THE JOURNAL OF AGRICULTURE AND NATURAL RESOURCES SCIENCES

Journal homepage: http://www.journals.wsrpublishing.com/index.php/tjanrs
Online ISSN: 2383-238X Print ISSN: 2423-4397

Original Article

Effect of nitrogen application on growth, yield, and shelf-life of onion (*Allium Cepa* L.) Varieties in Fedis district

Gebisa Bededa Benti
Horticulture Research Division, Fedis Agricultural Research Center, Oromia Regional Agricultural Research Institute, Ethiopia

ABSTRACT

Farmers in Fedis district cultivate onion from unknown seed sources and small bulb sizes, which lead to low bulb yield and short shelf life. The framers also apply different fertilizers in different rates. Considering these problems, a field experiment was conducted at the Fedis Agricultural Research Center, during the main cropping season of 2013/2014 to investigate effect of nitrogen application on growth, yield, and shelf life of onion varieties. The results revealed that nitrogen rate significantly affected bolting percentage, bulb diameter ($P<0.001$) and leaf length and marketable bulb yield ($P<0.05$). There were significant ($P<0.01$) differences in bolting percentage, physiological maturity, mean bulb weight, total bulb yield, leaf length, leaf number, bulb neck diameter, bulb dry weight and marketable bulb yield. Significant interaction effects of nitrogen rate and variety were observed in shoot dry weight and TSS content of bulbs. Application of 200 kg N ha^{-1} decreased total soluble solids and reducing sugars by about 7 and 26%, respectively, as compared to control treatment. In general, application of 150 and 200 kg N ha^{-1} had no significant difference from 100 kg N ha^{-1} for leaf length, physiological maturity, mean bulb weight, shoot dry weight, bulb dry weight, and marketable bulb yield due to the varietal differences. Similarly, application of 100 kg N ha^{-1} significantly reduced physiological weight loss, rotten and sprouted bulbs by about 4, 7 and 10 %, respectively, than application of 150 kg N ha^{-1}; and by about 9, 9 and 10%, respectively, than the application of 200 kg N ha^{-1} at 90 days after storage periods. Bombay Red was found to be superior in performance under Fedis condition among the other tested varieties. In conclusion, application of 50 to 100 kg N ha^{-1} and using the variety Bombay Red resulted in maximum bulb yield and postharvest quality of the bulbs in the study area, implying that application of this rate of N fertilizer to this variety results in optimum bulb yield and quality in the study area.

Keywords: Adama Red, Bombay Red, interaction, Nasik Red, nitrogen, postharvest

Corresponding Author: Gebisa B. Benti < bantiig@gmail.com >
How to Cite this Article: Benti, G.B. (2017). Effect of nitrogen application on growth, yield, and shelf-life of onion (*Allium Cepa* l.) Varieties in Fedis district. *The Journal of Agriculture and Natural Resources Sciences,* 4(1), 1-22.
Retrieved from http://www.journals.wsrpublishing.com/index.php/tjanrs/article/view/306
Article History: Received: 2015-07-16 Accepted: 2015-11-02

INTRODUCTION

Onion (*Allium cepa* L. 2n=16) is an important vegetable belonging to the family *Alliaceae*. It is the most widely grown and popular crop among the *Alliums*. From the list of worldwide cultivated vegetable crops, onion ranks third, only preceded by tomatoes and potatoes (FAOSTAT, 2012). It is an indispensable item in every kitchen as a vegetable and condiment used to flavor many of the food stuffs. Therefore, onion is popularly referred to as "Queen of Kitchen" (Selvaraj, 1976).

Onion is produced all round seasons and has comparatively low storage ability and bulbs are usually stored until the harvest of next season crop or for longer periods due to seasonal glut of onion in the market. Significant losses in quality and quantity of onion occur during storage. Storage of onion bulbs has, therefore, become a serious problem in the tropical countries like Ethiopia. The losses, where no bottom ventilation is provided, are estimated to the extent of 30 to 35 percent due to drainage, 10 to 12 percent by decay and 8 to 12 percent on an account of sprouting, depending upon the relative humidity and temperature during the rainy season (Maini and Chakrabarti, 2000).

It has been reported that application of nitrogen caused significant improvement in growth and bulb yield of onion; however, high nitrogen application shortens the storage life of the crop (Brewster, 1994). Generally, overuse of plant nutrients are known to affect quality (total soluble solid, weight loss, pungency, sugar contents) and storability of onion and shallots, while exogenous nitrogen application is known to increase yield of onions (Sebsebe and Seyoum, 2010). Under suitable agro-climatic conditions, nutrient management is the main factor which influences the growth and yield of onions to a great extent.

In Ethiopia, EIAR recommends nitrogen fertilizer of 150 kg ha^{-1} in the form of urea as a blanket recommendation (Lemma and Shimelis, 2003), which was not practiced in eastern part of Harerghe. The area produces mainly Khat (*Catha edulis* Forsk.), sorghum, groundnut, and onion during lean periods. Furthermore, in intensive cropping systems and monocropping, where a no-tillage system is adopted, depletion or deficiency of N in the soil is resulted. The major source of plant-available N in soil is mostly the N mineralized from soil organic matter and fresh crop residues. The rate of these processes is dependent on soil temperature and soil moisture content (Marschner, 1995). Farmers also remove plant residues from the soil and the nutrients in the soil become low affecting the yield of onion bulb. Farmers sometimes apply excess amount of fertilizers targeting only for bulb yield, but they do not consider postharvest effects of nitrogen fertilizers. High nitrogen supply favors the conversion of carbohydrate into protein which in turn promotes the formation of protoplasm; however, excessive dose of nitrogen produces succulent plants and enhances plants to be sensitive to water, temperature stress, lodging and pest incidence and also affect postharvest quality of onion bulbs (Olsen and Kurtz, 1982). The principal aims of bulb crops storage are to maintain the 'quality capital' present at harvest and to satisfy consumer demand for extended availability of bulbs of satisfactory quality (Gubb and Tavis, 2002). Farmers store onion bulbs in their living house immediately after harvest without curing and shortly they sell bulbs cheap due to the surplus of the onion bulbs in the markets.

In Eastern Ethiopia, farmers need to increase yields of their cash crops, which they use for purchasing cereals from neighboring surplus-producing regions (Kebede Woldetsadik, 2003). The author further noted that whenever available, growers use farmyard manure as well as nitrogen fertilizer to increase bulb yields. However, no data are available to substantiate the belief that benefits can be obtained from fertilization of onion, especially under low soil moisture conditions of eastern Harerghe. Since the land size is small, the fertilizer and animal manure use intensity is high (Bezabih Emana and Hadera Gebremedhin, 2007). Farmers also produce onions from unknown seed sources, which have small bulb sizes with low bulb yields. About 31% of the vegetable producers of Harerghe farmers used local varieties and improved varieties needed to produce the desired product are said to be unavailable. They produce shallot variety locally called "Fedis" which is low in bulb yield and shortly decay and which is not high yielder as that of onion.

Generally, a better understanding of the nitrogen fertilizer requirements of onion is needed in order to develop management strategies, which optimize fertilizer use of the crop. Moreover, improved varieties and fertilizer management for onions may help improve quality, particularly bulb size and storability, and thus offer growers premium prices. It was assumed that onion varieties would vary in their responses to nitrogen fertilization levels. It is important to investigate the nitrogen fertilizer requirement of the onion varieties at the area and justify its effect on the storage life of onion. Therefore, the objective of this study was to investigate the influence of nitrogen fertilizer on plant growth, bulb yield and shelf-life of onion varieties.

MATERIALS AND METHODS

Description of Experimental Site

The study was conducted at Fedis Agricultural Research Center of Oromia Agricultural Research Institute (OARI) at Boko sub-site, which is located at the latitude of 9^{o} 07' North and longitude of 42^{o} 04' East, and at the altitude of 1702 metres above sea level. The area is situated at the distance of about 24 km from Harar town in the southerly direction (Fedis Agricultural Research Center Profile).

The soil of the experimental site was black with surface soil texture of sand clay loam that contained 8.20% organic matter, 0.13% total nitrogen, available phosphorus of 4.99 ppm, soil exchangeable potassium of 1.68 cmol(+) kg^{-1} and a pH value of 8.26 (Table 2). The experimental area was characterized as lowland climate. The mean rainfall was about 860.4 mm for the last five years. The rainfall had a bimodal distribution pattern with heavy rains from April to June and long and erratic rains from August to October. The mean maximum and minimum annual temperatures were 27.7 and 11.3^{o}C, respectively for the last five years (Fedis Agriculture Research Center Metrological Station) (Appendix Table 10).

Description of Experimental Materials

The experiment was conducted with three dominantly cultivated improved onion varieties (Adama Red, Nasik Red, and Bombay Red) in eastern Ethiopia. The seeds were collected from Melkassa Agricultural Research Center.

Variety Adama Red and Nasik Red are firm, very pungent, whereas Bombay Red is light pungent. Adama Red and Bombay Red are susceptible to purple blotch disease; however, Nasik Red is relatively tolerant to this disease. Adama Red flowers and set seed very easily; while Nasik Red is not easily bolting. Bombay Red has a high proportion of split bulbs and has short shelf life compared to Adama Red. Adama Red is accepted both by producers and by consumers and is successfully produced by small farmers and commercial growers in most regions of the country. The detailed description of the varieties is given in the Table 1.

Treatments and Experimental Design

The treatments consisted of three improved onion varieties (Adama Red, Nasik Red and Bombay Red) and five nitrogen doses (0, 50, 100, 150 and 200 kg N ha^{-1}) in the form of urea. The experiment was laid out as a randomized complete block design (RCBD) in a factorial arrangement with three replications per treatment. Each treatment combination was assigned randomly to experimental units within a block. The gross plot size was 2 m x 3 m and net plot size of 1.60 m x 2.80 m. Plants were planted in a single row by 20 cm x 10 cm between rows and plants, respectively. There were 10 rows per plot and 30 plants per row and 300 plants per plot. Plants in the middle eight rows were considered for recording data. Plants on the border rows as well as those at both ends of each row were not used for data recording to avoid edge effects.

Experimental Procedures

The experimental plots were ploughed to a depth of 25 - 30 cm by a tractor. The experimental plots were harrowed to a fine tilt manually before planting. The land was leveled well. Triple super phosphate (TSP) of 100 kg ha^{-1} was added uniformly into the prepared ridges in bands before sowing at nursery. Seeds were sown on well prepared seed beds on 12 July 2013. The seedlings were raised on a 5.0 m x 1.2 m of raised beds in 5 cm spaced rows. Watering and weeding of seedling at nursery were carried out manually.

Transplanting the seedlings into the experimental plots was done on 18 August 2013. When seedlings were at the growth stage of 3 or 4 leaves or when they reached the height of 12 to 15 cm (five weeks after sowing), they were transplanted into the experimental field. Normal and uniform seedlings were transplanted. Nitrogen was side dressed in the form of Urea (46% N) in two splits of equal amounts after 3 and 6 weeks after transplanting depending on the specified rate.

Plots were supplemented with irrigation during transplanting and two weeks after transplanting due to shortage of rainfall. Watering was carried out using watering can and provided equally to each plot. Due to high humidity and erratic rainfall during bulb initiation, recommended rates of chemical Mancozeb (3 kg ha^{-1}) was applied to the plots to control downy mildew. Weeding and hoeing were done manually. Harvesting was done at the end of December 2013 when the bulbs attained full size and 80% of the tops fell over or senesced.

Soil Sampling and Laboratory Analysis

Pre-planting soil samples were taken randomly in a zigzag pattern from the entire experimental plots at the depth of 0 - 30 cm. Ten soil cores were taken by an auger from the whole experimental field and combined to a composite sample. The soil was broken in to small crumbs and thoroughly mixed. From this mixture, a sample weighing 1 kg was filled in to a plastic bag to analyse in triplicates. The soil was air-dried and sieved using a 2 mm sieve. The soil samples were analyzed for parameters relevant to the study at the Ziway Research Center Soil Laboratory (ZRCSL). Pre-sowing samples were analyzed for soil texture, pH, CEC, EC, organic carbon, total N, available P and exchangeable K. Soil pH was determined by diluting the soil in a 0.01 M $CaCl_2$ solution in the ratio of one soil volume to 2.5 volume of the $CaCl_2$ solution. Thus, twenty-five ml of the 0.01 M $CaCl_2$ solution was added into soil sub samples each weighing 10 g. After equilibrating for 2-3 hours, the suspensions were filtered and the pH was measured by a glass electrode. Texture of the soil was determined by the hydrometer method (Piper, 1966).

Total nitrogen of the soil was determined by the micro Kjeldhal procedure (Jackson, 1970). Organic carbon was determined by the Walkley and Black method (Walkley and Black, 1954). The organic matter content was obtained by multiplying the organic C content with the factor 1.729 according to Nelson and Sommers (1982). Available phosphorous content of the soil was determined by extracting the soil with 0.5 M $NaHCO_3$ solution (Olsen *et al*., 1954). Phosphorus in the extracts was determined by atomic absorption spectrophotometer calorimetrically according to the molybdenum blue colour method of Murphy (1962). Exchangeable potassium was determined using a flame photometer after extracting the soil with 0.5N ammonium-acetate (Jackson, 1973).

Storage Study

In the experiment, after harvesting, bulbs from each treatment were cured for five days and subjected to storage treatments in clean and cemented room on wooden shelf were used for storage. Onion bulbs were stored for three months at average maximum and minimum temperatures of 29.4 ºC and 8.6 ºC, respectively, and mean relative humidity of 40.3%, respectively. Onion bulbs of uniform size numbering 200 were obtained from each plot and stored. The observations in bulb weight loss were recorded at 10 days' intervals till 90 days of storage.

Data Collection

Plant maturity: The number of days required to reach physiological maturity was recorded when most leaves dried and fell off. Onion is considered to be matured when the leaves become senesced and top fallen off.

Number of leaves per plant: Number of leaves per plant was recorded at maturity by counting from 10 plants per plot.

Leaf length (cm): This refers to the average length of leaf blades of 10 randomly selected plants measured at maturity using a ruler and expressed in centimetres.

Plant height (cm): Plant height was measured in centimetres from the ground level to the tip of the plant from 10 randomly taken plants and average records were taken at 30, 60, 90 and 120 days after transplanting.

Bolting (%): Plants that showed flower escapes during vegetative growth were counted and calculated as the ratio of bolters per total plants in the plot and the values were expressed in percentage.

Shoot dry weight (ton ha^{-1}): The above ground biomass of 15 plants were harvested by cutting the plants at the crown during bulb formation from rows that were not considered for other data recorded and were oven-dried at the temperature of 65 ºC until a constant weight was obtained and the shoot dry weight was determined.

Bulb dry matter content (%): The fresh weight of 15 randomly taken mature bulbs of the sample plants was measured and averaged after curing for five days and the average bulb fresh weight was determined and expressed in gram. The randomly sampled fifteen mature bulbs from each plot were chopped to small pieces and samples of 200 g chopped bulbs were taken for each plot and oven dried at 70^{0}C in duplicates until a constant weight was obtained and the weight was measured using a digital balance, then percent dry matter was calculated using the following formula:

$$DW (\%) = [(DW+CW)-CW]/[(200 g] \times 100$$

Where: DW = dry weight; CW = container weight; and FW = fresh weight

Dry total bulb biomass (ton ha^{-1}): This was determined by summing up the shoot and bulb dry weights of sample plants.

Neck diameter (cm): The average neck diameter of fifteen randomly taken mature bulbs at harvest was measured using a veneer calliper and expressed in centimetre after harvest.

Bulb diameter (cm): The average bulb diameter of fifteen randomly taken mature bulbs was measured by using a veneer calliper and bulb diameter was expressed in centimetres after harvest.

Marketable bulb yield (ton ha^{-1}): Marketable bulb yield refers to the weight of healthy bulbs ranging 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 (Lemma and Shimelis, 2003). Accordingly, this parameter was determined from all plants in the central rows at the final harvest.

Unmarketable bulb yield (ton ha^{-1}): It includes diseased, under size (below 20 g in weight), oversize (above 160 g in weight) and split bulbs were considered as unmarketable bulbs.
Total bulb yield (ton ha^{-1}): To obtain the value of total bulb yield, marketable bulb yield and unmarketable bulb yield were summed up and expressed in tons ha^{-1}.
Physiological weight loss (%): Physiological weight loss was determined using samples of 30 bulbs of medium size randomly taken from each treatment. Weight loss of bulbs was recorded in 10 days' intervals till 90 days of storage period. The physiological weight loss was calculated using the formula:

$$PWL\ (\%) = \frac{\text{Initial weight} - \text{Final weight at } 10^{th} \text{ intervals}}{\text{Initial weight}} \times 100$$

PWL = Physiological Weight Loss
Sprouted bulb (%): Percentage of sprouted bulbs was cumulative, which was based on the number of bulbs sprouted in storage period. The incidence of sprouting was ascertained by counting the number of bulbs that sprouted in 10 days' intervals. The sprouted bulbs were discarded after each count to avoid double counting. Bulbs that sprouted and rot at the same time were classified as sprouting, and computed as:

$$LDS\ (\%) = \frac{\text{Number of sprouted bulbs at } 10^{th} \text{ days intervals}}{\text{Total number of bulbs}} \times 100$$

LDS = Loss Due to Sprouting
Rotten bulbs (%): Percentage of rotten bulbs was cumulative and was based on the number of bulbs rotten in storage period. The incidence of rotting was determined by counting the number of bulbs rotten in 10 days' intervals. The rotten bulbs were discarded after each count to avoid double counting. The total number of onion bulbs which were decayed due to rotting were counted and computed in percent using the formula:

$$LDR\ (\%) = \frac{\text{Number of rotten bulbs at } 10^{th} \text{ days intervals}}{\text{Total number of bulbs}} \times 100$$

LDR = Loss Due to Rotting

Total soluble solids (TSS %): The total soluble solid (TSS) was determined from fifteen randomly selected bulbs using the procedures described by Waskar *et al*. (2000). Aliquot juice was extracted using a juice extractor and 50 ml of the slurry was centrifuged for 15 minutes. The TSS was determined by a hand refractometer (ATAGO TC-1E) with a range of 0 to 32 ^{o}Brix and resolutions of 0.2 ^{o}Brix by placing 1 to 2 drops of clear juice on the prism, washed with distilled water and dried with tissue paper before use. The refractometer was standardized against distilled water (0% TSS). Amount of total soluble solids present in the bulb was expressed in percentage.
Reducing sugar (%): Reducing sugar was determined from fifteen randomly selected bulbs using the standardization of the Fehling's solutions. Reducing sugar was calculated from standard methods of titration. Fist pipette 10 ml of mixed Fehling's solutions into each of two 250 ml conical flasks and 50 ml burette filled with the solution and titrated. Almost the whole volume of sugar solution required to reduce the Fehling's solutions was added, so that 0.5 ml to 1.0 ml was required to complete the titration. The contents of the flask were mixed and heated for 2 minutes and then 3 drops of methylene blue solutions were added. Titration was completed by adding 2 to 3 drops of sugar solutions at 5 to 10 seconds' intervals within 1

minute, until the indicator was completely decolorized. In this way, reducing sugar was calculated from invert sugar as follows:

$$\text{Factor for Fehling's solutions (g of invert sugar)} = \frac{\text{Titre} \times 2.5}{1000}$$

$$\text{Reducing sugar (\%)} = \frac{\text{mg of invert sugar x dilution} \times 100}{\text{Titre} \times \text{Weight or volume of sample} \times 100}$$

Total sugars (%): Total sugar was determined from fifteen randomly selected bulbs as invert sugar from extracted aliquot. Fifty ml of the clarified solution was pipetted into a 250 ml conical flask. After adding 5 g of citric acid and 50 ml of water, it was boiled gently for 10 minutes to complete the inversion of sucrose, and then cooled. Then it was transferred to a 250 ml volumetric flask and neutralized with 1 N NaOH using phenolphthalein as an indicator. Clarified aliquot of 50 ml was transferred and diluted solution to a 250 ml flask. After adding10 ml of HCl (1 + 1) allowed to stand at room temperature (20 ^{o}C or above) for 24 hrs. Neutralized with concentration of NaOH solution and made up to volume. Then aliquot was taken and a total sugar was determined as invert sugars. First total sugars as invert sugars were calculated as in equation above on total sugars using titre value obtained in the determination of total sugar after inversion.

$$\text{\% Sucrose} = (\text{\% Total invert sugars - \% Reducing sugars originally present}) \times 0.95$$

$$\text{\% Total sugars} = (\text{\% reducing sugars + \% sucrose})$$

Statistical Data Analysis

Data were subjected to analysis of variance using the Generalized Linear Model of SAS Statistical Software package (SAS institute, 2003). Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance. Pearson correlation coefficients were determined for parameters

RESULTS AND DISCUSSION

Experimental Soil Properties

The analysis of the collected sample for experimental site soil properties (Table 2) indicated that the soil was sandy clay loam in texture and basic in reaction (pH 8.26). According to Bruce and Rayment (1982) range, the soil was low in total nitrogen (0.13%). Similarly, according to Olsen *et al*. (1954), the experimental site had low available phosphorus (4.99 mg kg^{-1} soil). According to Emerson (1991) range of organic matter content of soil, the experimental soil had high organic matter (8.20%) contents. This high content of organic matter in the experimental field was due to the pre-legume (haricot bean) crops produced and added crop residues after threshing. This very high content of organic matter indicated good soil structural condition, high structural stability and soils probably water repellent. According to Metson (1961), the soil of the experimental site had very high cation exchange capacity (113.05 cmol kg^{-1} soil) and high in exchangeable potassium (1.68 cmol (+) kg^{-1} soil) (Table 1).

Plant Maturity

Onion variety had a significant (P<0.01) influence on days to physiological maturity. However, the effect of nitrogen as well as its interaction with variety did not significantly affect the parameter.

The variety Bombay Red matured significantly earlier than the Nasik Red and the Adama Red varieties by 19 and 11 days, respectively (Table 2). This result is in line with the report of Mandefro Nigussie *et al.* (2009), which indicated differences in maturity periods of the tested varieties. The result of this study is also in contrast to the findings of Abdissa *et al.* (2011) who reported that N fertilization extended physiological maturity by about 6 days over the unfertilized treatment. Lack of significant differences among the nitrogen rates might be due to the high organic matter content of the soil, which may have contributed much more nitrate for uptake by the plant thereby making the external application of nitrogen ineffective in affecting physiological maturity (Landon, 1991) as organic matter is the precursor of mineralized nitrogen for plant uptake.

Table 1. Selected soil physical and chemical properties of the experimental plots

Physical properties	Value
Clay (%)	22
Silt (%)	20
Sand (%)	58
Textural Class	Sandy clay loam
Soil chemicals	
Total nitrogen (%)	0.13
Available phosphorous (mg kg^{-1} soil)	4.99
Exchangeable potassium (cmol (+) kg^{-1} soil)	1.68
Organic matter (%)	8.2
Electro-conductivity (mmhos cm^{-1})	0.55
Cation exchangeable capacity (meq 100 g^{-1} soil)	113.05
pH (soil to water ratio 1:2.5)	8.26

Plant height

Onion variety significantly ($P < 0.05$) influenced plant height at 60 and 90 days after transplanting, but not at 30 and 120 days after transplanting. However, neither nitrogen application rate nor its interaction with variety affected plant height significantly. Variety Nasik Red exhibited highest plant (37.41 cm) and (47.51 cm) at 60 and 90 days after transplanting, respectively, while Adama Red and Bombay Red were statistically in parity at both days after transplanting. Plant heights of Nasik Red variety exceeded that of the variety Bombay Red by about 8.0% during both stages of growth. Lack of significance in plant height due to application of nitrogen rates might be attributed to the high organic matter contents (8.26 %) of the experimental soil that could contain ample nitrogen for uptake by plants. This is because soil organic matter is the main storage of carbon (Zingore *et al*., 2005), that determines soil fertility (Tiessen *et al*. 1994), supplies nitrogen, phosphorus, and sulphur to plants (Palm *et al*., 2001), improves soil aggregation, reduces soil sealing and crusting, enhances water infiltration, and increases CEC.

This result is supported with the findings of Kolota *et al*.(2013) who reported that increment of nitrogen rate from 75 to 150 and 225 kg·ha^{-1} did not affect the growth of bunching onion as well as height of plants. The author further noted that the rate of nitrogen fertilizer did not influence all tested morphological features such as height of onion plant. This result is also in agreement with the findings of Perner et al. (2007) who conducted a pot experiment in the greenhouse conditions and did not observe differences in plant heights of onion in treatments supplied with nitrate and ammonium nitrate rate. In another study, Fageria (2009) reported that more than 90% of the N in most soils is in the form of organic matter. The author further noted that organic form of N protects the N from loss; however, it is also not available to crop plants. Nitrogen may also be lost due to denitrification in the soil without benefiting onion plants. The author further noted that denitrification usually occurs in soils which are high in organic matter, under extended periods of temperature rises.

Leaf length and leaf numbers per plant

Nitrogen application significantly ($P<0.05$) influenced leaf length of onion. Similarly, variety also significantly ($P<0.01$) influenced leaf length of onion. Application of 100 kg N ha^{-1} increased leaf length by about 11% as compared to control (Table 2). However, the leaf length of onion plants grown in plots treated with 100, 150, and 200 kg N ha^{-1} were all in statistical parity (Table 2). It means that beyond the rate of 100 kg N ha^{-1}, increasing the rate of nitrogen did not increase leaf length. The positive effect of N on leaf length might be due to its role on chlorophyll, enzymes and proteins synthesis. The result is in agreement with Bungard *et al.* (1999) who reported that N is the major constituent of proteins and the presence of abundant protein tends to increase the size of the leaves and ultimately increase carbohydrate synthesis. This result is also supported by the study of Abdissa *et al.* (2011) who stated that application of 69 kg N ha^{-1} increased leaf length by about 11.5% as compared to the control. Variety Adama Red had higher leaf length than Nasik Red and Bombay Red by about 3% and 11.6%, respectively (Table 2). The leaf length of variety Adama and Nasik Red were in statistical parity.

Onion variety significantly ($P < 0.01$) influenced number of leaves produced per plant. However, the interaction of the two factors did not significantly affect leaf number of the plant. However, nitrogen rate did not significantly affect leaf number. This result is in conformity with the study of Kolota *et al.* (2013) who reported that increment of nitrogen rate from 75 to 150 and 225 kg·ha^{-1} did not affect the growth of bunching onion as well as number of leaves. The author further noted that the rate of nitrogen fertilizer did not influence all tested morphological features such as leave numbers and plant height of onion. This result is also in agreement with the findings of Perner *et al.* (2007) who reported that pot experiment conducted in the greenhouse conditions did not observe the differences in leave numbers of onion in treatments supplied with nitrate and ammonium nitrate rate. The leaf numbers of variety Nasik and Bombay Red were not significantly different. Unlike leaf length, both varieties exceeded Adama Red in leaf numbers by about 18 and 22%, respectively.

Table 2. Mean effect of nitrogen rate and varieties on days to maturity, leaf length (cm), number of leaves per plant and bolting (%) of onion varieties

Nitrogen rate (kg ha^{-1})	Days to maturity	Leaf length	Leaf numbers	Bolting
0	120.30	30.21b	8.00	5.60a
50	120.80	32.39ab	9.89	4.58b
100	121.60	34.08a	9.22	4.32bc
150	122.80	33.72a	10.22	4.08cd
200	124.00	33.46a	9.56	3.80d
LSD (0.05)	NS	2.48	NS	0.48
Variety				
Adama Red	120.50b	34.45a	8.00b	4.57a
Nasik Red	131.90a	33.42a	9.80a	4.08b
Bombay Red	113.30c	30.44b	10.27a	4.78a
LSD (0.05)	2.41	1.92	1.24	0.31
CV (%)	2.60	7.90	17.70	11.20

NS: non-significant. Means in the same column sharing the same letter(s) are not significantly different at P=0.05.

Bolting percentage

Both nitrogen and variety significantly (P < 0.001) influenced bolting in onion. However, the two factors did not interact to influence this parameter significantly. Increasing the rate of nitrogen application from nil up the highest level almost linearly reduced bolting of the onion plants. Plants that received no or lower rates of nitrogen had higher bolting percentages than those that received higher rates of the fertilizer. Thus, increasing the rate of nitrogen application from nil up to the 50 and 100 kg N ha^{-1} reduced bolting percentage by about 18 and 23% respectively, as compared to control treatment. Increasing the rate of nitrogen further from nil to 150 and 200 kg N ha^{-1} reduced bolting percentage by 27 and 32%, respectively, as compared to control (Table 2). Bolting of onion plant is not affected by day length only and there may be other factors such as temperature, nutrients like limited nitrogen, and status of the field which could modify the bolting of the plant (Gautam *et al.*, 2006). The result of this study corroborate the findings of Abdissa *et al.* (2011) who reported the proportion of onion bolters per plot decreased by about 11 and 22% in the control in response to the application of 69 and 92 kg N ha^{-1}, respectively. This result was also in agreement with the finding of Yamasaki and Tanaka (2005) who found that low nitrogen promoted bolting in *Allium fistulosum* L. plants exposed to low temperature for 35 days.

The varieties differed in the number of bolting plants, with the Nasik Red variety having fewer numbers of bolting plants than the other two varieties (Table 2). This showed that bolting is a genetic characteristic on top of being under the influences of agronomic practices such as N supply as well as environmental factors such as temperature. The onion genotypes also differ in ease of seed stalk development and kinds of physiological defects like pre mature bolting (Mandefro Nigussie *et al.*, 2009). The authors further reported that variety Nasik Red was not easily bolted type like the other varieties. This result is consistent with the findings of Diaz-Perez *et al.* (2003) who reported that bolting varied among varieties, with onion variety 'Pegasus' having the highest incidence regardless of the N fertilization rate.

Average fresh bulb weight

Onion variety significantly (P < 0.01) affected average fresh bulb weight of onion. However, Average fresh bulb weight was affected neither by nitrogen nor by the interaction effect of nitrogen and variety. The average fresh bulb weight of the Bombay Red onion variety was significantly higher than the average fresh bulb weights of the Nasik Red and Adama Red varieties by about 8 and 15%, respectively (Table 3). The significant differences in average fresh bulb weights among the three onion varieties are attributable to their genetic differences. This suggestion is consistent with the findings of Barzegar *et al.* (2008) who reported significant difference in bulb weight between varieties. This result is also supported by the study of Soleymani and Shahrajabian (2012) who reported significant differences in average bulb weight of onion varieties. This result is in line with the report of Mandefro Nigussie *et al*. (2009) who noted that onion varieties differ in bulb size or bulb weight where variety Bombay Red had the highest bulb weight followed by Nasik Red and the lowest was Adama Red (Table 3).

Bulb and neck diameter

The analysis of variance revealed that bulb diameter was significantly affected by both nitrogen (P < 0.01) and variety (P < 0.05) but not by the interaction of the two factors. The analysis also showed that neck diameter was significantly (P < 0.01) affected by variety but not by the nitrogen as well as by the interaction of the two factors. This could be due to the minimal direct effect of fertilization in the formation of neck diameter of onion bulbs. In response to increasing the rate of nitrogen from nil to 50 kg N ha^{-1}, there was no increase in bulb diameter. However, increasing the rate of the fertilizer to the higher levels significantly increased this parameter. For example, the bulb diameter of onion plants grown in the control treatment markedly exceeded the bulb diameter of onion plants grown with 200 kg N ha^{-1} by about 17%. This might be attributed to the role nitrogen plays in promoting cell growth and development through hormonal activities (Anwar *et al.,* 2001). The onion varieties also showed differences in terms of bulb diameter. The Bombay Red variety exceeded the Nasik and Adama Red varieties by 4 and 5%, respectively. The difference in bulb diameter might be attributed to generic variations. This suggestion is consistent with that of Gautam *et al.* (2006) who reported that onion varieties differed in bulb sizes or diameters in accordance with varietal differences.

Table 3. Mean effect of nitrogen application on average fresh bulb weight (g), bulb diameter (cm), neck thickness (cm), and bulb dry weight (%) of onion varieties

Nitrogen rate (kg ha^{-1})	Average fresh bulb weight	Bulb diameter	Neck diameter	Bulb dry weight
0	72.63	5.56c	1.26	13.05
50	73.56	5.80c	1.32	13.68
100	76.69	6.26b	1.35	13.97
150	76.70	6.72a	1.37	14.58
200	72.83	6.53ab	1.29	14.88
LSD (0.05)	NS	0.28	NS	NS
Variety				
Adama Red	69.63c	6.06b	1.38a	13.87b
Nasik Red	74.19b	6.10b	1.33a	15.12a
Bombay Red	80.09a	6.36a	1.25b	13.11b
LSD (0.05)	4.25	0.22	0.07	1.13
CV (%)	7.60	4.80	7.80	10.80

NS: non-significant. Means in the same column sharing the same letter(s) are not significantly different at P=0.05.

The Adama Red and Nasik Red varieties had significantly higher neck diameter than the Bombay Red variety by about 10 and 6%, respectively (Table 3). The variation in neck diameter among the onion varieties could be due to genetic attributes. Large neck diameter occurs mainly when some proportion of the bulb fail to complete bulbing and leaves continue growing and heavy and continuous watering and late application of nitrogen also contribute to large neck diameter. Such bulbs have short postharvest life. In agreement with this result, Brewester (1987) reported that neck diameter is a physiological disorder that is influenced by seasons, sites and varieties, not by fertility. Narrow neck diameter is desired for onions since the photosynthetic translocation remain in bulbs that may contribute to the bulb diameter and bulb yield. Neck diameter in onion is an important character, because it indicates bulb storage ability where the onion variety with narrow neck diameter store better than large neck diameter (Gautam *et al*., 2006). Therefore, variety Bombay Red is better than the other two varieties. Increasing the rate of nitrogen from nil to 50 kg N ha^{-1} significantly increased bulb diameter; indicating that nitrogen promotes growth of bulbs in size**.** This result is in agreement with Nasreen *et al.* (2007) who reported a significant increase in the diameter of bulbs due to the application of N up to 120 kg ha^{-1}. Similar results were reported by Yadav *et al*. (2003) who found that application of N at 150 kg ha^{-1} enhanced the formation of bulbs with larger diameters. This result is also consistent with the results of Abdissa *et al.* (2011) who reported that, regardless of the rate, N fertilization increased bulb diameter.

Bulb dry weight and dry total biomass

Bulb dry weight was significantly (P < 0.01) influenced by the effect of variety. However, the effect of nitrogen rates did not significantly influence bulb dry weights. Similarly, both nitrogen rates and variety did not significantly influence dry total bulb biomass. The bulb dry weight of the Nasik Red onion variety exceeded the bulb dry weights of Adama Red and Bombay Red varieties by about 9 and 15%, respectively (Table 3). These results indicate that shoot and bulb dry weights are attributes of varietal differences (Mandefro Nigussie *et al*., 2009). Thus, Adama Red and Nasik Red varieties were superior to the Bombay Red variety in terms of bulb dry matter contents whereas the Nasik Red variety was superior to the other two varieties in terms of bulb dry weight. A high bulb dry matter content is a welcome attribute for consumers as well as producers. One advantage of a high bulb dry matter contents could be better bulb storability under ambient conditions. Onion varieties having higher dry matter contents were reported to store better than those having low dry matter contents (Toul and Pospisilova, 1968). Another advantage of higher dry matter contents could be better culinary qualities. Consistent with this suggestion, Kodic (1971) found that onion varieties with higher dry matter contents retained their aroma for a longer time than those lower dry matter contents.

Shoot dry weight

The interaction effect of nitrogen and variety significantly (P<0.05) affected shoot dry weight of onion. Variety Nasik Red had the highest shoot dry weight at 50 and 150 kg N ha^{-1} while variety Bombay Red and Adama Red at 100 kg ha^{-1}.

Table 4. Interaction effect of nitrogen rate and varieties on shoot dry weight (t ha^{-1})

	Nitrogen rate (kg ha^{-1})				
Variety	0	50	100	150	200
Adama Red	1.06abc	0.84bcd	1.13ab	0.85bcd	0.89bcd
Nasik Red	0.82bcd	1.22a	0.85bcd	1.00abcd	0.96abcd
Bombay Red	0.78cd	0.89bcd	1.00abcd	0.71d	0.74cd
	CV (%) =	18.2	LSD (0.05) =	0.28	

Means followed by the same letter (s) are not significantly different at P=0.05.

Total and marketable bulb yields

The analysis of variance indicated that variety significantly (P < 0.01) affected total bulb yield. Similarly, the analysis of variance also showed that there were significant influences of nitrogen (P < 0.05) as well as variety (P < 0.01) on marketable bulb yield. However, neither the main effect of nitrogen nor the interaction effect of nitrogen and variety influenced this parameter significantly. Similar to the effect on total bulb yield, there was no significant interaction effect of the two factors on marketable bulb yield. Increasing the rate of nitrogen from nil to 50 kg N ha^{-1} significantly enhanced marketable bulb yield (about 8% increases) (Table 5). However, increasing the rate of nitrogen beyond 50 kg N ha^{-1} did not increase marketable bulb yield of onion. This is because nitrogen concentration ranges in specific plant parts, and changes within this range of concentrations do not increase or decrease growth or production (Fageria, 2009). Consistent with the results of this study, in the central rift valley of Ethiopia, irrigated onion plants benefited from application of 90 to120 kg ha^{-1} N compared to the unfertilized crops (Aklilu, 1997). Furthermore, Jahan *et al*. (2010) reported that the highest marketable bulb yield of onion (8.53 ton ha^{-1}) was obtained in response to the application of 120 kg N ha^{-1} but, further increase of N rate did not show any significant increase in yield of onion and the lowest yield (6.70 ton ha^{-1}) was recorded in the control treatments. The result of this study also agrees with the findings of Abdissa *et al.* (2011) who reported that application of N at a rate of 69 kg ha^{-1} improved marketable bulb yields of onion by about 5.74 and 4.06 ton respectively compared to the control treatment. Similarly, Krasteva and Panayotov (2009) reported that increase in N doses up to 300 kg N ha^{-1} was followed by a steady increase in the bulb yield of the marketable production.

Table 5. Mean effect of nitrogen rate and varieties on total, marketable and unmarketable bulb yield (t ha^{-1}) of onion

Nitrogen (kg ha^{-1})	Fresh bulb yield		
	Total	Marketable	Unmarketable
0	28.12	22.50b	5.62
50	29.6	24.02ab	5.58
100	29.37	24.25a	5.12
150	30.2	24.93a	5.27
200	28.75	23.37ab	5.38
LSD (0.05)	NS	0.95	NS
Variety			
Adama Red	28.45b	23.35b	5.10b
Nasik Red	28.31b	23.08b	5.23b
Bombay Red	30.87a	25.00a	5.87a
LSD (0.05)	0.77	0.74	0.31
CV %	5.90	7.00	9.09

NS: non-significant. Means in the same column sharing the same letter(s) are not significantly different at P =<0.0 5.

Similarly, significant ($P < 0.01$) difference was observed among the three varieties in total bulb yield. Variety Bombay Red was the highest in total and marketable bulb yield than Adama Red and Nasik Red. Adama Red and Nasik Red were statistically identical in total and marketable yield. Variety Bombay Red exceeded Adama and Nasik Red by about 8% in total bulb yield, and also higher than the two varieties by about 7 and 8% in marketable bulb yield respectively. The onion bulb yield also attributed due to the varietal differences. This result was in line with the study of Gautam *et al*. (2006) who reported that the mean highest fresh bulb yield (16.6 t ha^{-1}) was observed on the variety N-53 whereas the lowest yield (7.25 t ha^{-1}) was recorded for variety Nasik Red. This might be due to the highest bulb size and diameter of the variety that could directly increase bulb yield. However, the highest unmarketable bulb yield (5.87 t ha^{-1}) was exhibited by variety Bombay Red. Bulbs like double bulbs, under sized, oversized and diseased bulbs were all considered as an unmarketable bulb yields. In the current study, total bulb yield strongly and positively correlated with leaf length ($r^2 = 0.458$), bulb diameter ($r^2 = 0.57$) and negatively associated with bolting percentages ($r^2 = -0.516$). Marketable bulb yield significantly and positively correlated with leaf length ($r^2 = 0.595$), neck thickness ($r^2 = 0.306$), bulb diameter ($r^2 = 0.42$) and total bulb yield ($r^2 = 0.92$). This positive correlation contributed for the increasing of marketable bulb yield while negative relationships contributed for the reduction of marketable bulb yield like that of bolting.

Bulb weight loss

Nitrogen significantly influenced bulb weight loss starting 30 days after storage to further storage periods. Similarly, nitrogen rate significantly ($P < 0.05$) influenced bulb weight loss at 30 days after storage. Variety significantly ($P < 0.05$) affected bulb weight loss at storage periods of 10 and 20 days. Neither variety nor its interaction with nitrogen had any significant effect on bulb weight loss. Bulb weight loss increased by about 18, 22, 25, 27, 23, 22 and 20 % over control in respect to 30, 40, 50, 60, 70, 80 and 90 days of storage periods, respectively

in response to the application of 200 kg N ha^{-1} (Table 6). Increasing nitrogen rate from nil to higher rate linearly increased bulb weight loss throughout all the storage periods. The weight loss was associated with the resumption of higher incidence of sprouting and rotting presumably through increase in the rate of respiration. Throughout the storage period, there was an increase in percent weight loss where this could be associated with physiological parameters that lead to higher respiration rate under the ambient storage condition of this experiment (average daily 29.4°C maximum and 8.6°C minimum temperature and 40.3% RH). Increasing nitrogen application from nil to 150 kg ha^{-1} showed statistical parity in bulb weight loss at 30 and 40 days after storage.
According to Mandefro Nigussie et al., (2009)., the percentage weight loss of onion bulb was 10.6%, 15.9% and 25.2% in three months of storage period and 14.0%, 32.7% and 61.8% in six months of storage periods under storage temperature of 1, 4.5 and 21 ºC, respectively. In conformity with this result, Msika and Jackson (1997) described onion variety specific weight losses of between 2 and 5% per month in warm ambient storage in Zimbabwe. Even though non-significant effect in weight loss was observed among the three varieties, except at 10 and 20 days after storage, slight differences in bulb weight losses were observed through the storage periods. At early storage periods, variety Adama Red had 11.8 and 12% bulb weight losses over Bombay Red at 10 and 20 days after storage, respectively (Table 6). However, through the storage periods, weight loss among the varieties did not influence significantly. This result is in conformity with findings of Kospell and Randle (1997) who reported loss in variety dehydrator 'Number 3' and cultivar 'Granex 33' during the first month of storage, which was gradual weight loss with increased storage time. The changes in the chemical composition of bulbs can accelerate or inhibit certain physiological processes (Jurgel-Malocka and Suchorska-Orlowska, 2008), and significantly affect the bulb shelf life.

Sprouted bulbs

Both nitrogen and variety significantly influenced percentage of sprouted bulbs throughout the storage periods. Percentage of sprouted bulbs significantly influenced by nitrogen starting from 30 days after storage and onwards. Similarly, variety also significantly ($P < 0.001$) affected sprouted bulbs at 30 days and at further storage periods. However, nitrogen and variety had no significant interaction effect on sprouted bulbs throughout the storage periods. Application of 200 kg N ha^{-1} increased sprouted bulbs by about 27.6, 25, 29, 31, 28.6, 30, 29 and 22.5% after storage periods of 20, 30, 40, 50, 60, 70, and 80 and 90 days, respectively, as compared to control (Table 7). In line with this result, Celestino (1961) explained that the role of N in increasing the sprouting of bulbs could be attributed to increase in the concentration of growth promoters than inhibitors with high N nutrition. Percentage of sprouted bulbs at 30, 40 and 50 days after storage in response to application of 50 and 100 kg N ha^{-1} were statistically non-significant. This means that application of nitrogen up to 100 kg ha^{-1} had no significant differences on sprouted bulbs as it contributed for bulb yield increment (Table 7).
In line with the present result, Dankhar and Singh (1991) showed that high dose of N produced large neck diameter bulbs that increased sprouting in storage due to greater access of oxygen and moisture to the central growing point. This result was on par with that of Bhalekar *et al.* (1987) who observed that sprouting of onion was increased with increasing nitrogen levels from 0 to 150 kg N ha^{-1}. Variety Adama Red had the highest percentage of sprouted bulbs throughout the storage period while Nasik Red was the lowest. Variety Adama Red and Bombay Red produced lower bulb dry weight as compared to Nasik Red as it might be contributed to percent of sprouting bulbs. Percentage of sprouted bulbs of Adama and Bombay Red did not significant differences at almost all storage periods, except at 80 days after storage (Table 7).

Table 6. Mean effect of nitrogen application on percentage bulb weight loss of onion varieties

Nitrogen				Storage	periods(days)				
(kg ha^{-1})	10	20	30	40	50	60	70	80	90
0	(1.92)1.38	(3.88)1.96	(5.18)2.27b	(6.55)2.55b	(8.51)2.91c	(10.58)3.24d	(14.16)3.76d	(16.87)4.10d	(19.88)4.46d
50	(1.80)1.33	(3.68)1.91	(5.64)2.36b	(7.92)2.79b	(10.63)3.24ab	(13.91)3.71c	(17.06)4.12c	(20.42)4.51c	(23.83)4.88c
100	(1.77)1.31	(3.69)1.88	(5.76)2.37b	(8.08)2.82b	(11.22)3.33b	(15.06)3.87bc	(18.93)4.34bc	(22.53)4.74bc	(26.15)5.11bc
150	(1.76)1.32	(3.77)1.93	(6.02)2.44b	(8.47)2.90b	(12.70)3.54ab	(17.15)4.13ab	(21.16)4.58ab	(25.18)5.00ab	(28.48)5.32b
200	(1.93)1.38	(4.26)2.06	(7.84)2.77a	(10.69)3.25a	(15.15)3.88a	(19.71)4.43a	(24.06)4.90a	(27.56)5.25a	(31.38)5.60a
LSD (%)	NS	NS	0.33	0.34	0.37	0.36	0.32	0.31	0.28
Variety									
Adama Red	(2.08)1.44a	(4.38)2.09a	(6.28)2.49	(8.26)2.86	(11.48)3.38	(15.01)3.85	(19.32)4.37	(23.27)4.80	(27.05)5.18
Nasik Red	(1.79)1.33ab	(3.73)1.92ab	(6.13)2.44	(8.28)2.85	(11.55)3.35	(15.16)3.86	(18.72)4.30	(22.01)4.67	(25.33)5.02
Bombay Red	(1.64)1.27b	(3.46)1.83b	(5.86)2.39	(8.49)2.88	(11.89)3.42	(15.67)3.92	(19.18)4.35	(22.26)4.69	(25.44)5.02
LSD (%)	0.12	0.18	NS	NS	NS	NS	NS	NS	NS
CV (%)	12.00	12.50	14.10	12.50	11.30	9.60	7.80	6.80	5.70

NS=non-significant; means in the same column sharing the same letter(s) are not significantly different at P=0.05; means in the brackets are original values while means out of brackets are transformed.

Table 7. Mean effect of nitrogen rate and varieties on percentage sprouted bulbs of onion

Nitrogen	Storage periods(days)							
(kg ha^{-1})	20	30	40	50	60	70	80	90
0	(0.94)1.18b	(2.06)1.54b	(3.56)1.76b	(5.06)2.11b	(6.94)2.52b	(8.89)2.91d	(11.06)3.26c	(15.17)3.85c
50	(1.28)1.32ab	(2.83)1.79ab	(4.72)2.12ab	(7.33)2.65ab	(9.56)3.04ab	(11.62)3.38c	(14.11)3.74b	(16.72)4.08c
100	(2.17)1.59a	(3.28)1.91ab	(5.28)2.27ab	(7.89)2.79ab	(10.39)3.20ab	(13.28)3.63bc	(18.11)4.22a	(20.00)4.47b
150	(2.06)1.57ab	(3.94)2.05a	(6.28)2.41ab	(9.50)2.96a	(11.94)3.34a	(15.83)3.93ab	(20.72)4.52a	(24.67)4.96a
200	(2.28)1.63a	(3.94)2.06a	(6.56)2.48a	(9.83)3.08a	(13.06)3.53a	(17.44)4.15a	(21.11)4.58a	(25.00)4.97a
LSD (%)	0.28	0.34	0.46	0.50	0.51	0.38	0.43	0.33
Variety								
Adama Red	(2.20)1.60a	(4.40)2.17a	(6.80)2.57a	(9.57)3.06a	(12.73)3.53a	(15.53)3.90a	(20.13)4.43a	(22.40)4.69a
Nasik Red	(1.23)1.28b	(2.03)1.54b	(3.20)1.69b	(5.07)2.12b	(6.80)2.50b	(10.17)3.12b	(13.94)3.67b	(17.77)4.18b
Bombay Red	(1.80)1.49ab	(3.20)1.90a	(5.83)2.37a	(9.13)2.97a	(11.60)3.36a	(14.53)3.77a	(17.00)4.09ab	(20.77)4.53a
LSD (%)	0.21	0.27	0.36	0.39	0.40	0.29	0.35	0.26
CV (%)	19.60	19.00	21.50	19.00	16.90	11.10	11.10	7.80

Means in the same column sharing the same letter(s) are not significantly different at P=0.05; means in the brackets are original values while means out of brackets are transformed.

Rotten bulbs

Nitrogen significantly ($P < 0.001$) affected percentage of rotten bulbs at 70, 80 and 90 days after storage. However, percent of rotten bulbs was not significantly influenced by nitrogen at 60 days after storage. Similarly, variety significantly ($P < 0.05$) affected rotten bulbs at 60 and 70 days after storage; but not at 80 and 90 days of storage. The interaction effect of nitrogen and variety was not significant on percent of rotten bulbs throughout the storage periods. Moreover, during the storage periods, no rotten bulbs were observed till 50 days after storage. The highest percent of rotten bulbs were observed due to the application of 200 kg N ha^{-1}, while the lowest was with unfertilized plot through the storage periods (Table 8). Application of 200 kg N ha^{-1} increased the percent of rotten bulbs by about 16, 45.6, 36.6 and 30% as compared to controls at 60, 70, 80 and 90 days after storage periods, respectively. Rotten bulbs at 70, 80 and 90 days after storage in response to application of 150 and 200 kg N ha^{-1} were statistically identical. Increasing the amount of N fertilizer linearly increased the percentage of rotten bulb through all the storage periods. In conformity with this result, ASHS (2003) also stated that percent of decayed bulbs increased at a steady rate with the rate of N applied. This study is also in agreement with the study of Jones and Mann (1963) who reported that onion bulb produced without nitrogen application had the lowest rotting (22%) while highest rotting (36 - 54%) was recorded in bulbs produced under high dose of nitrogen.

Table 8. Mean effect of nitrogen application on percentage rotten bulbs and reducing sugars (%) of onion varieties

Nitrogen	Storage periods (days)				Reducing
(kg ha^{-1})	60	70	80	90	sugar
0	(0.17)0.80ab	(1.33)1.12c	(2.83)1.66d	(4.94)2.21d	2.87a
50	(0.06)0.74b	(1.94)1.37c	(3.78)1.91c	(6.89)2.61c	2.92a
100	(0.22)0.84ab	(2.89)1.68b	(5.11)2.25b	(8.28)2.87b	2.56b
150	(0.33)0.88ab	(4.22)2.01a	(6.78)2.58a	(9.67)3.10a	2.40b
200	(0.44)0.95a	(4.33)2.06a	(6.94)2.62a	(10.11)3.17a	2.13c
LSD (%)	0.16	0.25	0.23	0.20	0.16
Variety					
Adama Red	(0.10)0.77b	(2.83)1.62ab	(4.87)2.163	(7.97)2.794	2.58
Nasik Red	(0.20)0.82ab	(2.50)1.52b	(4.93)2.171	(7.63)2.729	2.63
Bombay Red	(0.40)0.94a	(3.50)1.80a	(5.47)2.278	(8.33)2.851	2.53
LSD (%)	0.12	0.19	NS	NS	NS
CV (%)	19.80	15.70	10.70	7.30	6.50

NS=non-significant; means in the same column sharing the same letter(s) are not significantly different at P =<0.0 5; means in the brackets are original values while means out of brackets are transformed.

The increase in percentage of rotten bulbs due to increased nitrogen rate could be attributed to the fact that higher rates of nitrogen enhanced plants to produce bulbs with soft succulent tissues which make them susceptible to the attack by a disease caused by microorganisms and leads to production of bulbs with large neck diameter which are difficult to dry (Gautam *et al.*, 2006). Each increase of N fertilizing dose, was followed by the significant increase of the quantity of rotten bulbs. Practically, the weight of rotten bulbs at the highest N fertilizer dose doubled compared to the use of no fertilizer or the use of least fertilizer dose on experimental plots (ASHA, 2003). This result is also supported with findings of Wright (1993) who reported that bulbs of onions given 240 kg N ha^{-1} (double the local recommended rate) had more rots during storage than onions that received no N or 120 kg N ha^{-1} and onions that received N late in the growing season had more storage rots than onions that received N early in the season, or was not supplied with N. In the present result, there were differences among varieties in rotten bulbs at 60 and 70 days of storage periods. Variety Bombay Red had more percent of rotten bulbs by about 13 and 18% at 60 days; and 16 and 10% at 70 days after storage over Nasik and Adama Red, respectively. This means that rotten bulbs might be contributed to the varietal differences. This result is in line with that of Diaz-Perez *et al.* (2003) who reported that after an 8 months storage, the percent of decayed bulbs was higher in 'Pegasus' (63%) than in 'Granex 33' (52%).

Total and reducing sugars

Reducing sugars was significantly ($P < 0.001$) affected by the effect of nitrogen fertilizer use. However, the effect of variety as well as its interaction with nitrogen rate did not significantly influence concentrations of reducing sugars. Similarly, both nitrogen rates and variety did not have significant effect on total sugars. Application of 50 kg N ha^{-1} did not show significant difference on reducing sugar concentrations as compared to control, however, there was a slight increase in reducing sugars in response to application of nitrogen fertilizers from nil to 50 kg ha^{-1} (Table 8). According to the study of Banu *et al*. (2007) in potato, higher nitrogen level, 480 kg ha^{-1} increased the reducing sugars content (268 mg100 g^{-1}) compared to 240 kg N ha^{-1} (185 mg 100 g^{-1}) in potato varieties. However, application of nitrogen linearly decreased the reducing sugar concentration of onion bulb. Application of 200 kg N ha^{-1} decreased reducing sugars by about 25.9% as compared to onion with unfertilized plots. Application of nitrogen fertilizer beyond 50 kg ha^{-1} did not increase reducing sugars of onion bulbs. In agreement with this result, Maier *et al.* (1990) reported that glucose and fructose concentrations of onion bulb decreased significantly ($P < 0.05$) as rate of applied N increased where at 0 kg N ha^{-1}, glucose and fructose concentrations were 24.3-29.5 and 9.2-13.2 mg g^{-1} fresh weight, respectively, while at 590 kg N ha^{-1} the concentrations were 20.9-27.0 and 8.5-9.7 mg g^{-1}, respectively.

Total soluble solids (TSS)

Nitrogen significantly ($P<0.001$) affected TSS content of onion bulbs. Similarly, nitrogen and variety interact to influence TSS content of onion significantly ($P<0.001$). However, no significant difference for TSS content due to the main effect of variety was noted. It was observed that nitrogen application steadily decreased TSS content of onion bulbs. This result is in agreement with that of Singh and Dhankar (1989) who observed the application of nitrogen consistently decreased TSS content of onion bulbs. This might be due to proportional rise in respiration and carbohydrate metabolism that brings a rapid decline in TSS content of bulbs. This decrease might be due to the effect of curing onion bulbs before total soluble solids were analyzed. The highest TSS content of onion bulb was recorded at no nitrogen fertilization for the three onion varieties. But, variety Adama Red and Nasik Red had the lowest TSS content at nitrogen application of 200 kg ha^{-1}, whereas Bombay Red had the lowest at 150 kg N ha^{-1} (Table 9). Variety Adama Red and Nasik Red were statistically non-significant in response to the application of 100 kg N ha^{-1}. Increasing nitrogen rate from nil to 50 and 100 kg ha^{-1} reduced TSS content of onion bulb by about 5% in variety Adama Red and also further increasing nitrogen rate from 150 and 200 kg ha^{-1} reduced TSS content of onion bulb by about 4 and 11% in the same variety as compared to control treatment. Application of 200 kg N ha^{-1} decreased TSS content of bulbs by about 11% than unfertilized plots in variety Nasik Red.

Table 9. Interaction effects of nitrogen rate and onion varieties on total soluble solids.

	Nitrogen rate (kg ha^{-1})				
Variety	0	50	100	150	200
Adama Red	11.02a	10.97abc	10.43de	10.53bde	9.85fg
Nasik Red	10.97ab	10.80abcd	10.42de	10.51de	9.76g
Bombay Red	11.03a	10.66abcde	10.26ef	9.93fg	10.87abcd
	LCD (%) =	0.39	CV (%) =	2.20	

Means followed by the same letter (s) are not significantly different at P<0.001.

CONCLUSION

Onion is the most important crop grown in eastern part of Ethiopia on small scale lands. Farmers produce onion bulbs from seed of unknown sources and small bulb size with low bulb yield and also apply different fertilizer rates in a ring method. Fedis was lowland, where more dosage and suboptimal fertilizer application was expected to affect the bulb yield and postharvest quality of onion due to low moisture conditions of the soil. Therefore, improved varieties and fertilizer management for onions may help to increase yield, improve quality, particularly bulb size and storability, and thus offer growers premium prices.

In general, application of 150 and 200 kg N ha^{-1} did not have significant differences on leaf length, physiological maturity, mean bulb weight, shoot dry weight, bulb dry weight and marketable bulb yield as compared to application of 100 kg N ha^{-1}. Similarly, application of 100 kg N ha^{-1} significantly reduced physiological weight loss, rotten bulbs and sprouted bulbs by about 4, 7 and 10%, respectively, than application of 150 kg N ha^{-1}; and by about 9, 9 and 10%, respectively, than the application of 200 kg N ha^{-1} at 90 days after storage periods. Considering the conditions of the area, variety Bombay Red could be recommended based on its high total bulb yield, marketable bulb yield, and early maturity and for superior storage quality over the two varieties. In conclusion, the use of the Bombay Red variety at the N fertilizer application rate of 50 to 100 kg N ha^{-1}, results in maximum bulb yield and quality of onion in the study area.

ACKNOWLEDGEMENTS

I am greatly indebted to the Oromia Agricultural Research Institute for funding the research. I am also most grateful to Amsalu Wegari and Adane Ashebir for their involvements in field data collection.

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