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Effects of Different Levels of Nitrogen, Phosphorus and Potassium Fertilization on Growth and Yield 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. 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 growth and yield 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 growth and yield 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 growth, yield and yield parameters like plant height, leaf diameter, leaf length, number leaves per plants, leaf sheath length, harvest index, mean bulb weight, bulb length, bulb diameter and on quality parameters like TSS (^{o}Brix), DMC (%) and bulb shape index. 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. 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: Growth, Nitrogen, Onion, Phosphorus, Potassium, Yield

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 growth and yield 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
Growth Parameters
Days to Physiological maturity
Main application of N, P and K had shown a highly significant (p<0.001) difference on the number of days to attain physiological maturity. However the interaction effect of N, P and K did not showed significant difference (Figure1). Regardless of levels, maximum application of N at 150 kg ha^{-1} extended the day to attain physiological maturity by about 6 days over the unfertilized plot (105 days). This could be due to the fact that N fertilization extended the vegetative growth period of plants; as a result it delayed maturity. This result is in agreement with the findings of Brewester, (1994), Sorensen and Grevsen, (2001) and Abdissa *et al.* (2011) who reported that too much nitrogen promotes excessive vegetative growth and delayed maturity.

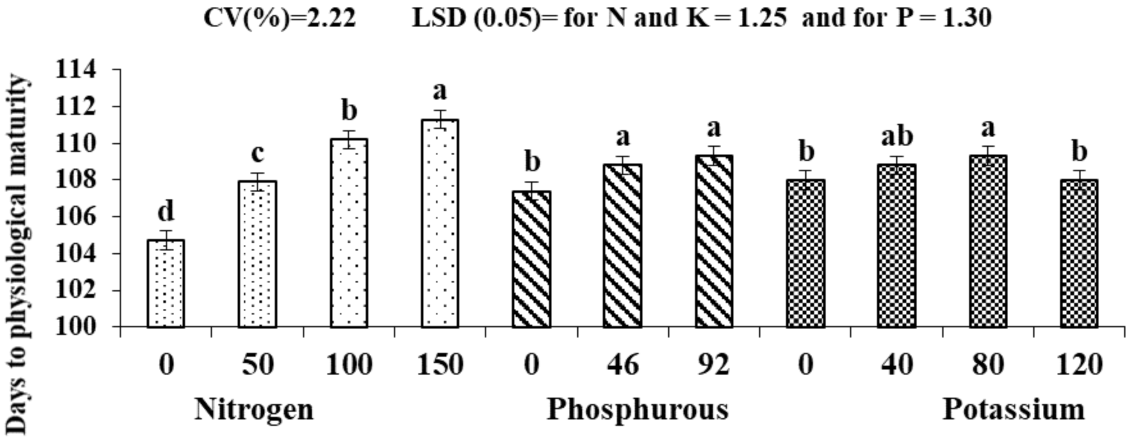

Figure 1. Main effect of N, P and K fertilizer on days to attain physiological maturity

Similarly, P application had shown a highly significant (p<0.001) difference on days to attain physiological maturity. Application of P at a rate of 46 kg ha^{-1} delayed days to attain physiological maturity by about 3 days as compared to control (107 days) which is statically the same with results recorded in maximum application of P at 92 kg ha^{-1}. The results of this study showed that further application of P above 46 kg ha^{-1} had no significant effect on the days to attain physiological maturity in onion plants (Figure 1).

In the same manner, K application at rates of 80 kg ha^{-1} delayed the days to attain physiological maturity; while further application of K above 80 kg ha^{-1} did not delay the days to attain physiological maturity by about 3 days and further application above 80 kg ha^{-1} led to decreasing in days to attain physiological maturity (Figure 1). A significant delaying effect of K application at 80 kg ha^{-1} may be because of the additional sulfur nutrients in the Potassium Sulphate fertilizers used as K source and this sulfur helps the crop to stay in vegetative growth period.

Plant height
Main application of N, P and K had shown a highly significant (p<0.001) effect on mean plants height at physiological maturity. However, the interaction effect of N, P and K on mean plant height was not significant (Figure 2). 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).

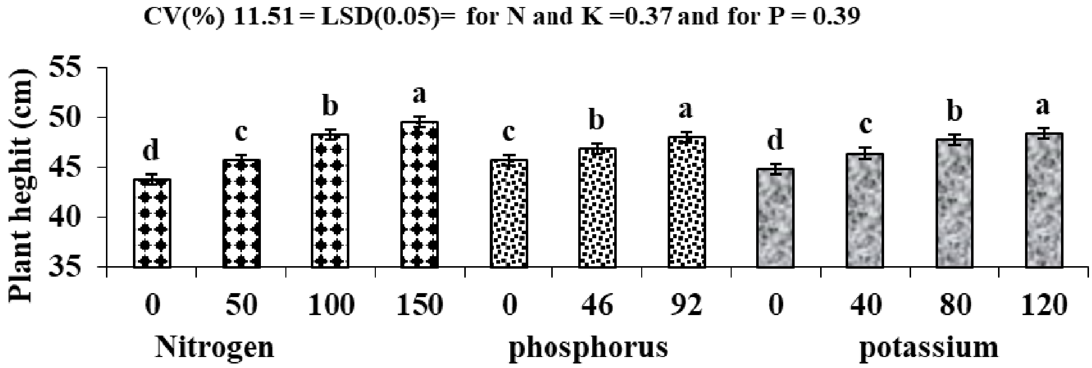

Figure 2. Main effects of N, P and K on mean height o f onion plants

Similarly, application of P had shown a highly significant ($P< 0.001$) difference on the mean plants height at physiological maturity (Figure 2). Maximum application of P at 92kg ha^{-1} increased the mean plants height of Bombay red Onion plant by about 5% as compared to control (45.86). The positive response of onion to P fertilization was mainly due to the fact that the plants have weak root system to effectively explore and utilize soil P and it is role as part of the enzyme system having a vital role in the synthesis of other compounds from carbohydrates and is considered as a constituent of nuclear proteins. Similar positive responses of P on onion plant height were reported by El-Sheekh (1997), El-Shaikh (2005) and Shaheen *et al.* (2007).

The results of the present study (Figure 2) also revealed that, application of K had shown a highly significant ($p<0.001$) effect on the mean plants height at physiological maturity. The maximum mean plants height (48.37 cm) was recorded in the plot that received K at 120 kg ha^{-1}, while the minimum mean plants height (44.82 cm) was observed in the unfertilized plot. Regardless of levels, maximum application of K at 120 kg ha^{-1} increased the mean plants height by about 7% as compared to control. This may be because of its role in protein synthesis and it plays a potential role in the transport of water and essential nutrients throughout the plant. The result of this study is in line with the finding of Hariyappa (2003) who reported that application of K at 125 kg ha^{-1} showed significantly highest plants height in onion. There are also many other investigators who reported on increasing plants vegetative growth due to increased potassium fertilization levels on other different crops; El-Masry (2000), Nassar *et al.* (2001) and Fawzy *et al.* (2005) on sweet pepper; Chen Zhen De *et al.* (1996) and Fawzy *et al.* (2007) on egg plant; Nanadal *et al.* (1998), Al-Karaki (2000) and Gupta and Sengar (2000) on tomato and Lester *et al.* (2006) on muskmelon.

Number of leaves per plant

The number of leaves is an important yield component. Leaves manufacture food with the help of chlorophyll and translocation it down for bulb development. Leaf number per plant at physiological maturity was highly significantly ($p<0.001$) different in the combined application of N and P (Figure 3). Similarly, the main effect of N, P and K had shown significant difference on the mean number of leaves per plant at physiological maturity. The highest mean value (11.62) was obtained from the combined application of 150:92 kg of N-P ha^{-1} and the lowest mean values (8.02) was recorded in the control treatment. Combined application of N and P at 150:92 kg ha^{-1} increased the mean number of leaves by about 31% as compared with the unfertilized plot. The combined effect of N and P were better than main application of N and P in terms of mean number of leaves per plant. This could probably be attributed to better absorption of the nutrients by their complementary function in stimulating of lateral root production (Drew, 1995; Thaler and Pages, 1998; Zhang and Forde, 1998; Zhang *et al.,* 1999). The findings of this investigation are in close conformity with Patel *et al.* 1990, who reported significant effects of nitrogen and phosphorus application on mean leaf number of onion plants.

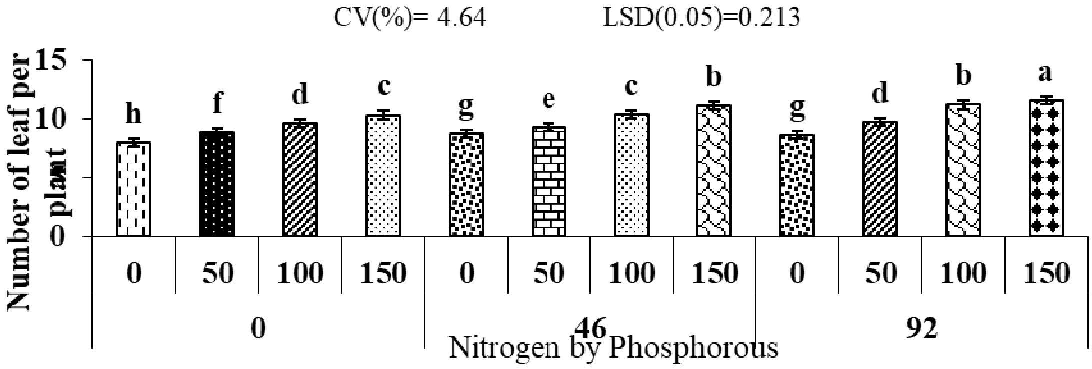

Figure 3. Number of leaves per plants as influenced by combined effect of N and P

Leaf length

A highly significant variation ($p<0.001$) in the leaf length (cm) was observed at the main application of N, P and K treatments. However, their interaction did not show significant difference (Figure 4). 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.

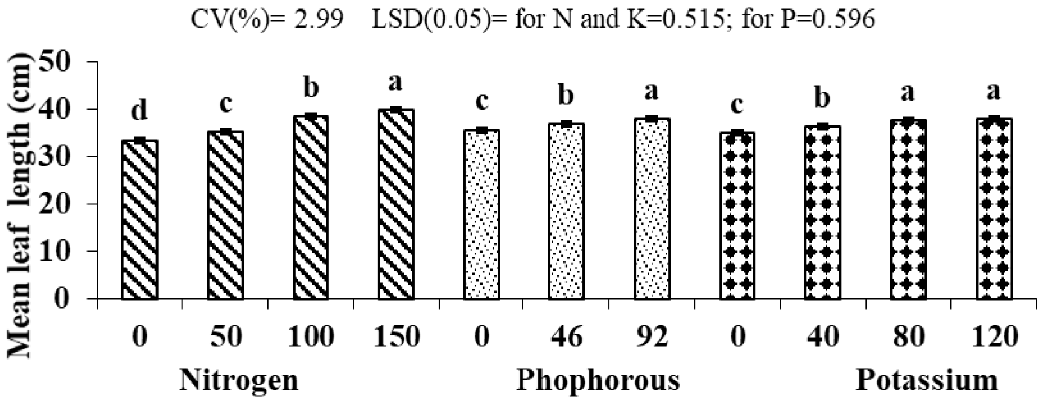

Figure 4. Main effects of N, P and K on mean leaf length of onion plants

Results pertaining to leaf length were presented in Figure 4 indicate that, application of P had shown a highly significant ($p<0.001$) difference on the leaf length of Bombay red onion plants. Maximum application of P at rate of 92 kg ha^{-1} showed a significant increment in leaf length by about 6.2% as compared to control (35.67). This might be because of P is an essential nutrient and the presence of P in the soil encourages plant growth. The results are correlated to the findings of Nikolay et al. 1996, Vacchain and Patel 1996, Warade et al. 1996, Hinsinger 2001, Pant and Reddy 2003 and Shafeek et al. 2004.

Similarly, the results of this study revealed that application of K at different rates showed a highly significant ($p<0.001$) difference on the mean leaf length per plant (Figure 4). The plots that received maximum levels K at 120 kg ha^{-1} significantly increased the mean leaf length per plants by about 8% which is statistically the same (7.01%) with plot that received 80 kg of K ha^{-1} and it indicates that further application of K above 80 kg ha^{-1} did not bring changes. The lowest mean leaf length (35.07cm) was recorded in the control treatments. Similar opinion was reported by El-Bassiouny (2006) as K significantly increases the mean leaf length of onion due to increased K application.

Leaf diameter

The various levels of N, P and K fertilizer application showed a highly significant ($p<0.001$) difference in terms of leaf diameter. The results of this study revealed that main applications of N showed a very highly significant ($p<0.001$) differences on the mean leaf diameter of onion plants, while their interaction did not show significant difference (Figure 5). Respect less of levels, maximum fertilization N at 150 kg ha^{-1} significantly increased the mean leaf diameter by about 29% as compared to control treatments (7.57 mm). This may be due to an adequate supply of N is associated with vigorous vegetative growth and more efficient use of available inputs.

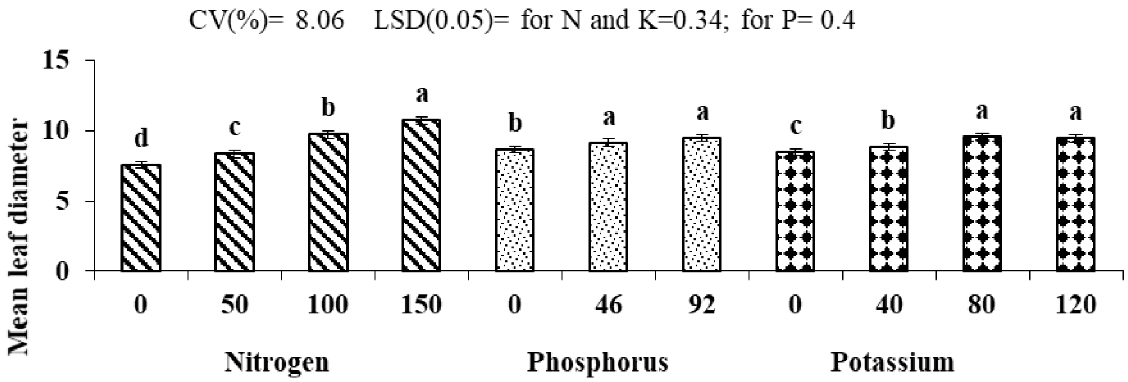

Figure 5.The main effect of N, P and K on mean leaf diameter of onion plants

Similarly, main application of P and K had shown a highly significant ($p<0.001$) difference on the mean leaf diameter per plant (Figure 5). However, the plants did not respond for further application of P and K above 46 kg ha^{-1} and 80 kg ha^{-1}, respectively. This may be technically the optimum level for P and K in growth of Onion leaf diameter. The results of this investigation are in line with the findings of Pettigrew, (2008) who reported that potassium deficiency can lead to a reduction in both the number of leaves produced and the size of individual leaves.

Leaf sheath (shaft) length

The analysis of variance indicated that main fertilization of N, P and K had a highly significant ($p<0.001$) influences on the mean leaf sheath length, while their interaction did not (Figure 6). 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.

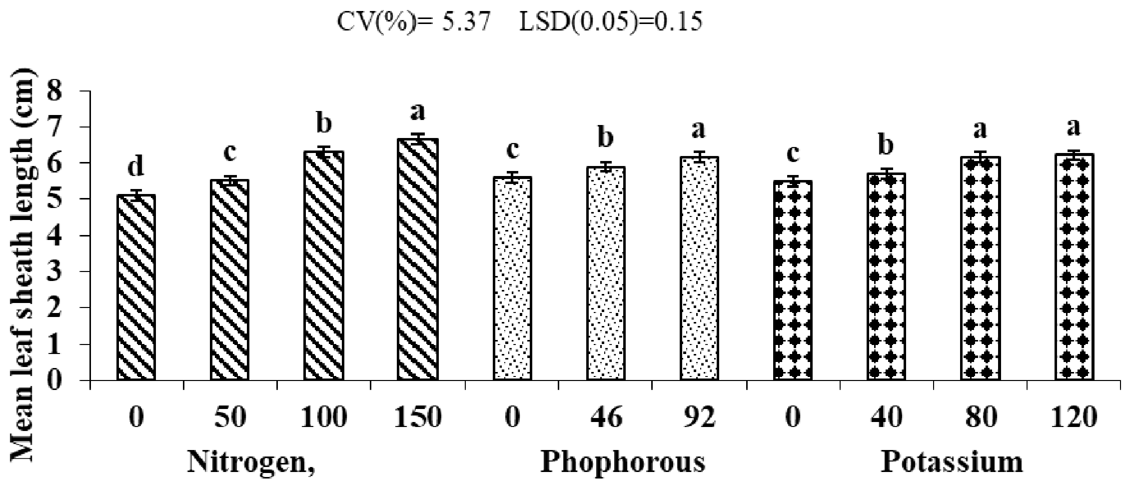

Figure 6. Main effects of N, P and K on leaf sheath (shaft) length

The results from figure 6 revealed that the increasing levels of P and K had shown a highly significant ($P<0.001$) effect on the mean leaf sheath length. However, further application of K above 80 kg ha^{-1} did not bring change in leaf sheath length. Regardless of the levels, 80 kg K ha^{-1} increased the mean leaf sheath length by about 12% as compared to the control treatments (5.49 cm). This result is in line with the finding of Pettigrew (2008) who reported that potassium deficiency can lead to a reduction in both the number of leaves produced and the size of individual leaves, which is also similar for the mean leaf sheath length.

Percentage of bolters

Percentage of bolted plants was highly significantly affected by N, P and K application, but their interaction effects were not significant (Figure 7). 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, while K application had shown an increment in bolting percentage and their interaction did not have effect. 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.

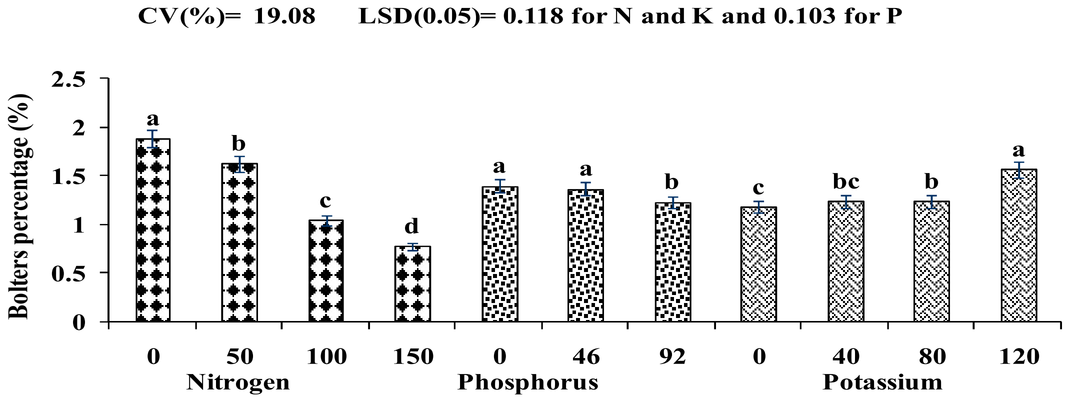

Figure 7. Main effects of N, P and K on bolting percentage

P application had shown a significant ($p<0.001$) effect on percentage of bolted plants. Statically high bolting percentage (1.45%) was recorded in the control treatments and followed by application of 46 kg P ha^{-1}. The result of this study also revealed that maximum application of P at 92 kg ha^{-1} reduces percentage of bolted plants (Figure 7). Similar findings have been reported by Amans (1982) and Umar (2000) as P application can suppress bolting onion.

The result from figure 7 revealed that K application also had shown a significant ($p<0.001$) difference on the percentage of bolted plants. The highest percentage of bolted plants (1.56%) in this study was recorded in the plots that received maximum levels of K at 120 kg ha^{-1}. Respect less of the levels; higher application of K at 120 kg ha^{-1} increased the bolted percentage by about 24.24% as compared with the control treatments. This might be because of K application is important in early maturity and decreases the days to attain physiological maturity. So the crop switch vegetative growth phase and enter to reproductive phase. Similarly Singh and Singh (2000) have been reported that as maximum bolting (1.5%) were recorded with application of 50 kg K_2O ha^{-1}. Bolting may be varied due to genetic factors, changes in temperature, poor seed quality, poor soil and cultural practices affecting the growth, relative length of day and night, spacing, and seedling size (Salunkhe, 1998).

Yield Parameters

Bulb diameter and Bulb length

Main application of N at different levels had shown a highly significant ($P<0.001$) difference on mean bulb diameter and length of Onion plants. However, the interaction with P and K did not show significant effect (Table 5). 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.

Similarly, P application had shown a highly significant ($P<0.001$) difference on mean bulb diameter and length (Table 5). The highest mean bulb diameter (5.76cm) was recorded in the plot that received maximum P at 92 kg ha^{-1} which is statically similar with the results obtained in application of 46 kg ha^{-1} and the lowest mean bulb diameter was recorded in the control treatments (5.43cm). This effect of P on the mean bulb diameter of onion may be through its influence on the bulb development of onion plants. There is also similar report by El-Rehim (2000).

Table 5: Main effect of N, P and K 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
Phosphorus (kg ha^{-1})		
0	5.43^{b}	4.59^{b}
46	5.55^{ab}	4.81^{ab}
92	5.76^{a}	4.94^{a}
SE(±)	0.051	0.039
LSD	0.268	0.233
CV (%)	8.89	9.01
Potassium (kg ha^{-1})		
0	5.32^{b}	4.53^{b}
40	5.45^{b}	4.63^{b}
80	5.74^{a}	4.90^{ab}
120	5.82^{a}	5.07^{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%

Results from Table 5 above indicates that, K application had shown a highly significant ($p<0.001$) difference on the mean bulb diameter and length. Statically higher mean bulb diameter was recorded in the plots that received K at rate of 80 kg ha^{-1} and at 120 kg ha^{-1} in the case of mean bulb length. The results again showed that further application of K above 80 kg ha^{-1} did not bring change in both mean bulb length and diameter. In the other hand for both parameters the lowest records were observed in the unfertilized plot. Lower records in the control treatments may be because of K requirement of onion plants increases with yield and its functions are linked to photosynthesis (Greenwood and Stone, 1998). This result is in line with the findings of Hariyappa (2003) who reported that, application of potassium at 125 kg ha^{-1} showed higher bulb weight, bulb length, bulb diameter and bulb yield as compared to control.

Mean bulb weight

There was statistically highly significant ($p<0.001$) difference in mean bulb weight due to application of N, P and K at different levels, but their interaction were not statistically significant different ((Table 6). Regardless of levels, 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.

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Table 6: Mean bulb weight of onion per plant as influenced by main effect of N, P and K

Treatments	Average 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
Phosphorus (kg ha^{-1})	
0	42.86^{b}
46	45.61^{a}
92	47.52^{a}
SE(±)	0.72
LSD	2.069
CV (%)	8.45
Potassium (kg ha^{-1})	
0	40.94^{c}
40	44.72^{b}
80	47.25^{a}
120	48.41^{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%

Similarly, mean bulb weight of onion is highly and significantly affected by application of P. Higher application of P at 92 kg ha^{-1} gave maximum mean value (47.52 g) which was statistically the same with the results (45.61g) obtained in application of P at 46 kg ha^{-1} (Table 6). This result indicated that, further application P above 46 kg ha^{-1} had no significant effect on mean bulb weight. Similar views were given by Marschner (1995) and Greenwood *et al.* (2001) who reported that P application has vital role in mean bulb weight of onion plant.

As illustrated on Table 6, application of K had shown a highly significant ($P<0.001$) difference on the mean bulb weight values. Without considering levels, application of K at a rate of 120 kg ha^{-1} increased the mean bulb weight values by about 16% over control treatments (40.94g). This finding is supported by Yadav *et al*. (2002) who reported that a significantly higher yield of bulb (247.79 q per ha) and fresh weight of bulbs (49.53g) with application of 150 kg K_2O ha^{-1} over other potassium levels. Marschner, (1995) and Greenwood & Stone, (1998) also point out that K requirement of onion plants increases with yield and its functions are linked to photosynthesis.

Marketable bulb yield and marketable bulb percentage

The interaction effect of N-P-K had shown a highly significant ($p<0.001$) difference on the marketable bulb yield, while the main effect of N, P and K significantly affected the values of marketable bulb percentage (Table 7). Regardless of levels, maximum combined application of N-P-K at 150:46:120 kg ha^{-1} increased the marketable bulb yield by about 47% as compared with the control treatments (9.83 ton) and the result is on par with the results of fertilizer level at 150:92:120; 150:46:80; 150:92:80 and 100:92:120 kg of N-P-K ha^{-1}.This findings is in consistent with the result of Girigowda *et al*., (2005) who recorded that the higher marketable bulb yield (41.69 t/ha) was recorded with fertilizer level of 188:75:188 kg of N-P-K ha^{-1}

Table 7: Marketable bulb yield per hectare as influenced by interaction effect of N-P-K

Nitrogen*Phosphorous* Potassium	Marketable yield ha^{-1} (ton)	Nitrogen*Phosphorous* Potassium	Marketable yield ha^{-1} (ton)
N_0 P_0K_0	9.83^{z}	**N_{100} P_0K_0**	11.98^{vwx}
N_0 $P_{46}K_0$	10.73^{yz}	**N_{100} $P_{46}K_0$**	14.35^{mnopq}
N_0 $P_{92}K_0$	11.36^{xyz}	**N_{100} $P_{92}K_0$**	15.43^{jkl}
N_0 P_0K_{40}	10.67^{za}	**N_{100} P_0K_{40}**	14.32^{nopq}
N_0 $P_{46}K_{40}$	11.96^{vwx}	**N_{100} $P_{46}K_{40}$**	16.00^{hij}
N_0 $P_{92}K_{40}$	12.69^{tuvw}	**N_{100} $P_{92}K_{40}$**	16.41^{ghi}
N_0 P_0K_{80}	11.42^{xyz}	**N_{100} P_0K_{80}**	15.17^{jklmn}
N_0 $P_{46}K_{80}$	12.79^{stuv}	**N_{100} $P_{46}K_{80}$**	17.09^{defg}
N_0 $P_{92}K_{80}$	14.05^{opq}	**N_{100} $P_{92}K_{80}$**	17.68^{bcde}
N_0 P_0K_{120}	12.02^{uvwx}	**N_{100} P_0K_{120}**	17.05^{defg}
N_0 $P_{46}K_{120}$	14.89^{klmno}	**N_{100} $P_{46}K_{120}$**	17.30^{cdef}
N_0 $P_{92}K_{120}$	15.30^{jkl}	**N_{100} $P_{92}K_{120}$**	17.91^{abcd}
N_{50} P_0 K_0	10.81^{yz}	**N_{150} P_0K_0**	13.13^{rst}
N_{50} $P_{46}K_0$	11.57^{xy}	**N_{150} $P_{46}K_0$**	15.56^{ijk}
N_{50} $P_{92}K_0$	13.63^{qrs}	**N_{150} $P_{92}K_0$**	17.20^{defg}
N_{50} P_0K_{40}	11.91^{wx}	**N_{150} P_0K_{40}**	15.00^{klmn}
N_{50} $P_{46}K_{40}$	12.89^{rstu}	**N_{150} $P_{46}K_{40}$**	17.20^{defg}
N_{50} $P_{92}K_{40}$	13.76^{pqr}	**N_{150} $P_{92}K_{40}$**	16.98^{efg}
N_{50} P_0K_{80}	12.63^{tuvw}	**N_{150} P_0K_{80}**	17.05^{defg}
N_{50} $P_{46}K_{80}$	14.59^{lmnop}	**N_{150} $P_{46}K_{80}$**	18.49^{ab}
N_{50} $P_{92}K_{80}$	15.22^{jklm}	**N_{150} $P_{92}K_{80}$**	18.14^{abc}
N_{50} P_0K_{120}	14.37^{mnopq}	**N_{150} P_0K_{120}**	17.40^{cdef}
N_{50} $P_{46}K_{120}$	15.19^{jklmn}	**N_{150} $P_{46}K_{120}$**	18.57^{a}
N_{50} $P_{92}K_{120}$	16.67^{fgh}	**N_{150} $P_{92}K_{120}$**	18.50^{ab}
		Mean	**14.68**
		LSD (0.05)	**0.0187**
		CV (%)	**3.67**

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

Unmarketable bulb yield

The main effect of N, P and K had shown a highly significant (P<0.001) difference on the unmarketable bulb yield (t/ha), while their interaction did not shows significant effect (Table 8). The result indicates that higher application of N, P and K 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 8: The influence of different rates of N, P and K 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
Phosphorus (kg ha^{-1})	
0	0.82^{a}
46	0.71^{b}
92	0.62^{c}
SE(±)	0.031
LSD (0.05)	0.083
CV (%)	21.33
Potassium (kg ha^{-1})	
0	0.91^{a}
40	0.79^{b}
80	0.64^{c}
120	0.51^{d}
SE(±)	0.036
LSD (0.05)	0.072
CV (%)	21.46

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

In similar manner, the result of this study revealed that, application of K had shown a highly significant ($P<0.001$) difference on the unmarketable bulb yield (Table 8). A plot that received 120 kg K ha^{-1} showed a decreased level of unmarketable bulb by about 5% as compared to the control. The lowest unmarketable bulbs yield and its best physical properties with increasing potassium rate might be attributed to that, potassium is as an essential elements and it plays many vital roles in plant nutrition. It increases root growth, improves drought resistance, enhances several enzyme functions, bulbs cellulose, reduces lodging, controls plant turgidity, maintains the selectivity and integrity of the cell membranes, helps translocation of sugars and starch, reduces water loss, reduces respiration, prevents energy loses, helps in protein synthesis and uplifts the protein content of plants, produces grain rich in starch and controls plants diseases Shaheen, (2007). This result is in line with the reports of Abozeid and Farghali, (1996) that carried out field trials and the highest marketable yield was obtained with 120 kg K_2SO_4 ha^{-1} sandy calcareous soils.

Total bulb yield

The interaction of N-P-K had shown a highly significant ($P<0.001$) difference on the total bulb yield of per hectare. The results from Table 9 revealed that regardless of levels, the maximum combined application of N-P-K at 150:92:120 kg ha^{-1} increased the total bulb yield by about 40% as compared with the unfertilized plot (11.11 tones) and this result is on par with the results of fertilizer levels at 150:46:120; 150:46:80; 150:92:80; 100:92:120 and 100:92:80 kg of N-P-K ha^{-1}. This might be because of an increased photosynthetic area in response to N-P-K fertilization had substantially contributed to enhance onion productivity that could be through the production of more assimilates. The result of this finding is in consistent with the result of Singh *et al*. (2000) who point out that onion productivity could be enhanced considerably by application of 100:30.8:83N-P-K kg ha^{-1}. Koondhar (2001) also showed that the highest bulb yield (48.67 kg) was obtained when the plots received 100-80-75 kg NPK per hectare. Similarly, Girigowda *et al*. (2005) also reported that higher bulb yield (41.69 tone ha^{-1}) was recorded with fertilizer level of (188:75:188, N, P_2O_5 and K_2O kg ha^{-1}) and was on par with fertilizer level of 156:63:156 kg N, P_2O_5 and K_2O ha^{-1}. Yadav *et al*. (2002) also noticed that increased bulb yield of garlic (97.24q/ha) was obtained with 150:80:50 kg N, P_2O_5 and K_2O ha^{-1} application.

Table 9: Total bulb yield per hectare as affected by interaction effects of N-P-K fertilization

Nitrogen*Phosphorous* Potassium	Total bulb yield/ha (ton)	Nitrogen*Phosphorous* Potassium	Total bulb yield/ha (ton)
N_0 P_0K_0	11.11[u]	**N_{100} P_0K_0**	12.87[rs]
N_0 $P_{46}K_0$	11.86[tu]	**N_{100} $P_{46}K_0$**	15.28[jkl]
N_0 $P_{92}K_0$	12.38[st]	**N_{100} $P_{92}K_0$**	16.16[ghi]
N_0 P_0K_{40}	11.75[tu]	**N_{100} P_0K_{40}**	15.21[jklm]
N_0 $P_{46}K_{40}$	12.92[rs]	**N_{100} $P_{46}K_{40}$**	16.64[efg]
N_0 $P_{92}K_{40}$	13.64[opqr]	**N_{100} $P_{92}K_{40}$**	17.08[def]
N_0 P_0K_{80}	12.42[st]	**N_{100} P_0K_{80}**	15.89[ghij]
N_0 $P_{46}K_{80}$	13.69[opqr]	**N_{100} $P_{46}K_{80}$**	17.60[bcd]
N_0 $P_{92}K_{80}$	14.87[klmn]	**N_{100} $P_{92}K_{80}$**	18.16[ab]
N_0 P_0K_{120}	13.01[qrs]	**N_{100} P_0K_{120}**	17.55[bcd]
N_0 $P_{46}K_{120}$	15.70[hijk]	**N_{100} $P_{46}K_{120}$**	17.80[bcd]
N_0 $P_{92}K_{120}$	16.07[ghij]	**N_{100} $P_{92}K_{120}$**	18.02[abc]
N_{50} P_0 K_0	11.80[tu]	**N_{150} P_0K_0**	14.03[nop]
N_{50} $P_{46}K_0$	12.46[st]	**N_{150} $P_{46}K_0$**	16.28[fgh]
N_{50} $P_{92}K_0$	14.47[lmno]	**N_{150} $P_{92}K_0$**	17.80[bcd]
N_{50} P_0K_{40}	12.86[rs]	**N_{150} P_0K_{40}**	15.78[ghij]
N_{50} $P_{46}K_{40}$	13.83[opq]	**N_{150} $P_{46}K_{40}$**	17.74[bcd]
N_{50} $P_{92}K_{40}$	14.40[mnop]	**N_{150} $P_{92}K_{40}$**	17.52[bcd]
N_{50} P_0K_{80}	13.59[pqr]	**N_{150} P_0K_{80}**	17.55[bcd]
N_{50} $P_{46}K_{80}$	15.34[ijkl]	**N_{150} $P_{46}K_{80}$**	18.72[a]
N_{50} $P_{92}K_{80}$	15.97[ghij]	**N_{150} $P_{92}K_{80}$**	18.25[ab]
N_{50} P_0K_{120}	14.82[lmn]	**N_{150} P_0K_{120}**	17.70[bcd]
N_{50} $P_{46}K_{120}$	15.83[ghij]	**N_{150} $P_{46}K_{120}$**	18.78[a]
N_{50} $P_{92}K_{120}$	17.25[cde]	**N_{150} $P_{92}K_{120}$**	18.78[a]
		Mean	**15.4**
		LSD (0.05)	**0.877**
		CV (%)	**3.52**

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

Harvest index

The results from Table 10 revealed that main application of N, P and K 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.

In the same manner, application of P had shown an increment in harvest index. Maximum application of P at 92 kg ha^{-1} increased the harvest index by about 9% as compared with the control. These characters showed a tendency to increase with P up to 46 kg ha^{-1} and then statistically the same and further application above 46 kg ha^{-1} did not bring changes. The presence of high harvest index is associated with the production of high bulb weight relative to the other biomass. There is a finding indicated in soils that are moderately low in P, onion growth and yield can be enhanced in response to P fertilization (Alt *et al.*, 1999).

Similarly, application of K at different rate had shown a highly significant ($p<0.001$) difference on the harvest index of onion plants (Table 10). The highest mean values (0.78) was recorded in the plots that received K at rate of 120 kg ha^{-1} and the lowest mean values (0.69) from the unfertilized plot. This may be because of the K requirement of onion plants increases with yield and its functions are linked to photosynthesis. In addition to this it may be because of presence of sulphur in the potassium sulphate fertilizer applied; which exert significant influence on number of leaves/plant, plant height, bulb size, and weight of onion plant. The result from this study showed that increasing level of K application increases the harvest index of the onion plants. This result may be in line with the finding of Marschner (1995) who reported that Potassium provides resistance against pest and diseases and drought as well as frost stresses.

Table 10: Harvest indexes of Onion plant as influenced by main effect of N, P and K

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
Phosphorus (kg ha^{-1})	
0	0.70^{b}
46	0.75^{a}
92	0.77^{a}
SE(±)	0.009
LSD(0.05)	0.024
CV (%)	5.88
Potassium(kg ha^{-1})	
0	0.69^{c}
40	0.74^{b}
80	0.74^{b}
120	0.78^{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%

Summary and Conclusions

The results of the study showed that main effects of N, P and K as well as their interactions had considerable influence on different parameters. All physical and chemical properties as well as storage life of the bulbs showed a significant differences due to the treatments applied. The result of these experiments indicates that as growth and yield of Bombay Red onion plants significantly affected by various interaction and main applications of N, P and K. The interaction effect showed significance difference on number of leaves per plants, TSS (^{o}Brix), marketable bulb yield (tone/ha) and total bulb yield (tone/ha). Regardless of the levels, maximum combined application of N-P-K at 150:46:120 kg ha^{-1} increased the marketable bulb yield by about 47% as compared with the control treatments (9.83 ton) and the result is on par with the results of fertilizer level at 150:92:120; 150:46:80; 150:92:80 and 100:92:120 kg of N-P-K ha^{-1}. At the same time, maximum combined application of N-P-K at 150:92:120 kg ha^{-1} increased the total bulb yield by about 40% as compared with the unfertilized plot (11.11 tones) and this result is on par with the results of fertilizer at levels 150:46:120; 150:46:80; 150:92:80; 100:92:120 and 100:92:80 kg of N-P-K ha^{-1}. Combined application of N and P at 150:92 kg ha^{-1} showed higher mean number of leaves per plant (11.62). The ultimate goal of onion production is profitability through yield enhancement; the result revealed that combined application of N-P-K appeared to be superior for total and marketable bulb yield at the study area although it needs repeated research for complete recommendation.

In general, from growth and marketable yield 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. 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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