Quality and Storage Life of Onion (Allium cepa L.) as Influenced by Applications of Nitrogen, Phosphorus and Potassium Fertilizer, 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 on vegetables and fruits. Thus, a field experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine Research field in dry season to study the effects of Nitrogen (N), Phosphorus (P) and Potassium (K) fertilizer on quality and storage life of irrigated onion under Jimma condition, South Western Ethiopia. The treatments consisted of factorial combinations of four levels of Nitrogen (0, 50, 100 and 150 *kg N* ha^{-1}), three levels of *Phosphorus (0, 46, and 92 kg* P_2O_5 ha^{-1}*)* and four levels of Potassium (0, 40, 80, and 120 kg K_2O ha^{-1}) laid out in Randomized Incomplete Block Design with three replications. Data on 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; N, P and K had shown a highly significant effect on quality parameters like TSS (^{o}Brix), 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 (%) are highly influenced by application of N, P and K at different levels. The higher total bulb yield per hectare (18.78 ton) was recorded with combined application of 150:92:120 kg of N-P-K ha^{-1} and it is statistically the same with the results obtained in the combined applications of 150:46:120 and 150:46:80 kg of N-P-K ha^{-1} which were significantly superior over the rest of other treatments. Excessive Nitrogen caused higher bulb rots (%); bulb sprouts (%) and weight loss (%); while, potassium significantly decreased the bulb rots (%), bulb sprouts (%) and weight loss (%) during the two month storage time at ambient temperature. However, according to the partial budget analysis; the highest economic benefit was obtained at 150:46:80 kg of N-P-K ha^{-1} where as the lowest net benefit was obtained from the control treatment. This can be recommended for use by potential onion investors or farmers with high initial capital in the study area. Nevertheless, more researches are needed in different locations and on different soils to come up on general recommendation.
Keywords: Nitrogen, Onion, Phosphorus, Potassium, Quality, Storage life.

Introduction

Onion is an important vegetable crop worldwide, ranking second among all vegetables in economic importance next to Tomato. Onion contributes significant nutritional value to the human diet and has medicinal properties and is primarily consumed for their unique flavor or for their ability to enhance the flavor of other foods (Randle, 1998). The primary center of origin for Onion is Central Asia with secondary center in Near East and the Mediterranean region. From these centers, the Onion has spread widely to other many countries of the world (Astley, 1982). Onion is different from the other edible species of alliums for its single bulb and is usually propagated by true botanical seed. According to FAO among the onion producers, the first is China in terms of area of production. The highest productivity is from Korea Republic (67.25 t/ha) followed by USA (53.91 t/ha), Spain (52.06 t/ha) and Japan (47.55 t/ha). India being the second major Onion producing country in the world has a productivity of 10.16 t/ha only. 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.

Different cultural practices and growing environments 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 and adopting improved management practices. Mineral nutrition is main that affects yield and quality of onion (Chung, 1989). Nitrogen and Phosphorus and Potassium are 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, 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, 2002). Plant demand for N can be satisfied from a combination of soil and fertilizer to ensure optimum growth.

In Ethiopia, so far there was a general understanding that Ethiopian soils are rich in K and there was no need for its application based on the research conclusion of some 50 years ago (Murphy, 1968). However, research report indicated that K is removed through deforestation, crop export, leaching of cations and other possible reasons, especially in some highland areas of Southern Ethiopia and possibly in other similar areas of the country (Wassie, 2009). Similarly, a significant higher bulb yield (247.79 q ha-1) and fresh bulbs weight (49.53 g) were registered with application of 150 kg K ha-1 over other levels. Worldwide, post-harvest losses in fruits and vegetables range from 24 to 40% or even greater, reaching up to 50% in developing tropical countries (Raja, 1993). A post-harvest loss in onion has been estimated to reach 30% in Sudan (Hayden, 1989) and 50 to 76% in Nigeria (Denton, 1990). A comprehensive statistics for such losses is not available for Ethiopia.

However, Proper management techniques such as fertilizers, soil moisture and disease control, harvest time and curing enhance Onion produce (Kabir, 2007). Optimization of such practices results in significant decrease in post harvest losses and increase bulb yield in Onion. Decrease in post harvest losses will be instrumental in market stability and exploiting opportunities to export Onion and earn foreign exchange. Best quality Onion can be produced through application of well balanced fertilizers (Murashkina, 2006).

In general, 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. In the light of the above aspects, the present research was initiated to identify the economical level of potassium fertilization for onion (*Allium cepa* L.) optimum quality and storage life under Jimma conditions, Southwestern Ethiopia.

Materials and Methods

Description of the experimental site

The field experiment was conducted at Jimma under irrigation condition. Before planting the analysis of soil samples from the top 30 cm depth was done and indicated in Table 1.

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

Experimental materials

Onion (Allium cepa L.) variety Bombay Red which is released by Melkassa Agricultural Research Center in 1980 through selection was used as a planting material for the study.

Experimental design and layout

Onion seedlings were raised in the nursery on a well prepared seedbed whose dimension was 5 m × 1 m. 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 51 days old seedlings were transplanted to the prepared field at spacing according to the EARO, 2004 recommendation. All the twelve treatment combinations were randomly assigned and there were 10 plants in each row and 60 plants per plot with three replications. During the course of the study Mancozeb was applied to prevent the damage of disease at rate of 4.0 kg ha-1 mixed in 600 liter of clean water. All other agronomic management practices were provided as per the recommendation equally for all the treatments (Getachew, 2009).

Finally, bulbs from the central four rows were harvested after 60% neck-break and used for analysis. Curing of bulbs was done for ten days under partial shade and ten sample bulbs were used for storage. Naturally ventilated house was constructed from wire mesh wall and corrugated iron sheet roofing then kept in boxes made of wire mesh to record data on storage life of onion bulb. Daily storage room temperature and relative humidity was recorded using digital sling Psychrometer (AZ8706 model, China). The storage time was from the month of May to July for three months under the average monthly temperatures and relative humidity of 17.23oc and 16.72oc, 75.32% and 77.65%, respectively.

Statistical analysis
The data were analyzed using GenStat versions 12.1 (2009) with the REML variance component analysis. Mean differences were tested following least significant difference (LSD) at ($P<0.05$).

Results and Discussions
Quality Parameters of Onion Bulb
Total soluble sugars content (TSS)
Regarding the total soluble sugars content (TSS), the interaction of N-P had shown a highly significant (Table 1) difference. The highest TSS value (11.67 ^{o}Brix) was recorded in the combined application of N-P at the rate of 150:92 kg ha^{-1}; while the minimum TSS value (8.08 ^{o}Brix) was recorded in control treatments. Regardless of the levels, maximum combined application of N-P (150:92 kg ha^{-1}) increased the TSS by about 30% as compared to control (8.08 ^{o}Brix).

Table 1: TSS of onion bulb as influenced by combined effects of N and P

Nitrogen (kg N /ha)	**Phosphorus levels (kg P2O5/ha)**		
	0	46	92
0	8.08^{h}	8.83^{g}	8.84^{g}
50	8.75^{g}	9.58^{f}	9.71^{f}
100	9.63^{f}	10.38^{d}	11.34^{b}
150	10.00^{e}	10.83^{c}	11.67^{a}

LSD (0.05) = 0.222
CV (%) =4.85

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

Similarly, the results from Table 2 revealed that combined application of N-K had shown a highly significant effect on the TSS of onion bulbs. The highest TSS value (11.56 ^{o}Brix) was recorded in the combined application of N-K at the rate of 150:80 kg ha^{-1}; while the minimum TSS value (7.99 ^{o}Brix) was recorded in control treatments. Regardless of the levels, maximum application of N-K at (150:80 kg ha^{-1}) increased the TSS by about 31% as compared to control (7.99 ^{o}Brix).

Table 2: TSS of onion bulb as influenced by combined effects of N and K

Nitrogen (kg/ha)	**Potassium levels (kg K2O/ha)**			
	0	40	80	120
0	7.99^{j}	8.28^{i}	8.99^{h}	8.99^{h}
50	8.83^{h}	9.66^{ef}	9.56^{ef}	9.33^{g}
100	9.49^{fg}	10.28^{d}	10.78**c**	11.23^{b}
150	9.78^{e}	10.73^{c}	11.56^{a}	11.28^{b}

LSD (0.05) = 0.222
CV (%) = 4.85

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, P and K at different levels had shown a highly significant ($P<0.001$) difference on the bulb shape index, while their interaction did not (Table 3). This result also showed that the null and lower application of N, P and K fertilizers increased the percentage of shape rejects as compared to the plot received higher levels of N, P and K (150 kg N ha^{-1}, 92 kg P ha^{-1} and 120 kg K ha^{-1}), respectively. Similarly, Geremew, (2009) reported as bulb shape of onion is affected by mineral nutrients.

Table 3: Bulb shape index as affected by main effects of N, P and K

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
Phosphorus (kg ha^{-1})	
0	0.84^{b}
46	0.86^{ab}
92	0.87^{a}
SE(±)	0.006
LSD(0.05)	0.024
CV (%)	5.15
Potassium (kg ha^{-1})	
0	0.84^{b}
40	0.85^{ab}
80	0.85^{ab}
120	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%

Regardless of levels, higher application of N at (150 kg ha^{1}), P at (92 kg ha^{-1}) and K at (120 kg ha^{-1}) increased the bulb shape index by about 3%, 3% and 2.5% over control, respectively (Table 3). The reason why N, P and K fertilization increased the bulb shape index of onion may be because of their vital role in plant growth and development. Kimani et al. (1993) reported as bulb shape difference is among onion cultivars and affected by growing environment and also further explained that globe shaped (shape index = 1) are preferred by the consumers.

Dry matter contents

Regarding the dry matter contents, main application of N, P and K had shown a highly significant effect, while their interaction did not (Table 4). The increasing levels of N, P and K 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%), (10.30%) and (10.42%) recorded with higher application of N, P and K at rate of 150, 92 and 120 kg ha^{-1}, respectively. The minimum dry matter contents (9.26%), (9.54%) and (9.20%) detected in control respectively (Table 4). This finding is in consistent with the result of Mojsevich (2008) 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 4: Dry matter contents as affected by main effect of N, P and K.

Treatments	Dry matter contents (%)
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
Phosphorus (kg ha^{-1})	
0	9.54[c]
46	9.89[b]
92	10.30[a]
SE(±)	0.075
LSD(0.05)	0.205
CV (%)	3.82
Potassium(kg ha^{-1})	
0	9.20[d]
40	9.78 [c]
80	10.23[b]
120	10.42[a]
SE(±)	0.086
LSD(0.05)	0.18
CV (%)	3.82

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

Shelf Life Parameters of Onion Bulb

Bulb storage rots percentage

N and K application had a highly significant ($p \leq 0.05$) effect on the bulb rotting percentage during the storage time; while P and their interaction did not (Table 5). 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) and Pandey and Pandey (1994) 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.

Similarly, application K had shown a highly significant ($p<0.001$) difference on the bulb storage rots percentage of onion plants (Table 5). The findings indicated that the maximum application of K at 120 kg ha^{-1} showed a significantly decreased in the bulb rot percentage which is about 53.5% when compared with the unfertilized plots. The results of these finding are supported by the reports of Singh and Dhankar (1989) recorded that rotting percentage was reduced considerably during storage in the bulbs produced by the application of 100 kg K_2O ha^{-1}. Similarly, Nandi *et al*. (2002) also recorded that the lowest rotting (7.60 %) with application of K at 180 kg ha^{-1} as compared to control.

Table 5: Storage rots of bulb (%) as affected by main effect of N, P and K.

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
Phosphorus (kg ha^{-1})	
0	10.83 (2.99)
46	9.58 (2.87)
92	11.25 (3.16)
SE(±)	0.34
LSD(0.05)	**ns**
CV (%)	30.08
Potassium(kg ha^{-1})	
0	19.44 (4.41^{a})
40	10.00 (3.07^{b})
80	7.22 (2.50^{c})
120	5.56 (2.05^{d})
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 6). 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.

Table 6: PWL (%) and bulb sprouts (%) of onion as influenced by main effects of N, P & K

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
Phosphorus (kg ha^{-1})		
0	35.93	59.38 (7.68)
46	35.80	61.04 (7.79)
92	35.66	61.46 (7.89)
SE(±)	0.398	0.086
LSD(0.05)	**ns**	**ns**
CV (%)	5.50	5.55
Potassium(kg ha^{-1})		
0	36.39^{a}	66.11 (8.11^{a})
40	36.27^{a}	59.72 (7.72^{b})
80	35.54^{ab}	58.89 (7.59^{b})
120	34.99^{b}	57.72 (7.66^{b})
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.

At the same time K also had a highly significant ($P<0.001$) effect on the weight loss percentage of onion bulb. In opposite to N; K application decreases the weight loss of the bulb. The results from table 6 of the present study revealed that K application at 80 kg ha^{-1} showed a significantly lower weight loss as compared to the unfertilized plots and the results also indicated that further application of K above 80 kg ha^{-1} had no significant effect on bulb weight loss percentage. The results of these finding are supported by the reports of Singh and Dhankar (1989) recorded that loss in total weight was reduced considerably during storage in the bulbs produced by the application of 100 kg K_2O ha^{-}. Similarly, Nandi *et al.* (2002) also recorded that the low weight loss (9.21%) with application of K at 180 kg ha^{-1} compared to control.

Bulb Sprouts percentage and weeks to 50% bulb sprouts

Sprouting is physiological change that occurs on bulbs of onion in storage. N and K application had shown a significant ($P<0.001$) difference on percentage bulb sprouts; K application also had a significant effect on weeks to 50% bulb sprouts, while their interaction did not (Table 6). 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.

K application significantly decreased the sprouts percentage (Table 6). The maximum sprout of bulb recorded with control treatment, while the minimum sprouts occurred in the treatment of K at 40 kg ha^{-1} and further application had no significant effect on the bulb sprouts percentage. Similarly, Nandi *et al.* (2002) also recorded that the lowest sprouting (20.00%) with application of K at 180 kg ha^{-1} compared to control. Masalkar *et al.*, (2005 a) also reported that sprouting of bulbs in storage had declined with successive increase of K.

In case of weeks to 50% bulb sprout the result revealed that as K levels increased the weeks to attain 50% bulb sprouts also extended. Regardless of the levels, maximum K application at 120 kg ha^{-1} increased the weeks to attain 50% bulb sprouts by about 1.3 weeks as compared to the unfertilized plots. This result is in line with the finding of Masalkar *et al.*, (2005 a) who reported that sprouting of bulbs in storage had declined with successive increase of K.

Summary and Conclusions

Yield, quality and storage life of onion plants were affected with application of N, P and K at different levels.

Higher mean bulb weight (49.78g, 47.52g and 48.41g) at higher levels of N (150kg/ha), P (46kg/ha) and K (80kg/ha) application, respectively; lower unmarketable bulb yield (0.47ton/ha, 0.62ton/ha and 0.51ton/ha) at higher levels of N (150kg/ha), P (92kg/ha) and K (120kg/ha) application, respectively; higher harvest index (0.80%, 0.77% and 0.78%) at higher levels of N (150kg/ha), P (46kg/ha) and K (120kg/ha) application, respectively; higher dry matter content (10.54%, 10.30% and 10.42%) at higher levels of N (150kg/ha), P (92kg/ha) and K (120kg/ha) application, respectively; higher storage rot percentage (3.69%) at higher levels of N (150kg/ha); lower storage rot percentage (2.05%) at higher levels of K (120kg/ha); higher bulb weight loss (39.53%) at higher levels of N (150kg/ha); lower bulb weight loss (34.99%) at higher levels of K (120kg/ha); higher bulb sprouts percentage (8.12%) at higher levels of N (150kg/ha); lower bulb sprouts percentage (7.59%) at 80kg/ha levels of K.

In general, from marketable yield, post-harvest quality and storability point of view, N-P-K fertilization was very sound; especially for our country farmers where their production is once in a year. If these methods are integrated and well applied, year round production of this crop may not be required. In addition, problem of market glut could be stabilized with balanced costs from stored bulbs dispatch. Therefore, the result of this study has shown that N-P-K fertilization, have a sound and promising impact for post-harvest quality that could be applied for onion production. However, this study was done using one cultivar under one location for one season alone, so it's difficult to give general recommendation.

Future Prospective

- Multi-location experiments are required to recommend and use the output sustainably.
- Combined experiments with other organic fertilizers in the same field may reflect the sustainability of this practice.
- Similar field and economic feasibility studies need to be carried out for a number of seasons in different soils.
- Optimization of fertilizers with Planting density and water requirement for the different varieties under different agro-ecological condition to understand their yield performance.
- Nutritional quality analysis also need further study

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