

Effects of different levels of potassium fertilization on yield, quality and storage life of onion (*Allium cepa* L.) at Jimma, Southwestern Ethiopia.

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Abstract

In Ethiopia the yield of Onion (*Allium cepa* L.) is far below the national standards owing to several factors; absence of location specific fertilizer recommendation being the major among others. Thus, field and laboratory experiments were undertaken at Jimma in collaboration with Jimma University, Department of Post-harvest Management. Potassium sulphate fertilizer as TSP was used at 0, 40, 80 and 120 kg ha⁻¹ levels with three replications. GenStat 12.1 version computer software packages were employed to analyze the data. From the results potassium fertilizer application at different levels showed significant effects on growth, yield and quality parameters i.e. Plant height, leaf length, leaf number, sheath length, bolters percentage, days to maturity, harvest index, mean bulb weight, bulb length, bulb diameter, TSS (°Brix), DMC (%) and bulb shape index. Similarly, keeping quality of the onion bulbs including bulb sprouts (%), weight loss (%), weeks to 50% bulb sprouts and storage rots (%) were highly influenced by application of K at different levels. Maximum (120 kg ha⁻¹) application of potassium significantly decreased bulb rots (%), bulb sprouts (%), weight loss (%) and prolonged weeks to 50% bulb sprout during the two month storage time at ambient storage temperature and humidity. This could be recommended for the uses by potential onion investors or farmers in the study area. Nevertheless, more researches are needed in different locations and on different soils in various season to come up with specific soil test based fertilizer recommendation.

Keywords: Fertilization, Growth, Jimma, Onion, Potassium, Quality, Storage life, Yield.

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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 [1]. 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 [2]. 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 [3] 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 [4]. 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 [5]. Nitrogen comprises 7% of total dry matter of plants and is a constituent of many fundamental cell components [6]. 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 [7]. 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 [8]. 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 [9]. 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 [10]. A

post-harvest loss in onion has been estimated to reach 30% in Sudan [11] and 50 to 76% in Nigeria [12]. 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 [13]. 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 [14].

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 growth, yield, and quality and storage life under Jimma conditions, Southwestern Ethiopia.

Literature Review

The onion crop

Onion being a biennial crop, takes two seasons for seed production, but mainly it is grown for bulbs; although the green shoots of salad onion is also an important part. Drained friable loam soil with a pH of 6.0 to 6.8 is good for better yield [15]. The Onion bulb consists of the swollen bases (sheaths) of bladed leaves surrounding swollen bladeless leaves. Each leaf consists of a blade and sheath. Collectively, the grouping of these sheaths comprises the pseudostem. Leaves arise from the short, compressed, dislike stem which continues to increase in diameter with maturation and resembles an inverted cone. The onion skin is formed from the dry paper like outer most leaf scales that lose their freshness during bulbing. Major bulb features are uniformity of shape, size and skin color, pungency and dry matter content [16].

Agronomic characteristics of onion

The onion root system is fibrous, spreading just beneath the soil surface to a distance of 30 to 46 cm. It has few laterals, and total root growth is sparse and not especially aggressive. Competition from aggressive root systems (as from weed growth) severely limits onion growth [17]. In Ethiopia Onion can grow from sandy loam to heavy clay, but it prefers well drained sandy loam. Due to build up of soil borne diseases, it should be rotated with unrelated crops such as beans, and cereals. Onion could be planted at an interval of 3 to 4 years [18]. The best growing altitude for onion in Ethiopian is from 700-2200 m.a.s.l and the optimum growing temperature ranges between 15°C and 23°C [19,20].

Onion dry bulb can be produced throughout the year if dependable irrigation water, and diseases and insect pests control measures are available. However, the yield of onion is vary from season to season due to diverse climatic conditions prevailing in the production areas. Findings of the research done by Melkassa Agricultural research center at the upper Awash

rift valley revealed that 20 cm between rows on the bed and 10 cm between plants with 333,300 plants ha⁻¹ gave high yield (150 q/ha) and was easy to manage the plant. This is suitable for small-scale hand operated production system for the Melkassa and other areas with similar agro-ecologies. The spacing could be adjusted depending on the availability of facilities especially for tractor operated large scale production [18].

Climatic requirements of onion crop

Onion requires moist soil throughout the growing period. Moderate rainfall is preferable since excessive soil water and high humidity encourage diseases. The optimum water requirement for yield is between 350 to 550 mm of water [21]. A cool period promotes early leaf development, while high temperatures encourage bulb development but flower and seed production is only possible where the bulbs are subjected to low temperatures. Bulb setting in any onion variety is determined by day length and temperature. The optimum temperature for bulb setting is 20 to 25°C. At 10 to 15°C bulbs do not develop well regardless of day length. Temperature can also have another effect on plant development, and therefore production. Once an onion plant reaches a certain physiological age (50 to 80 days old) it may respond to certain temperature conditions (below 14 to 10°C) by initiating a flower head, which then develop flower stalk up to 1 m high.

Potassium nutrient requirements of onion crop

Potassium plays a pivotal role in plant growth and development. Like other vegetable crops, onion is very responsive to potassium fertilization. It has a crucial role in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relation. Also K plays a key role of crop quality. It improves size of fruit and stimulates root growth. It is necessary for the translocation of sugars and formation of carbohydrates.

According to report by Madan and Sandhu [22] the trials with Onion cv. Punjab 48 with the application of 185:117:105 kg N, P₂O₅ and K₂O ha⁻¹ gave the maximum bulb yield. Similarly, Singh and Dankhar [23] also noticed that application of K alone and in combination with zinc (100 kg K₂O + 25 kg ZnSO₄) increased plant growth (61.62, 64.9 cm) yield and dry matter of bulbs (15.05 g and 14.9 g), respectively. Onion dry matter production, bulb size and bulb yield increased with the increase in levels of K from 0 to 150 kg ha⁻¹ as reported by Salimath [24]. The similar results again observed by a study [25] that significant differences among the fertilizer doses with respect to Onion plant height. Plants were the tallest when 90 kg N and 120 kg K₂O ha⁻¹ were applied. Again, a study [26] also recorded that the higher number of leaves per plant (11.56, 11.68), weight of bulb (50.42 from 51.83 g) and bulb yield (226.66 from 227.66 q/ha) with increase in Potassium application from 100 to 150 kg ha⁻¹.

The increase in K application significantly increased the dry weight of tops and bulbs, bulb diameter, 100 bulb weight and bulb yield up to 40 kg K₂O ha⁻¹ [27]. The application of fertilizers at RDF (125 kg N, 33 kg P₂O₅ and 50 kg K₂O ha⁻¹) and 150% RDF (187 kg N, 49 kg P₂O₅ and 75 kg K₂O ha⁻¹) registered 42 and 56% increases in bulb yield of onion, respectively over 50% NPK dose [28]. In similar way a study [29] also noticed

that a significantly higher yield of bulb (247.79 q ha⁻¹) and fresh weight of bulbs (49.53 g) with application of 150 kg K₂O ha⁻¹ over other potassium levels. Increased bulb yield of garlic (97.24 q ha⁻¹) was obtained with 150:80:50 kg N, P₂O₅ and K₂O ha⁻¹ application. However, considering economics of crops balanced use of N, P₂O₅ and K₂O fertilizers at 100:40:50 gave optimum returns [30]. The application of Potassium at 125 kg ha⁻¹ recorded significantly highest plant height, total dry matter production which was on par with 150 kg ha⁻¹. Same treatment recorded significantly higher bulb weight (106.44 g/plant), bulb length (4.68 cm), bulb diameter (5.32 cm) and bulb yield (22.87 t/ha) over control [31].

In Ethiopia, the study conducted at Jimma in comparing N and P with N, P and K application on potato indicated that the tuber yield of potato was increased from 11.77 t/ha⁻¹ in the N-P treatments to 34.93 t/ha⁻¹ in the N-P-K treatments, which means N-P-K application increased the tuber yield by 197% over the N-P treatments suggesting that K is critically deficient in the area and disproved the long standing conclusion by Murphey that Ethiopian soil are rich in potassium [9]. Potassium nutrient is an essential nutrient which is vital in photosynthesis activity of leaf, as it helps in translocation of food. Besides, plants require large amount of K than the soil can supply. Generally, onion takes up potassium nutrient in quantities nearly equivalent to N [32-34].

Material 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.

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 (Table 2).

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

Table 1. Soil physical and chemical properties of the experimental site.

Characteristics	Status
Sand (%)	8
Silt (%)	44
Clay (%)	48
Textural class	Silty clay
Organic carbon (%)	1.46
Exchangeable K	0.83 meq/100 g
pH 1:1 water	5.94
Electric conductivity (1:1)	53.1 (μS/cm)
Bulk density (g/cm ³)	1.58

Table 2. Details of the onion variety used in the study.

Variety Name	Year of Release	Area of adaptation		Days to maturity	Yield (t/ha)
		Altitude (m)	Rain fall (mm)		
Bombay Red	1980	700-2000	Irrigated	<120	25-30

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 [35].

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 17.23°C and 16.72°C, 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

Growth parameters

Plant height: Main application of K had shown a highly significant (p<0.001) difference on mean plants height at physiological maturity (Table 3). The maximum mean plants height (48.37 cm) was recorded in the plots that received K at 120 kg ha⁻¹, while the minimum (44.82 cm) was observed in the unfertilized plots. Increasing the level of applied K from 0 to 120 kg ha⁻¹ increased the mean plants height by about 7% as compared to the control. Similar results reported that application of K at 125 kg ha⁻¹ had showed significantly the highest plants height in onion [31]. There are also many other investigators who reported that an increase in vegetative growth with increased potassium fertilization levels on sweet pepper, egg plant, tomato and muskmelon [36-41].

Number of leaves per plant: The number of leaves is an important yield component. Leaves manufacture food with the help of chlorophyll and translocate it down for bulb development. Leaf number per plant at physiological maturity was highly and significantly (p<0.001) affected by application of K (Table 3). The plots that were fertilized with the maximum rate of K (120 kg ha⁻¹) showed about 14.7% increase in mean

number of leaves per plant which is statistically the same with value (14.2%) registered from plots that received only 80 kg ha⁻¹. Further application of K above 80 kg ha⁻¹ did not bring change on onion mean number of leaves per plant. However, the minimum result (8.93) was recorded in the control treatment. There is a similar report that the higher number of leaves per plant (11.56, 11.68), weight of bulb (50.42 from 51.83 g) and bulb yield (226.66 from 227.66 q/ha) with increase in Potassium application from 100 to 150 kg ha⁻¹ [26].

Leaf length: Potassium fertilizers application at different levels showed a highly significant ($p < 0.001$) effect on the mean leaf length per plant (Table 3). The plots that were fertilized with the maximum rate of K (120 kg ha⁻¹) showed about 8% increase in mean leaf length per plant which is statistically the same with value (7.01%) registered from plots that received only 80 kg of K ha⁻¹. Further application of K above 80 kg ha⁻¹ did not bring change on onion mean leaf length. However, the minimum mean leaf length (35.0 cm) was recorded in the control treatment. This result is correlated with the report of a study [37] indicated that mean leaf length of onion plants increased with increased K application. Similarly [25] also reported that as there is a significant difference among the fertilizer doses with respect to Onion plant height. Plants were the tallest when 90 kg N and 120 kg K₂O ha⁻¹ were applied.

Leaf sheath (shaft) length: The mean leaf sheath length of Onion is highly influenced with application of different levels of K (Table 3). However, further application of K above 80 kg ha⁻¹ did not bring change. Application of K up to 80 kg ha⁻¹ increased the mean leaf sheath length by about 12% compared to the control treatment (5.49 cm). In Similar there is a report that potassium deficiency may lead to a reduction in number and size of individual leaves produced, which is also the same for the mean leaf sheath length [42].

Days to physiological maturity: Application of K had shown a highly significant ($p < 0.001$) difference on days to physiological maturity. Potassium fertilizers application at the rates of 80 kg ha⁻¹ delayed the days to attain physiological maturity by about three days; while further application of K above 80 kg ha⁻¹ did not increase the days to attain physiological maturity and the graph started to decline.

Table 3. Mean effect of potassium on mean plant height, leaf length, leaf number and neck length.

Treatments Potassium (kg ha ⁻¹)	Plant height (cm)	Leaf number/plant	Leaf length (cm)	Shaft length (cm)
0	44.82 ^d	8.939 ^d	35.07 ^d	5.491 ^c
40	46.41 ^c	9.549 ^c	36.45 ^c	5.701 ^b
80	47.79 ^b	10.209 ^b	37.69 ^b	6.166 ^a
120	48.37 ^a	10.476 ^a	38.08 ^a	6.221 ^a
SE (±)	0.245	0.1260	0.259	0.0324
CV (%)	2.78	3.71	4.73	3.74

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

Table 4. Mean effect of potassium on onion bulb diameter, length and mean bulb weight.

Treatments Potassium (kg ha ⁻¹)	Bulb length (cm)	Bulb diameter (cm)	Mean bulb weight (g)
0	5.32 ^b	4.53 ^b	40.94 ^c
40	5.45 ^b	4.63 ^b	44.72 ^b
80	5.74 ^a	4.90 ^{ab}	47.25 ^a
120	5.82 ^a	5.07 ^a	48.41 ^a
LSD (0.05)	0.232	0.202	1.791
CV (%)	8.89	9.01	8.45

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

Yield parameters

Bulb diameter and bulb length: Results from Table 4 below indicated that, K application showed a highly significant difference on both the mean bulb diameter and bulb length of onions. Statistically the highest mean bulb diameter and length were observed in plot at rate of 80 kg ha⁻¹ and at 120 kg ha⁻¹. The results again showed that further application of K above 80 kg ha⁻¹ did not bring any additional increase in both mean bulb length and diameter. On the other hand for both parameters the lowest records were observed in the unfertilized plot. Similarly, there is a report that potassium application at 125 kg ha⁻¹ showed higher bulb length and bulb diameter when compared with control [31] (Table 4).

This findings are in line with the reports that the higher number of leaves per plant (11.56, 11.68), weight of bulb (50.42 from 51.83 g) and bulb yield (226.66 from 227.66 q/ha) with increase in Potassium application from 100 to 150 kg ha⁻¹ [26].

Similarly, a study [27] observed that the increase in K application significantly increased the dry weight of tops and bulbs, bulb diameter, 100 bulb weight and bulb yield up to 40 kg K₂O ha⁻¹.

Mean bulb weight: There was statistically highly significant ($p < 0.001$) difference encountered in mean bulb weight due to application of K at different levels. Of all levels considered in the study, application of K at a rate of 120 kg ha⁻¹ increased the mean bulb weight values by about 16% over control treatments (40.94 g). The increase in mean bulb weight with the supply of K fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthates which helped in producing bigger bulb, hence resulting in higher yields. Similar results are reported that a significantly higher yield of bulb (24.7 ton ha⁻¹) and fresh weight of bulbs (49.53 g) with application of 150 kg of K₂O ha⁻¹ over other potassium levels [29].

Marketable bulb yield: The results from Table 5 below indicated that as K application is resulted in a highly significant ($p < 0.001$) difference in marketable bulb yield. Among all levels of treatment the application of K at 120 kg ha⁻¹ increased the marketable bulb yield by about 47% as compared with the control treatment (12.96 ton ha⁻¹) (Table 5).

In similar manner, [24] also indicated that Onion dry matter production, bulb size and bulb yield increased with the increase in levels of K from 0 to 150 kg ha⁻¹. A study [29] again reported that a significantly higher yield of bulb (247.79 q ha⁻¹) and fresh weight of bulbs (49.53 g) with application of 150 kg K₂O ha⁻¹ over other potassium levels.

Total bulb yield: With regard to total bulb yield of onion per hectare, there was a highly significant (P<0.001) variation attributable to the application of K. The results depicted in Table 5 indicates that all the treatment levels the maximum application of K at the rate of 120 kg ha⁻¹ significantly increased the total bulb yield when compared with the lower levels and control. This finding is correlated with the findings of a study [26] reported that the higher number of leaves per plant (11.56, 11.68), weight of bulb (50.42 from 51.83 g) and bulb yield (226.66 from 227.66 q/ha) with increase in Potassium application from 100 to 150 kg ha⁻¹.

Unmarketable bulb yield: The application of K at different levels had shown a highly significant (P<0.001) difference in terms of unmarketable bulb yield (Table 5). The results indicate that higher rate application of K decreased the unmarketable bulb yield per hectare. Among all treatment levels the highest unmarketable bulb yield was recorded in the unfertilized plots. The lowest unmarketable bulb yield and its best physical properties achieved with increasing rate of potassium application might be attributed to many vital roles of potassium in plant nutrition. There is also a report that application of Potassium at 125 kg ha⁻¹ recorded significantly highest plant height, total dry matter production which was on par with 150 kg ha⁻¹. Same treatment recorded significantly higher bulb weight (106.44 g/plant), bulb length (4.68 cm), bulb diameter (5.32 cm) and bulb yield (22.87 t/ha) over control [31].

Harvest index: The results given in Table 5 above indicated that application of K had produced a highly significant (P<0.001) variation in respect of the harvest index of onion plants. A close analysis of the data further indicates that increasing the level of K application from 0 to 120 kg ha⁻¹ highly and significantly

Table 5. Effect of potassium fertilizers on marketable, unmarketable, total yield and harvest index.

Treatments Potassium (kg ha ⁻¹)	Marketable bulb yield/ha	Unmarketable bulb yield/ha	Total bulb yield/ha	Harvest index
0	12.96 ^d	0.9133 ^a	13.87 ^a	0.69 ^c
40	14.15 ^c	0.7983 ^b	14.95 ^c	0.74 ^b
80	15.36 ^b	0.6439 ^c	16.01 ^b	0.74 ^b
120	16.26 ^a	0.5103 ^d	16.78 ^a	0.78 ^a
SE (±)	0.097	0.01493	0.093	0.020
CV (%)	3.47	5.15	3.48	5.88

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

Table 6. TSS of onion bulbs as influenced by application of potassium at different levels.

Treatments Potassium (kg ha ⁻¹)	Total soluble solid (°brix)
0	9.02
40	9.74
80	10.22
120	10.22
SE (±)	0.0262
CV (%)	4.41

increased the harvest index. Maximum harvest index (0.78) was observed at K rate of 120 kg ha⁻¹ and the lowest mean value (0.69) was recorded from the unfertilized plot. The results from this study showed that increasing the level of K application increases the harvest index of the onion plants.

Quality parameters

Total soluble solid (TSS): Regarding the total soluble solid (TSS), the application of K had shown a significant difference (Table 6).

The highest TSS value (10.22 °Brix) was recorded as a result of the application of K at the rate of 120 kg ha⁻¹; while the minimum TSS value (9.03 °Brix) was recorded in control.

Bulb shape index: Onion bulb shape index is a function of variety and growth environment. It is vary from flat to globe to torpedo which has different requirements in different markets. 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 K at different levels independently resulted in a highly significant (P<0.001) difference on the bulb shape index (Table 7). This result also showed that the null and lower application of K fertilizers increased the percentage of shape rejects as compared to the plots that received higher levels of K (120 kg K ha⁻¹). Similarly, there is a report that as bulb shape of onion as affected by mineral nutrients [43].

Among the levels, higher application of K (120 kg ha⁻¹) increased the bulb shape index by about and 2.5% as compered with control (Table 7). Similar results reported that bulb shape to be different among onion cultivars and was affected by growing environment and that globe shaped bulbs (shape index=1) are preferred by the consumers [44,45].

Dry matter contents: Regarding the dry matter contents, application of K unilaterally resulted in a highly significant effect. The increasing levels of K encouraged bulbs with a significantly higher dry matter contents as compared to the unfertilized plot. The maximum dry matter content of onion bulbs (10.42%) was recorded with application of K at higher rates of 120 kg ha⁻¹. On the other hand, the minimum dry matter content (9.20%) was detected in controls for K (Table 7). Similar result is reported that an increase in the doses of K from 70 kg ha⁻¹ to 110 kg ha⁻¹ increased the dry matter content of bulbs from 14.6% to 15.5% [25]. There is also another reports that indicates Onion dry matter production, bulb size and bulb yield increased with the increase in levels of K from 0 to 150 kg ha⁻¹ [24].

Table 7. Bulb shape index and dry matter contents as affected by Potassium fertilizers.

Treatments Potassium (kg ha ⁻¹)	Bulb shape index	Dry matter contents (%)
0	0.84 ^b	9.20 ^d
40	0.85 ^{ab}	9.78 ^c
80	0.85 ^{ab}	10.23 ^b
120	0.87 ^a	10.42 ^a
LSD _(0.05)	0.021	0.18
CV (%)	5.15	3.82

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

Storage life of onion bulb

Bulbs storage rots percentage: K application had a highly significant effect on bulb rotting percentage during the storage time (Table 8). The findings indicated that the application of K at the maximum rate (120 kg ha⁻¹) significantly decreased bulb rot percentage which is about 53.5% when compared with the unfertilized plots. This finding is in harmony with the reports of rotting of bulbs reduced considerably during storage in the bulbs produced by the application of 100 kg K₂O ha⁻¹[23].

Physiological bulb weight loss percentage: Application of K at different levels had a highly significant (P<0.001) effect on the weight loss percentage of onion bulb during the storage. The results from Table 8 above indicated that K application decreased the weight loss of the bulb. K application at the rate of 80 kg ha⁻¹ showed a significantly lower weight loss as compared to the unfertilized plots. However, further application of K above 80 kg ha⁻¹ had no significant effect on bulb weight loss percentage. The results of the present study are in alignment with the reports that loss in total weight was reduced considerably during storage in the bulbs produced by the application of 100 kg K₂O ha⁻¹[23].

Bulb sprouts percentage and weeks to 50% bulb sprouts: Sprouting is a physiological change that occurs in onion bulbs during storage. K application had shown a significant (P<0.001) difference on percentage of bulb sprouts; K application had a significant effect on weeks to 50% bulb sprouts (Table 8). In this regard the maximum sprout of bulb was recorded with control treatment, while the minimum sprouts occurred in bulbs which were collected from plots fertilized with the K at the rate of 40 kg ha⁻¹. However, further application of K had no significant effect on the bulb sprouts percentage. Similar results also reported that the lowest sprouting (20.00%) with application of K at 180 kg ha⁻¹ compared to control and sprouting of bulbs in storage had declined with successive increase of K [25,46].

Keeping Onions for longer duration without sprouting and decay is a big challenge along the commodity chain. In the present study, the results of storage study pertaining to weeks to 50% bulb sprout revealed that as the amount of K applied in the field increased, the weeks to attain 50% bulb sprouts was also extended. Among the levels studied, k application at maximum rate (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 that sprouting of bulbs in storage had declined with successive increase of K fertilizer application [46-49].

Discussions

As to general discussion, the results of the study above showed that application of K 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 bulb yield and quality of Bombay Red onion variety was significantly affected by various applications of K. like higher bulb diameter (5.82 cm) was recorded at higher level of K (80 kg/ha) application; higher bulb length (5.07 cm) was recorded at higher level of K (120 kg/ha) application; higher mean bulb weight (48.41 g) was recorded at higher level of K (80 kg/ha) application; lower unmarketable bulb yield (0.51 ton/ha) was recorded at higher level of K (120 kg/ha) application; higher harvest index (0.78%) was recorded at higher level of K (120 kg/ha) application and higher dry matter content (10.42%) was recorded at higher level of K (120 kg/ha) application were recorded. Finally, maximum (120 kg/ha) application of potassium significantly decreased bulb rots (2.05%), bulb weight loss (34.99%) and prolonged weeks to 50% bulb sprout during the two month storage time at ambient storage temperature and humidity and application of K at 80 kg/ha lower bulb sprouts percentage (7.59%) as compared with the others.

Generally, all the physical and chemical properties as well as storage life of the bulbs showed a significant differences due to the treatment applied and the results of these experiments indicated that as growth, yield, quality and storage life of Bombay Red onion plants significantly affected by applications of K at different levels.

Summary and Conclusions

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 K 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 K. 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 (°Brix), DMC (%) and bulb shape index. Similarly, keeping quality of the onion bulbs like bulb sprouts (%), weight loss (%), weeks to 50%

Table 8. Storage rots (%), bulb weight loss (g) and bulb sprout (%) as affected by Potassium fertilizers.

Treatments Potassium (kg ha ⁻¹)	Storage rots of bulbs	PWL	Bulb sprouts percentage
0	19.44 (4.41 ^a)	36.39 ^a	66.11 (8.11 ^a)
40	10.00 (3.07 ^b)	36.27 ^a	59.72 (7.72 ^b)
80	7.22 (2.50 ^c)	35.54 ^{ab}	58.89 (7.59 ^b)
120	5.56 (2.05 ^d)	34.99 ^b	57.72 (7.66 ^b)
LSD _(0.05)	0.42	0.92	0.202
CV (%)	30.08	5.5	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 and storage rots (%) were highly influenced by application of K at different levels. The highest total bulb yield per hectare (18.78 t/ha) was recorded with the plot that received the maximum applications of K (120 kg ha⁻¹). Maximum (120 kg ha⁻¹) application of potassium significantly decreased bulb rots (%), bulb sprouts (%), weight loss (%) and prolonged weeks to 50% bulb sprout during the two month storage time at ambient storage temperature and humidity.

Future Prospective

1. Multi-location experiments and similar field and economic feasibility studies need to be carried out for a number of seasons in different soils.
2. Combined experiments with other organic fertilizers in the same field may reflect the sustainability of this practice.
3. Optimization of fertilizers with planting density and water requirement for the different varieties under different agro-ecological condition to understand their yield performance.

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