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Effects of Different Level of Nitrogen Fertilizer Application on Growth, Yield, Quality and Storage Life of Onion (Allium cepa L.) at Jimma, South Western Ethiopia

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Abstract
Onion (Allium cepa L.) is one of the most important vegetable crops produced in Ethiopia. Yield and productivity of the crop has been far below the regional and national standards owing to several factors; absence of location specific fertilizer recommendation being the major among others. In Ethiopia, post harvest loss of vegetables contributed up to 30% yield reduction. Thus, a field experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine Research field during dry season to study the effects of Nitrogen fertilizer application on growth, yield, quality and storage life of irrigated onion under Jimma condition, South Western Ethiopia. The treatments consisted of four levels of Nitrogen (0, 50, 100 and 150 $kg\ N\ ha^{-1}$) that laid out in Randomized Complete Block Design with three replications. Data on growth, yield, bulb quality and storage life parameters were recorded and analyzed using GenStat 12.1 version computer soft ware packages. Results of the study revealed that; Nitrogen fertilizer applications had shown a highly significant effect on growth, yield and quality of onion. Similarly, the keeping qualities of the Onion bulbs are highly influenced by application of N at different levels. Excessive application of Nitrogen fertilizer caused higher bulb rots (%); bulb sprouts (%) and weight loss (%) during the three month storage time at ambient temperature. This can be recommended for use by potential onion investors or farmers in the study area.
Keywords: Growth, Nitrogen, Onion, Quality, Storage life, Yield.
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INTRODUCTION

Onion was introduced to the agricultural community of Ethiopia in the early 1970's when foreigners brought it in. Though shallots were traditional crop in Ethiopia, Onion is becoming more widely grown in recent years. Currently, the crop is produced in different parts of the country for local consumption and for export of flowers to European markets (Lemma and Shimelis, 2003).

Onion is considerably important in the daily Ethiopian diet. All the plant parts are edible, but the bulbs and the lower stem sections are the most popular as seasonings or as vegetables in stews (MoARD, 2009). It is one of the richest sources of flavonoids in the human diet and flavonoid consumption has been associated with a reduced risk of cancer, heart disease and diabetes. Flavonoids are not only anti-cancer, but also are known to be anti bacterial, antiviral, anti-allergenic and anti-inflammatory. One Onion quality parameter, the percentage of single center bulbs, has become important to meet demands of both processing and fresh market buyers (Brewster, 1990 and Pelter, 2004).

Different cultural practices are known to influence yield and quality of dry bulb. So far, research in the country was mainly focused on the identification of superior cultivars of onions but mineral nutrition is main factors that affect growth, yield and quality of onion (Chung, 1989). Nitrogen mineral nutrient is often referred to as the primary macronutrients because of the probability of plants being deficient in these nutrients and because of the large quantities taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components (Bungard *et al.,* 1999). It is one of the most complexes in behavior, occurring in soil, air and water in organic and inorganic forms. For this reason, it poses the most difficult problem in making fertilizer recommendations (Archer, 1988). Plant demand for Nitrogen nutrient can be satisfied from a combination of soil and fertilizer to ensure optimum growth. Onion is more susceptible to nutrient deficiencies than most crops because of their shallow and un-branched root system; hence they require and often respond well to addition of fertilizers (Brewester, 1994).

A number of production constraints are responsible for such reduced bulb yield, quality and storage life of which lack of specific fertilizer recommendation for the area is in the top list. Better understanding of the nutrient requirements of Onion plant is needed in order to develop management strategies, which optimize fertilizer use of the crop and thereby increase returns with premium bulb qualities to the producers. Moreover, improved fertilizer management for Onion may help to improve quality, particularly bulb size and storability, and thus offer growers premium prices. Hence there is an urgent need to identify the optimum Nitrogen nutrient level for better productivity, bulb quality and storage life of Onion in the area. In the light of the above, the study was undertaken to determine the optimum level of N fertilizer for optimum growth, yield, bulb quality and storage life of Onion (*Allium cepa* L.) at Jimma, South Western Ethiopia.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted under field condition at Jimma University College of Agriculture and Veterinary Medicine research field under irrigation condition. Jimma University College of Agriculture and Veterinary Medicine is geographically located 346 km southwest of Addis Ababa at about 7^0, 33' N latitude and 36^0, 57' E longitude and an altitude of 1710 meter above sea level. The analysis of soil samples from the top 30 cm depth of the experimental site before the experiment was done. The mean maximum and minimum temperatures are 26.8^0C and 11.4^0C, respectively and the mean maximum and minimum relative humidities are 91.4% and 39.92%, respectively. The mean annual rainfall of the area is 1500mm (BPEDORS, 2000).

Table1. *Soil physical and chemical properties of the experimental site*

Characteristics	Units
Sand	8%
Silt	44%
Clay	48%
Textural class	Silty clay
Organic carbon	1.46%
Total nitrogen	1.42%
pH 1:1 water	5.94
Electric conductivity (1:1)	53.1(µS/cm)
Available P (ppm)	2.80ppm
Bulk density (g/cm3)	1.58

The Soil Physical and chemical properties of experimental site were done at Jimma Agriculture Research center and Jimma University College of Agriculture and Veterinary Medicine soil laboratory.

Experimental Materials

The experiment consisted of three types of fertilizer in different levels, which were Nitrogen (N) at four levels. Onion (*Allium cepa* L.) variety Bombay Red was used. The seed was collected from Melkessa Agricultural Research Center.

Table 2: *Details of Onion variety used in the study*

Variety Name	Year of release	Area of adaptation		Days to maturity
		Altitude(m)	Rain fall(mm)	
Bombay Red	1980	700-2000	Irrigated	<120

Source: - EARO (2004)

Experimental Design and Layout

The experiment was laid out in a 4x3 arrangement in a Randomized complete Block Design (RCBD) with three replications. The treatments were randomly assigned to the experimental plots. Onion seedlings were raised on a well prepared seedbed whose dimension was 5mX1m. The seeds were sown in rows marked 15 cm interval across the length of the seed bed and the beds were covered with dry grass mulch until emergence. Complete germination of the seeds took place within 7 to 10 days of sowing and seedlings were thinned out after three weeks in order to maintain optimum plant population and to keep them vigorous. Watering of the seed bed was done always in the morning and afternoon using watering can.

The seed beds were watered before uprooting the seedlings in order to minimize the damage of the roots. Healthy, uniform and 52 days old seedlings were transplanted to the prepared field at spacing of 20 cm between rows and 10cm between plants was used according to the EARO, 2004 recommendation. Finally, the seedlings were watered after transplanting and 50% of each levels of the N as UREA (46%) were side dressed and the remaining 50% of each levels of N was applied after a month of transplanted date. Weeds were controlled mechanically (by hand weeding). The plots were irrigated daily until maturity.

The size of each plot was 1.2 m^2 (1 m x 1.2 m). All the 12 treatments combinations were randomly assigned to the unit plot of each block so as to allot one treatment combination only once in each block. There were 10 plants in each row and 60 plants per plot. A foot path of 0.5m and 1 m were left between plots and replications, respectively. Mancozeb were applied three times to prevent the damage by of Fungi due to the humid weather condition at rate of 4.0 kg per ha with mixing 600 liter of clean water. All other agronomic management practices were provided as per the recommendation equally for all the treatments (Getachew *et al.,* 2009).

Lastly, bulbs from the central four rows were harvested after 60% top part fall and used for analysis. Curing bulb was done for ten days under partial shade and ten sample bulbs were taken to storage room. Bulbs were stored in naturally ventilated house constructed from mesh wire wall and corrugated iron sheet roofing. Daily storage room temperature and relative humidity was recorded using hand Psychrometer and the average daily maximum and minimum temperature during the two month storage periods were used.

Statistical Analysis

The parameters considered in this study were subjected to statistical analysis. Analysis of variance (ANOVA) was done using GenStat versions12.1 (VSN International, 2008) with the REML variance component analysis. Mean difference were tested following least significant difference (LSD) at ($P \leq 0.05$). Interpretations and use of some biometrical equations were made according to Gomez and Gomez (1984).

RESULTS AND DISCUSSIONS

Growth Parameters

Plant height

Application of N had shown a highly significant ($p<0.001$) effect on mean plants height at physiological maturity. The highest mean value (49.59 cm) was recorded from the plot that received 150 kg of N ha^{-1}. Respect less of levels, maximum application of N at 150 kg ha^{-1} increased the mean plants height by about 12% as compared to the control (43.84 cm). The increase in height at increased application of N could be attributed to its involvement as building blocks in the synthesis of amino acids, as they link together and form proteins and make up metabolic processes required for plant growth. Similar results have been reported by Amans *et al*. (1996), Kumar *et al*. (1998), Khan *et al*. (2002), El-Shaikh (2005), Shaheen *et al. (*2007) and Abdissa *et al.* (2011).

Leaf length

A highly significant variation ($p<0.001$) in the leaf length (cm) was observed at the application of N treatments. The highest mean value (39.84 cm) was obtained from the plot that received 150 kg of N ha^{-1}. Maximum application of N at 150 kg ha^{-1} increased mean leaf length per plants by about 16% when compared to control (33.51 cm). The positive effect of N on leaf length may be due to its role on chlorophyll, enzymes and proteins synthesis. The results of this study are in agreement with finding of Jilani (2004) who reported that, application of 200 kg N ha^{-1} significantly enhanced the length of onion leaves. Similarly, Kumar *et al.* (1998) and Singh and Chaure (1999) indicated that application of N at 150 kg ha^{-1} gave the best result with the regard to onion leaf length. Similarly Abdissa *et al.* (2011) also reported that N application showed significant effect on onion leaf length.

Leaf sheath (shaft) length

Without considering the levels, maximum application of N at 150 kg ha^{-1} increased the mean leaf sheath length by about 23% as compared with the unfertilized plot (5.09 cm). This could be shows that nitrogen plays an important role in leaf sheath length via its role in vegetative growth. These results are in conformity with the findings of Khan *et al*. (2002) who reported that number of leaves per plant increased with increasing nitrogen level up to 150 kg ha^{-1} which is also similar for leaf sheath length.

Percentage of bolters

Percentage of bolted plants was highly significantly affected by N application. All the levels of N showed a highly significant ($p<0.001$) difference on Onion percentage of bolted. Increased levels of N fertilization significantly reduced the bolting percentage. The proportion of percentage bolted decreased by about 15%, 36% and 59% in response to the application of 50, 100 and 150 kg of N ha^{-1}, respectively over the control treatments. This could be associated with the effect of N in extending the vegetative growth period of plants while delaying flowering. The findings of this investigation are in close conformity with those Yamasaki and Tanaka, (2005) who reported that, in *Allium fistulosum* L. low Nitrogen promoted bolting in onion plants. Abdissa *et al.* (2011) also reported similar results. As a general, significantly higher bolting percentage was observed on the control plants than the fertilized plants, which may be linked to limitation of N.

Bulb Yield Parameters

Bulb diameter and Bulb length

Application of N at different levels had shown a highly significant ($P<0.001$) difference on mean bulb diameter and length of Onion plants. Regardless of levels, maximum fertilization of N at 150 kg ha^{-1} increased the mean bulb diameter by about 13% in reference to the control treatments (5.22cm). Larger bulb diameter with higher yield in Onion due to N application is likely as because Nitrogen encourages cell elongation, above ground vegetative growth and to impart dark green color of leaves which may be linked to the increase in dry matter production and allocation to the bulb (Brady, 1985). This result is sustaining Nasreen *et al*. (2007) who reported that a significant increase in the mean diameter of bulbs due to the application of N up to 120 kg ha^{-1}. Similar results also reported by Yadav *et al*. (2003) who found that N at 150 kg ha^{-1}, enhanced the formation of bulbs with larger diameters. Kumar *et al*. (1998), Khan *et al*. (2002) and Abdissa *et al.* (2011) also reported that bulb diameter is significantly affected by the application of N.

***Table** 1: Effect of N fertilization on bulb length and bulb diameter*

Treatments	Bulb diameter (cm)	Bulb length (cm)
Nitrogen (kg ha^{-1})		
0	5.21^{c}	4.42^{c}
50	5.35^{c}	4.53^{c}
100	5.75^{b}	4.96^{b}
150	6.02^{a}	5.23^{a}
SE(+)	0.059	0.047
LSD	0.232	0.202
CV (%)	8.89	9.01

Means in a column followed by the same letter(s) are not significantly different at 5%

Mean bulb weight

There was statistically highly significant ($p<0.001$) difference in mean bulb weight due to application of N at different levels. The maximum application of N at a rate of 150 kg ha^{-1} increased the mean bulb weight by about 17%, as compared to the control treatments (41.35g). The mean bulb weight improvement in response to N application could be attributed to the increase in plant height, number of leaves produced, Leaf diameter, leaf length, and extended physiological maturity in response to the fertilization all might have increased assimilate production and allocation to the bulbs. Similarly, Kashi and Frodi (1998), Greenwood *et al*. (2001), Khan *et al*. (2002) and Abdissa *et al.* (2011) reported that significant increase in bulb weight due to increased N application.

***Table** 2: Mean bulb weight of onion per plant as influenced by applications of N*

Treatments	Mean bulb weight (g)
Nitrogen (kg ha^{-1})	
0	41.35^{d}
50	43.37^{c}
100	46.82^{b}
150	49.78^{a}
SE(±)	0.84
LSD	1.791
CV (%)	8.45

Means in a column followed by the same letter(s) are not significantly different at 5%

Marketable bulb yield

Regardless of levels, maximum application of N at 150 kg ha^{-1} increased the marketable bulb yield. This finding is in consistent with the result of Girigowda *et al*., (2005) who recorded that the higher marketable bulbs yield (41.69 t/ha) was recorded with fertilizer level of 188:75:188 kg of NPK ha^{-1}.

***Table** 3: Effect of N fertilizers on Marketable bulb yield*

Treatments	Marketable bulb yield/ ha (tons)
Nitrogen(kg ha^{-1})	
0	12.31**d**
50	13.60**c**
100	15.89**b**
150	16.93**a**
SE(±)	0.1084
LSD	0.2524
CV (%)	14.08

Means in a column followed by the same letter(s) are not significantly different at 5%

Unmarketable bulb yield

N had shown a highly significant ($P<0.001$) difference on the unmarketable bulb yield (t/ha). The result indicates that higher application of N decreased the unmarketable bulb yield per hectare and the highest unmarketable bulb yield was recorded in the unfertilized plots in all treatments. Without considering the levels, maximum application of N at rate of 150 kg ha^{-1} decreased the unmarketable bulb yield per hectare by about 5.2 % as compared to the unfertilized plot.

***Table** 4: The influence of different rates of N on Unmarketable bulb yield ha^{-1}*

Treatments	**Unmarketable bulb yield/ha (ton)**
Nitrogen (kg ha^{-1})	
0	0.98^{a}
50	0.78^{b}
100	0.63^{c}
150	0.47^{d}
SE(±)	0.036
LSD (0.05)	0.072
CV (%)	21.38

Means in a column followed by the same letter(s) are not significantly different at 5%

Total bulb yield

N had shown a highly significant (P<0.001) difference on the bulb yield (t/ha). The result indicates that higher application of N increased the bulb yield per hectare and the highest bulb yield (17.41t/ha) was recorded in the 150 kg ha^{-1} plots treatments as compared to the unfertilized plot.

***Table** 5: Main effect of N fertilizers on total onion fresh bulb yield*

Treatments	Total bulb yield per hectare (tone)
Nitrogen(kg ha^{-1})	
0	13.29**d**
50	14.39**c**
100	16.52**b**
150	17.41**a**
SE(±)	0.1111
LSD	0.2533
CV (%)	3.46

Means in a column followed by the same letter(s) are not significantly different at 5%

Harvest index

The results from Table 6 revealed that main application of N had shown a highly significant (P<0.001) difference on the harvest index of onion plants. Maximum application of N at 150 kg ha^{-1} increased the harvest index by about 17.6% over the respective checks. The observed harvest index improvement could be attributed to an increased photosynthetic area in response to N fertilization that enhanced assimilate production and partitioning to the bulbs. The investigation of Anwar *et al.* (2001) and Abdissa *et al.* (2011) on onion supports this result.

***Table** 6: Harvest indexes of Onion plant as influenced by applications of N*

Treatments	**Harvest index**
Nitrogen(kg ha^{-1})	
0	0.66^{d}
50	0.73^{c}
100	0.77^{b}
150	0.80^{a}
SE(±)	0.01
LSD(0.05)	0.0203
CV (%)	5.88

Means in a column followed by the same letter(s) are not significantly different at 5%

Quality Parameters of Onion Bulb

Total soluble sugars content (TSS)

Regarding the total soluble sugars content (TSS), the application of N had shown a highly significant (Table 7) difference. The highest TSS value (10.84 ^{o}Brix) was recorded in the application of N at the rate of 150 kg ha^{-1}; while the minimum TSS value (8.58 ^{o}Brix) was recorded in control treatments. Regardless of the levels, maximum application of N (150 kg ha^{-1}) increased the TSS by about 30% as compared to control (8.58 ^{o}Brix).

Table 7: *Effects of Nitrogen on TSS of onion bulb*

Treatments	Total soluble solid (°brix)
Nitrogen(kg ha^{-1})	
0	8.58**d**
50	9.35**c**
100	10.45**b**
150	10.84**a**
SE(±)	0.113
LSD	0.222
CV (%)	4.41

Means in a column followed by the same letter(s) are not significantly different at 5%

Bulb shape index

Considerable variation was observed in the result of bulb shape index. The shape of onion bulb can vary from flat to globe to torpedo which is in different markets having different requirements. The onion bulb shape was assessed by the bulb shape index; this was determined by the ratio of bulb length to diameter. The result of this study revealed that application of N at different levels had shown a highly significant (P<0.001) difference on the bulb shape index, while their interaction did not (Table 8). This result also showed that the null and lower application of N fertilizers increased the percentage of shape rejects as compared to the plot received higher levels of N (150 kg N ha^{-1}). Similarly, Geremew (2009) reported as bulb shape of onion is affected by mineral nutrients.

Table *8: Bulb shape index as affected by main effects of N*

Treatments	**Bulb shape index**
Nitrogen (kg ha^{-1})	
0	0.84^{c}
50	0.84^{bc}
100	0.86^{ab}
150	0.87^{a}
SE(±)	0.007
LSD(0.05)	0.021
CV (%)	5.15

Means in a column followed by the same letter(s) are not significantly different at 5%

Dry matter contents

Regarding the dry matter contents, main application of N had shown a highly significant effect, while their interaction did not (Table 9). The increasing levels of N encouraged bulbs with a significantly higher dry matter contents as compared to the unfertilized plot.

The maximum dry matter content of onion bulb (10.54%) was recorded with higher application of N at rate of 150 kg ha^{-1}. The minimum dry matter contents (9.26%) detected in control respectively (Table 9). This finding is in consistent with the result of Mojsevich (2008) and Bekele M (2018) who reported that with the increase of doses of the main fertilizer N, P and K 70, 45, 70 kg ha^{-1} to N, P and K 110, 75, 110 kg ha^{-1} caused the increase of dry matter content in bulbs from 14.6% to 15,5%.

Table *9: Dry matter contents as affected by applications of N.*

Treatments	**DMC (%)**
Nitrogen(kg ha^{-1})	
0	9.26^{d}
50	9.65^{c}
100	10.19^{b}
150	10.54^{a}
SE(±)	0.09
LSD(0.05)	0.18
CV (%)	3.82

Means in a column followed by the same letter(s) are not significantly different at 5%

Storage Life Parameters of Onion Bulb

Bulb storage rots percentage

N application had a highly significant (p≤0.05) effect on the bulb rotting percentage during the storage time (Table 10). The highest percent of bulb rot percentage (3.69%) recorded in the plots received 150 kg N ha^{-1} and the least bulb rot percentage is recorded with unfertilized plots. (Jones and Mann, 1963) also reported that onion bulbs produced without nitrogen application resulted in lowest rotting (22%), while highest rotting (36 to 54%) was recorded in bulbs produced under higher dose of nitrogen. Similarly in India, Singh and Dhankar (1991) also recorded that increasing the rate of applied nitrogen (N) from 50 to 150 kg ha^{-1} led to significant increases in storage rots of onion during 4 to 5 months under ambient conditions.

***Table** 10: Storage rots of bulb (%) as affected by applications of N.*

Treatments	Storage rotten bulbs (%)
Nitrogen(kg ha^{-1})	
0	7.78 (2.38^{c})
50	9.72 (2.88^{b})
100	10.83 (3.07^{b})
150	13.89 (3.69^{a})
SE(±)	0.39
LSD(0.05)	0.42
CV (%)	30.08

NS = not significant; Means in a column followed by the same letter(s) are not significantly different at 5%. Numbers in parenthesis are square root transformations.

Physiological weight Loss Percentage

N had a highly significant (P<0.05) effect on the weight loss percentage of stored onion bulb during the two month storage time (Table 11). Large weight loss percentage (39.53%) was seen at plot received maximum N at 150 kg ha^{-1}. This maximum weight loss may be associated with the resumption of higher incidence of sprouting and rotting presumably through increase in the rate of respiration. Regardless of the level, maximum N application at 150 kg ha^{-1} showed high weight loss percentage (19%) as compared to the control. Dankhar and Singh (1991) also reported similar result that weight loss of bulbs increased with the increase in the nitrogen level.

***Table11**: Percentage weight loss (%) and bulb sprouts (%) of onion as influenced by N application*

Treatments	PWL (%)	Bulb sprouts percentage (%)
Nitrogen(kg ha^{-1})		
0	32.05^{d}	60.28 (7.75^{b})
50	34.48^{c}	56.39 (7.49^{c})
100	37.14^{b}	59.72 (7.72^{b})
150	39.53^{a}	66.11 (8.12^{a})
SE(±)	0.46	0.099
LSD(0.05)	0.92	0.202
CV (%)	5.50	5.55

NS = not significant; Means in a column followed by the same letter(s) are not significantly different at 5%. Numbers in parenthesis are square root transformations.

Bulb Sprouts percentage and weeks to 50% bulb sprouts

Sprouting is physiological change that occurs on bulbs of onion in storage. N application had shown a significant (P<0.001) difference on percentage bulb sprouts. The highest incidence of sprouting was seen in the plot received maximum N at rates of 150 kg ha^{-1}; while the least record observed from unfertilized plots at the end of two months storage. There are similar reports by Bhalekar *et al.* (1987) who observed that sprouting was increased with increasing nitrogen levels from 0 to 150 kg N ha^{-1}. Dankhar and Singh (1991) also reported that high dose of nitrogen produced thick-necked bulbs that increased sprouting in storage due to greater access of oxygen and moisture to the central growing point.

SUMMARY AND CONCLUSION

Onion (Allium cepa L.) is introduced to the agricultural community of Ethiopia in the early 1970's when foreigners brought it in. Currently, the crop is produced at different parts of the country for local consumption. Ethiopia increased onion yield and seed production potential in recent years. Optimum levels practices varies with environment, purpose of the production and variety. Hence, there is no specific recommended agronomic practice including fertilizer rate and type to the study area. The results of the study showed that application of N had considerable influence on different parameters. All growth and yield properties as well as storage life of the bulbs showed significant differences due to the treatments applied. The result of the experiment indicated that growth, yield, quality and storage life of Bombay Red onion plants was significantly affected by various applications of N. Plant height, leaf diameter, leaf length, number leaves per plant, leaf sheath length, bolters percentage, days to physiological maturity, harvest index, mean bulb weight, bulb length, bulb diameter, TSS (oBrix), DMC (%) and bulb shape index. Similarly, keeping quality of the onion bulbs like bulb sprouts (%), weight loss (%), weeks to 50% bulb sprouts and storage rots (%) were highly influenced by application of N at different levels. The highest total bulb yield per hectare (17.41t/ha) was recorded with the plot that received the maximum applications of N (150 kgha^{-1}). Maximum (150 kgha^{-1}) application of N significantly increased bulb rots (%), bulb sprouts (%), weight loss (%) and shorten weeks to 50% bulb sprout during the two month storage time at ambient storage temperature and humidity.

Conflict of interest
Regarding the publication of this manuscript, there is no any conflict of interest.

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