs of 'Huruta' shallot planted at 20 cm intra-row spacing produced the highest bulb weight plant^{-1} while those planted at 10 cm intra-row spacing produced the lowest bulb weight plant^{-1}.

Farm yard manure application improved mean bulb weight compared to the control where FYM was not applied (Table 2). The increased in mean bulb weight at FYM rates of 10, 20 and 30 t ha^{-1}, respectively, which might be attributed to solubilization of plant nutrients by addition of FYM leading to increase in uptake of plant nutrients or it could be the ability of manure in creating suitable plant growing environment by improving moisture and nutrient status of the soil (Subbaiah et al., 1982). The result is in line with the finding of Eifediyi et al. (2010) who reported that fruit weight in cucumber increased with increase in the rate of FYM applied from 0 to 10 t ha^{-1}. Similarly, Zaharah et al. (1994) reported that when palm oil mill effluent was applied as organic component to soil in Malaysia, there was increase in bulb size of onion. Fisseha (2010) reported that with application of 20 t ha^{-1} FYM was about 32.9% higher than the bulb weight from the control.

Biological yield, total bulb, marketable and unmarketable bulb yield

Biological yield, total bulb, marketable and unmarketable bulb yield of onion was significantly affected by intra-row spacing, FYM and their interaction (Table 3). The highest biological yield (151.96 g plant^{-1}) was obtained from wider spacing of 15 cm combined with 30 t ha^{-1} FYM, which is about 60% higher over the biological yield recorded from 7.5 cm intra-row spacing combined with no FYM (Table 3). The highest total (58.74 t ha^{-1}) and marketable (57.77 t ha^{-1}) bulb yield was obtained from the treatment combination of narrower spacing of 7.5 cm and higher rate of FYM (30 t ha^{-1}), followed by same spacing treatment combined with FYM of 20 t ha^{-1}. Compared to the treatment of 15 cm intra-row spacing with no FYM applied, the minimum recorded total bulb yield was (24.43 t ha^{-1}) and for marketable bulb yield (23.91 t ha^{-1}), resulted in the increment of about 140.4 and 141.6%, respectively (Table 3).

The highest unmarketable bulb yield (1.59 t ha^{-1}) was obtained from treatments combinations of intra-row spacing of 7.5 cm and FYM rate of 10 t ha^{-1}, followed by 7.5 cm combined with no FYM which resulted in 1.17 t ha^{-1} while the least values were recorded from treatment combinations of 12.5 or 15 cm inter-row spacing with 30 t ha^{-1} FYM (Table 3). The increased in biological yield at wider spacing and higher rate of FYM might be due to increased bulb length, bulb diameter, leaf number, and mean bulb weight and due to accumulation of more assimilates in the bulbs. This finding is in conformity with the finding of Ademe et al. (2012) who reported that shallot bulbs planted at 20 cm intra-row spacing grew more vigorously and obtained more biological yield plant^{-1} than those planted at 10 cm spacing.

In the present study, application of FYM regardless of

Table 3. Interaction effects of intra-row spacing and FYM on biological yield, total bulb yield, marketable bulb yield and unmarketable.

Treatments		Biological yield (g/plant)	Total bulb yield (t ha^{-1})	Marketable bulb yield (t ha^{-1})	Unmarketable bulb yield (t ha^{-1})
Spacing (cm)	FYM (tha^{-1})				
7.5	0	94.93^{i}	37.53^{cde}	36.36^{cdef}	1.17^{b}
	10	104.06^{gh}	39.81^{cd}	38.23^{cde}	1.59^{a}
	20	110.23^{fgh}	54.34^{ab}	53.59^{ab}	0.74^{d}
	30	100.94^{hi}	58.74^{a}	57.77^{a}	0.97^{bc}
10	0	111.17^{fgh}	32.68^{cd}	38.88^{cde}	0.80^{cd}
	10	103.22^{hi}	32.24^{def}	31.09^{defg}	1.15^{b}
	20	119.75^{ef}	46.88^{bc}	46.25^{bc}	0.63^{de}
	30	111.79^{fgh}	39.41^{cd}	38.35^{cde}	1.05^{b}
12.5	0	111.05^{fgh}	28.03^{ef}	27.28^{fg}	0.75^{d}
	10	129.32^{cde}	41.92^{cd}	41.72^{c}	0.20^{f}
	20	139.93^{abc}	40.40^{cd}	39.68^{cd}	0.72^{de}
	30	134.72^{bcd}	39.95^{cd}	39.79^{cd}	0.16^{f}
15	0	117.58^{efg}	24.43^{f}	23.91^{g}	0.52^{e}
	10	147.07^{ab}	37.04^{cde}	36.82^{cdef}	0.22^{f}
	20	125.97^{de}	29.32^{ef}	29.05^{efg}	0.27^{f}
	30	151.96^{a}	36.69^{de}	36.56^{cdef}	0.13^{f}
LSD (5%)		13.69	10.17	10.25	0.67
SEM±		4.70	3.49	3.51	0.07
CV (%)		6.87	15.58	15.97	16.65

LSD least significant difference, SEM=standard error of mean; CV= coefficient of variation; FYM= farmyard manure. Means followed by the same letter are not significantly different at P< 0.05.

spacing variation showed 11.2 to 14.9% increase in biological yield compared to the control treatment. The increase in total and marketable bulb yield was due to application of farmyard manure are largely attributed to improved soil organic matter, soil physical, chemical and microbial properties that enhance plant growth as well nutrient availability and its uptake by the plants (Eifediyi et al., 2010). In agreement with this, Fisseha (2010) reported that application of 20 t ha^{-1} FYM gave about 33% more biological yield compared to non manured plots. Mekonnen (2006) has shown that marketable potato tuber number was increased as the rates of both FYM and vermicompost increased from 5 to 10 t ha^{-1} and 4 to 8 t ha^{-1}, respectively. Kokebe et al. (2013) found that the combined application of 150 kg ha^{-1} of N and 30 t ha^{-1} of FYM gave the maximum dry bulb of onion.

Satyanarayana and Prasad (2002) reported that organic manure plays an important role in improving soil permeability to air and water and water stable aggregates. Thus application of organic materials such as farmyard manure considerably improves soil physical properties and nutrient uptake resulting in greater growth, yield and yield components. Akoun (2004) has shown that increasing the rate of manure application from 5.6 to 22.4 t ha^{-1} caused significant difference in yield. The highest yield of 9.55 t ha^{-1} was obtained with application of 22.4 5.6 t ha^{-1}. Unlike chemical fertilizer that supplies only the major nutrients, farmyard manure is a store house of several other plants nutrients and act as a good soil conditioner (Mishra and Nayak, 2004).

The result is in agreement with the work of Bosekeng (2012) who reported that plants that are highly populated tend to produce high yield of small bulbs, whereas plants at low population produce larger bulbs but with low yield. Kahsay et al. (2013) observed that as intra-row spacing increased from 5 to 10 cm, marketable bulb yield decreased from 34.49 to 28.1 t ha^{-1}. Awas et al. (2010) also reported that, amongst the cultivars and plant density tested, Nasik Red at intra-row spacing of 4 cm earned the maximum bulb yield followed by Bombay Red planted at similar spacing while Adama Red at intra-row spacing of 10 cm (wider spacing) and 8 cm gave the lowest average total bulb yield.

The high unmarketable yield in closely spaced plants could be due to inter-plant competition that resulted in a fewer large sized bulbs than wider spacing that negatively affected the marketable yield and favored the production of small sized bulbs that were unmarketable. Lower unmarketable yield in higher rate of FYM and wider spacing, on the other hand, could be due to less competition for nutrients and space which results in larger bulbs which were marketable. This is in agreement with

Table 4. Effects of intra-row spacing and FYM rate on cumulative weight loss (%) of onion bulbs during storage period.

Treatment	Storage weeks					
	2nd	4th	6th	8th	10th	12th
Spacing (cm)						
7.5	5.20	10.01b	14.50	18.35b	21.32b	23.66c
10	5.30	10.07b	14.51	18.52b	21.52b	23.77c
12.5	5.35	10.38b	15.90	19.21b	22.46b	25.02b
15	5.59	11.66a	16.08	21.41a	24.41a	26.88 a
LSD (5%)	ns	1.02	ns	1.41	1.22	1.19
FYM (t ha^{-1})						
0	4.86	9.92	14.44	18.61	21.52b	23.98b
10	5.42	10.61	14.60	19.02	22.10b	24.78ab
20	5.57	10.83	15.98	19.69	22.73ab	24.79ab
30	5.61	10.85	16.06	20.00	23.34a	25.78a
LSD (5%)	ns	ns	ns	ns	1.2233	1.191
SEM±	0.29	0.37	0.56	0.48	0.42	0.43
CV (%)	16.94	11.57	12.49	8.76	6.54	5.75

LSD = Least significant difference; SEM = standard error of mean; CV= coefficient of variation; FYM = farmyard manure; ns = no significant difference at p<0.05. Means followed by the same letter/s within a column are not significantly different at P< 0.05.

the result of Ademe et al. (2012) who reported that shallot bulbs of 'Huruta' planted at 10 cm intra-row spacing produced the highest unmarketable yield ha^{-1} while at 20 cm intra-row spacing, the lowest unmarketable yield ha^{-1} were produced.

Bulb storage life

Bulb weight loss and bulb rotting

Onion intra-row spacing significantly (p<0.05) affected bulb weight loss (%) and bulb rotting of onion most part of the storage period (Tables 4 and 5). As the storage period extended, the cumulative bulb weight loss increased due to increase in water loss, rotting and sprouting. Higher weight losses during the 12 weeks of storage were observed in wider spacing (15 cm) than in bulbs from narrower spacing treatments (Tables 4 and 5). At the 12th week, bulb weight loss reached 26.88% in bulbs from 15 cm spacing while the least bulb weight losses were observed from 7.5 cm (23.66%) and 10 cm (23.77%) spaced plants. Higher bulb weight loss and rotting at wider spacing could be attributed to large bulb size with succulent tissues and thicker necks which are vulnerable to rotting, sprouting and water loss during storage period. Sing and Sing (2003) reported that, large size bulbs exhibited the highest weight loss compared to smaller sized bulbs. In agreement with the present result, Kahsay et al. (2013) reported that weight loss and rotting of bulbs from the widest spacing (10 cm) and the least spacing (5 cm) were greater than that of the middle one (7.5 cm). Similarly, Bosekeng (2012) reported that bulbs harvested from population of 95 plants m^{-2} lost significantly less moisture (9.83%) than bulbs from population of 61 plants m^{-2} (22.67%).

Application of FYM did not significantly affect bulb weight loss (%) and bulb rotting (%) until 8th and 6th weeks of storage period respectively. However, during 10th and 12th week of storage period, significant (p<0.05) weight loss of onion bulbs was observed between the FYM rates (Table 4). Rotting of bulbs from the 8th week of storage period onwards, was significantly affected by FYM (p<0.05) (Table 5). The highest bulb rotting was observed in treatment received 30 t ha^{-1} while the least bulb rotting was recorded in control which, however, did not vary statistically from those which received FYM at the rates of 10 and 20 t ha^{-1} (Table 5). The increase in percent bulb weight loss and rotting at higher rate of FYM could be due to improvement of soil physical and chemical properties, including addition of macro and micro nutrients which resulted in larger bulb size with succulent tissue prone to rotting. Zewude et al. (2010) observed that an increased in weight loss and rotting was due to increase in nitrogen rate. The increase in percent weight loss and rotting of bulbs due to increase in nitrogen could be attributed to the fact that higher rates of nitrogen encouraged plants to produce large bulbs with soft succulent tissues which make them susceptible to the attack of disease causing micro organisms.

Farmyard manure improves soil physical property, like reduced bulk density that allows the bulb to expand more, and improve supply of macronutrients which increases bulb size and thereby increasing the proportion of bulb neck thickness that favors bulb sprouting and loss of reserve carbohydrate and moisture. Syed et al. (2001)

Table 5. Effects of intra-row spacing and FYM rate on cumulative rotting (%) of onion bulbs during storage.

Treatment	Storage weeks					
	2nd	4th	6th	8th	10th	12th
Spacing (cm)						
7.5	0.14(0.77[b])	1.38(1.32[b])	2.50(1.71[b])	3.47(1.98[c])	4.86(2.28[b])	5.83(2.48[b])
10	0.42(0.90[b])	1.80(1.46[b])	3.05(1.86[b])	4.16(2.11[bc])	5.14(2.34[b])	6.39(2.59[b])
12.5	0.55(0.96[b])	1.80(1.47[b])	3.33(1.92[b])	4.86(2.28[ab])	5.69(2.45[ab])	7.22(2.72[ab])
15	1.66(1.40[a])	2.91(1.82[a])	4.72(2.28[a])	5.97(2.51[a])	7.22(2.76[a])	9.02(3.03[a])
LSD	0.27	0.32	0.26	0.89	0.34	0.36
FYM (tha^{-1})						
0	0.42(0.90)	1.66(1.45)	3.05(1.85)	3.89(2.04[b])	4.72(2.23[b])	5.55(2.41[b])
10	0.69(0.94)	1.80(1.44)	3.19(1.89)	4.03(2.11[b])	5.28(2.40[b])	6.80(2.66[b])
20	0.55(1.03)	1.94(1.51)	3.61(2.00)	5.00(2.28[ab])	5.55(2.45[ab])	7.08(2.71[ab])
30	1.11(1.17)	2.50(1.68)	3.75(2.04)	5.55(2.44[a])	7.36(2.77[a])	9.02(3.04[a])
LSD (5%)	ns	ns	ns	0.887	0.3358	0.3615
SEM±	0.09	0.12	0.09	0.10	0.12	0.13
CV (%)	32.12	25.67	15.93	15.61	16.38	16.04

LSD = Least significant difference; SEM = standard error of mean; CV = coefficient of variation; FYM = farmyard manure. Means followed by the same letter are not significantly different at P< 0.05. ns = no significant difference at p<0.05. Data in parenthesis are square root transformed values.

noted that small bulbs showed minimum weight loss (0.23%) while greater loss was noted in large bulbs (5.56%) after a storage period of 16 days. Agasimani (2010) observed that NPK + FYM tended to develop soft tissues with high moisture content which in turn rendered bulbs to higher storage loss in onion. Eze and Orkwor (2010) reported that the application of fertilizer (organic or inorganic) increased weight loss in yam varieties compared to where it was not applied, although difference was not statistically significant.

Bulb sprouting

Significant differences in sprouting bulbs were not observed between intra-row spacing, FYM rate and their interactions. Sprouting of bulbs was not observed until 8th weeks of storage. Absence of bulb sprouting at early stage could be attributed to the high temperature, low relative humidity, curing treatment which inhibits sprouting. Inherent characters of dormancy based on equilibrium of inhibitors in onion bulbs can be affected by temperature where lower and higher temperatures increase the dormant state of onion bulbs and moderate (10-15°C) temperature enhanced the sprouting by breaking dormancy (http://www.nhrdf.com). No sprouting occurs at storage temperature between -1 and 1°C or between 25 and 30°C (Miedema, 1994). But at 10th and 12th weeks of storage period, bulb sprouting was observed.

Summary

Onion is grown mainly for its bulb, which is used in every home daily. The upper and middle awash valley regions of Ethiopia have privileged position for production and marketing of onion as a cash crop. Onion yield in this region remained low, due to several factors, including low soil fertility, salinity effect and inappropriate cultural practices. A study was undertaken to assess the effect of intra-row spacing and application of farmyard manure (FYM) on yield and quality of Adama Red onion cultivar in Gewane, lower Rift Valley of Ethiopia.

The interaction effects of intra-row spacing (15 cm) and FYM (30 t ha^{-1}) gave the highest biological yield (151.96 g $plant^{-1}$), which was about 60% increase over the minimum biological yield recorded from 7.5 cm intra-row spacing combined with no FYM. The highest total (58.74 t ha^{-1}) and marketable bulb yields (57.77 t ha^{-1}) were obtained from the treatment combination of narrower spacing of 7.5 cm and higher rate of 30 t ha^{-1} FYM.

Higher weight losses during the 12 weeks of storage were observed in wider spacing (15 cm) than in bulbs from lower spacing treatments. The highest percent of bulb rotting was observed in plants planted at wider spacing (15 cm) while the least bulb rotting was observed in closer spacing (7.5 cm). Highest rate of FYM had increased bulb deterioration in storage period in all bulb storage life studied. Due to application of recommended dose of mineral fertilizer, FYM did not show significant difference in most parameters.

Conclusion

Onion intra-row spacing of 7.5 cm and 20 t ha^{-1} farmyard manure rate gave good marketable bulb yield and better onion storage life which can be stored for about three months. Highest rate of farmyard manure had increased bulb deterioration in storage period in all bulb storage life. As storage time extended, cumulative bulb weight loss, bulb rotting and sprouting increased.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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