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Effect of Potassium Levels on Productivity and Fruit Quality of Tomato (*Lycopersicon esculentum* L.)

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Abstract

Potassium has significant effect on quantity and quality of tomato yield because of its vital roles in photosynthesis, favoring high energy status and appropriate nutrient translocation and water uptake in plants. However, little is understood or it is being overlooked under Eritrean condition. Besides, poor soil fertility is among the major production constraints in Eritrea. The field experiment was therefore conducted to investigate the effect of potassium levels on productivity and fruit quality of tomato at Hamelmalo, Eritrea. The experiment was conducted in Randomized Complete Block Design with nine potassium levels (0, 50, 100, 150, 200, 250, 300, 350 and 400 kg K_2O/ha) replicated thrice. Data was collected on yield and fruit quality parameters and they were subjected to one-way analysis of variance (1-way ANOVA). The results of this study revealed that potassium had significant effect in all yield and quality parameters studied. Fruit diameter, fruit weight per plant, total yield, total soluble solids, specific gravity and fruit dry matter content showed significant increase with an increase in potassium level from 0 to 150 kg K_2O/ha and thereafter decreased while fruit moisture content was increased in the range of 150 - 400 kg K_2O/ha. As a result, highest fruit weight (1.39 kg/plant), fruit yield (15.45 t/ha), total soluble solids (3.84 ^{o}Brix), specific gravity, (1.46) and fruit dry matter (5.68%) were recorded from 150 kg K_2O/ha. Therefore it is recommended that potassium fertilizers should be used and balanced NPK fertilizers should be applied to improve yield and quality of tomato produced.

Keywords: *Lycopersicon esculentum* L., NPK-Fertilizers, Potassium, Quality, Yield

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most important and widely grown vegetables around the world. It is economically attractive and the area under tomato cultivation is increasing daily (Naika *et al*., 2005). Tomato is rich source of minerals and vitamins, its distinctive nutritional attributes play an important role in reducing risk of cardiovascular and associated diseases through their bioactivity in modulating disease process pathways (Dias, 2012). Moreover, it is an important source of lycopene, which is a powerful antioxidant that acts as an anticarcinogen (Burton-Freeman and Reimers, 2011). Tomato fruits are also an outstanding source of ascorbic acid, and are main source of vitamin C next to citrus (Rao and Rao, 2007 and Di Matteo *et al*., 2010).

In Eritrea, tomato production has a long tradition among farmers. It is highly valuable and most popular cultivated vegetable crop grown throughout the country. It serves as source of the livelihood of many rural farmers both as food and cash. Farmers prefer to cultivate tomato because of its high demand in the market, good return and reasonably good yield (Asgedom *et al*., 2011). A positive correlation between the yields of tomato and high income to farmers when it is cultivated on large scale has also been reported by (Naqvi *et al*., 2014). According to Asgedom *et al*. (2011), however, average yield of tomato in Eritrea has remained as low as 10.4 t/ha compared to average yield of 51, 41, 36 and 34 Mt/ha in America, Europe, Asia and the world respectively (FAOSTAT, 2010). This could be due to poor soil fertility and the imbalanced application of Nitrogen-Phosphorus-Potassium (NPK) fertilizers.

Tomato crop responds very well to manure and fertilizer application (Ramyabharathi *et al*., 2014). The potassium (K) requirements of tomato are high due to the fast growth of the plant in combination with higher fruit production (Chapagain and Wiesman 2004). However, the exact amount to be applied need to be determined based on fertility status of the soil and variety used. K is one of the major nutrients, essential for plant growth and development. It is involved in activation of enzymes important to energy utilization, starch synthesis, N metabolism and respiration. K plays an important role in photosynthesis, regulation of opening and closing of stomata, favors high energy status which helps in timely and appropriate nutrient translocation and water uptake in plants (Havlin *et al*., 2005). Ahmad *et al*., (2015) stated that K application significantly increased yield of tomato and 35.55 % yield advantage over the control was obtained from application of 120 kg K_2O/ha. Prajapati and Modi, (2012) also reported that K plays significant roles to enhance crop quality, disease resistance, and shelf-life of fruits and feeding values of produces. Besides, Javaria *et al*., (2012) founded that application of 375 kg/ha of K_2O had 27.44% and 101.23% increase of total solids and total soluble solids (TS and TSS), respectively as compared to control.

According to Negassi, *et al*., (2002) most farmers in Eritrea apply inorganic and some organic fertilizers to boost yield of commercial crops. A few kinds of fertilizers (DAP and Urea) are applied at relative low levels although it also varies among different farmers and area of cultivation but it remains to be below the recommended 225:112:112 kg/ha NPK rates (Hochmuth and Hanlon 2000). The most commonly used fertilizers in Eritrea are Di-ammonium Phosphate (DAP), urea and farmyard manure (Asgedom *et al*., 2011, Saleh *et al*., 2013, Ghebreslassie *et al*., 2014 and Zelelew *et al*., 2017) while application of K fertilizers is either very limited or no at all. This might be due to the hypothesis that the soil is originated from K rich parent material and contains adequate K to support crop growth (Murphy, 1968). However, recent research findings proved that K is deficient mineral (0.18 to 0.25 cmol/kg of soil) in Hamelmalo area (Million, 2014) which could be resulted due to erosion, frequent cultivation, over grazing and fuelwood and timber harvesting without replenishing of nutrients (Bein *et al*., 1996). Moreover, Zelelew *et al*., (2016) also recommended that K fertilizers should be introduced and used by the farmers in Hamelmalo (Eritrea) and other similar areas of the country to boost both yield and quality of produce. It is in the view of this background that the current study was designed to investigate the effect of potassium levels on productivity and fruit quality of tomato.

2. Materials and Methods

2.1 Site description

An open field experiment was carried out at the experimental field of Hamelmalo Agricultural College; Hamelmalo (Eritrea) during winter season of 2015-16. The study area is located 12 km north of Keren at 15^{0}52'18"north latitude, 38^{0}27'55" east longitude, and is situated at an altitude of 1280 meters above sea level. The climate of the area is semi-arid with 460 mm annual rainfall and temperature range of 11.1 ^{0}C to 34.7^{0}C during the growing season. Prior to transplanting, twelve soil samples from representative areas of the experimental field were taken with the help of an auger at 0-30 cm depth. Composite and representative soil sample was prepared by thorough mixing the samples taken. It was air dried and then passed through 2 mm sieve, the soil sample was analyzed and its physico-chemical properties are shown in Tables 1 and 2.

Table 1 Physical characteristics of the upper soil (0–30 cm) of the experimental site.

Physical properties				
Sand (%)	Clay (%)	Silt (%)	Organic Matter (%)	Soil texture class
67.8	22.1	10.1	0.30	Sandy loam

Table 2 Chemical characteristics of the upper soil (0–30 cm) of the experimental site.

Chemical properties								
N %	P (cmol/kg)	K (cmol/kg)	Mg (cmol/kg)	Ca (cmol/kg)	Na (cmol/kg)	CEC (cmol/kg)	EC (ms/cm)	pH
0.02	4.27	0.56	2	7	0.13	9.69	1.5	8.07

EC: Soil electrical conductivity
CEC: Cation exchange capacity

2.2 Experimental design

The experiment was conducted in plots using Randomized Complete Block Design (RCBD) with nine treatment of K levels (0, 50, 100, 150, 200, 250, 300, 350 and 400 kg K_2O/ha) replicated thrice. Full doses of K (K_2O) were applied through band method at the time of transplanting as per the treatments to each experimental plot. One month old healthy seedlings cultivar "Riogrande" were planted at a spacing of 75 × 45 cm in furrow plots (3 m x 3.6 m = 10.8 m^2) each. Irrigation was applied immediately after planting and subsequent irrigations were given as per the requirement of the crop. All other cultural practices were done uniformly for all the treatments.

2.3 Data collection

2.3.1 Yield parameters

Observations on yield parameters such as fruit diameter (cm), fruit weight (kg/plant) and fruit yield (ton/ha) were recorded right after harvest from net plot area (12 plants) of each treatments.

2.3.2 Fruit quality parameters

Data on specific gravity and total Soluble Solids (TSS) were determined from 100 sample fruits for each treatment by adopting weight-in-air/weight-in-water method and refractometer, respectively. Fruit dry matter and moisture content were determined using an oven and balance method.

2.4 Data analysis

The data obtained from each plot, were subjected to one-way analysis of variance (1-way ANOVA) using GENESTAT Software at 5% level of significance to assess treatment effects. Significant differences between means were determined using Least Significant Difference (LSD) and the relationships between components were tested by IBM SPSS statistical packages version 20. In addition, correlation analysis was also determined.

3. Results and Discussion

3.1. Yield and Yield components

Figure 1 shows the influence of K application on fruit diameter (cm). Significant difference ($p < 0.005$) was found on fruit diameter among treatments. Fruit diameter was gradually enhanced with increasing K levels up to 150 kg K_2O/ha. Maximum value (4.76 cm) was recorded from plots treated with 150 kg K_2O/ha and minimum fruit size (3.71cm) was obtained from control. The fact that the experimental field was deficient in K content (Table 2) has influenced the crop to have positive response towards K applications. K application increases the size of fruits, especially, in soil with low to medium nutrient content (Perkins-Veazie and Robert, 2003). Similarly Amjad *et al*., (2014) reported that K application significantly induced fruit diameter. This could be ascribed to activation of enzymes by K and its involvement in adenosine triphosphate (ATP) production which is important in regulating the rate of photosynthesis which enable the plants to have more food to be stored in the fruits (Havlin, *et al*., 2005). ATP is also used as the energy source for many plant activities (Van Brunt and Sultenfuss, 1998) including cell divisions. Then cell division determines to a large extent the final number of cells in a fruit and thereafter the final fruit size (Lemaire-Chamley *et al*., 2005).

Result of the current study also indicated that fruits weight (kg/plant) was significantly influenced by potassium applications and was appreciably increased with increasing K levels up to 150 kg K_2O/ha thereafter decreased (Figure 2). The highest fruit weight per plant (1.39 kg) was obtained from the application of 150 kg K_2O/ha whereas the lowest (0.807 kg) was recorded from 400 kg K_2O/ha. Correspondingly Ghourab *et al*., (2000) stated that application of adequate K increases fruit weight by increasing translocation of photosynthates to fruit and water use efficiency. However, the excessive application of 400 kg K_2O/ha might have resulted negative influence on the fruit production capacity of the plants. This is in close agreement with previous investigation of Pervez *et al*., (2013) who confirmed that excessive doses of K has negative impacts on potato tubers weight per plant. Besides, the importance of balanced K nutrition for tomato crop was also advocated by (Zia-ul-Hassan, 2016).

Results in Figure 3 further revealed that increasing potassium application from 0 to 150 kg/ha had increased the yield of tomato (t/ha) significantly (p=<0.05). Plots treated with 150 kg K_2O/ha gave maximum value (15.45 t/ha) with 67.75% yield advantage over the control (0 kg K_2O/ha). This is in close consistency with the finding of Iqbal *et al*., (2011) who concluded that K has significant effect on tomato yield and maximum yield (19 t/ha) was obtained from application of 130 kg K_2O/ha. In addition, Ahmad *et al*., (2015) reported that tomato yield was significantly increased and showed 35.55 % yield advantage over the control when K is applied at the rate of 120 kg K_2O/ha. This could be due to the fact that sufficient supplement of K helps plants for efficient photosynthetic activities and translocation of photosynthates from sites of production to storage organs (Cakmak *et al*., 1994, Abd El-Latif *et al*., 2011 and Patil, 2011). The positive response of the crop to K application could also be attributed to the poor K content of the experimental field (Table 2).

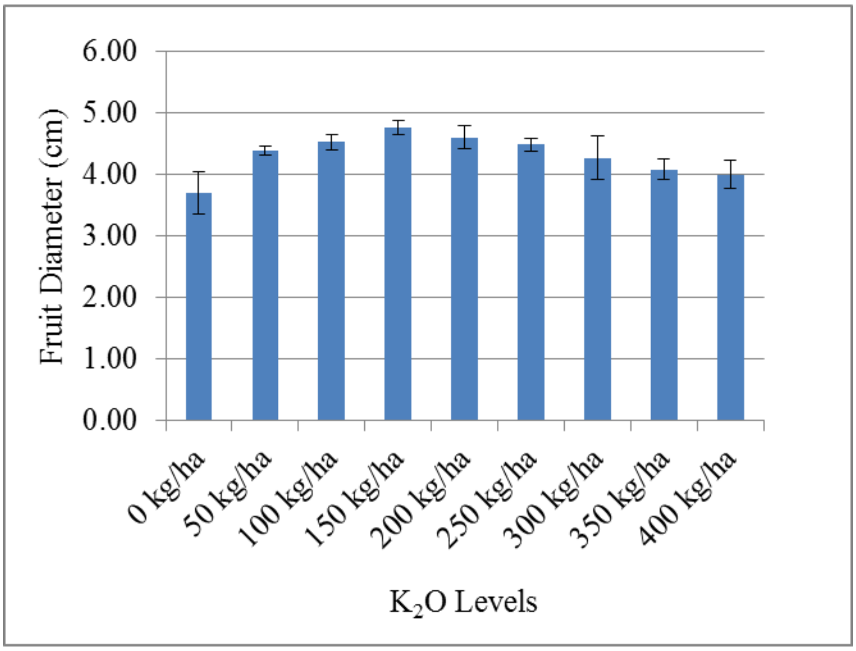

Figure 1 Effect of potassium on fruit diameter (cm)

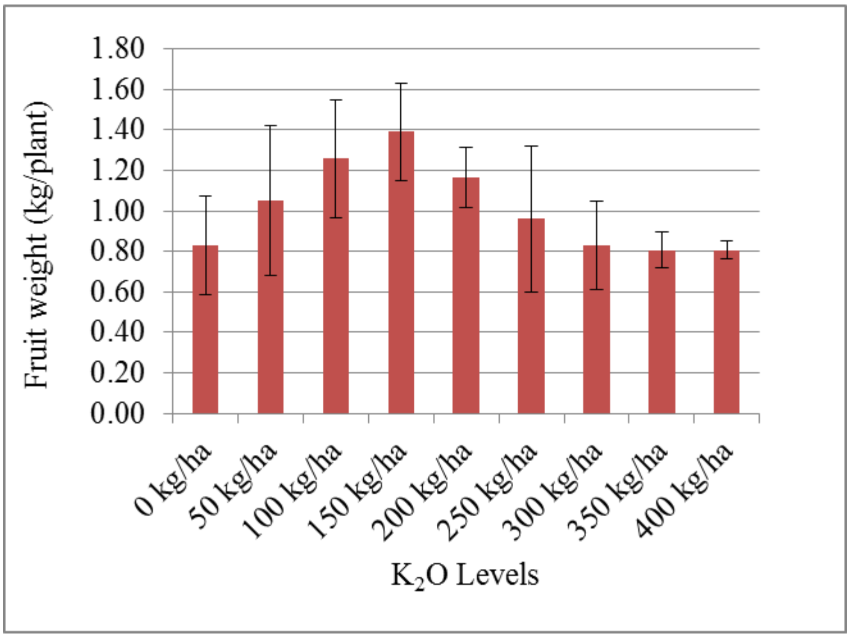

Figure 2 Effect of potassium on fruit weight (kg/plant)

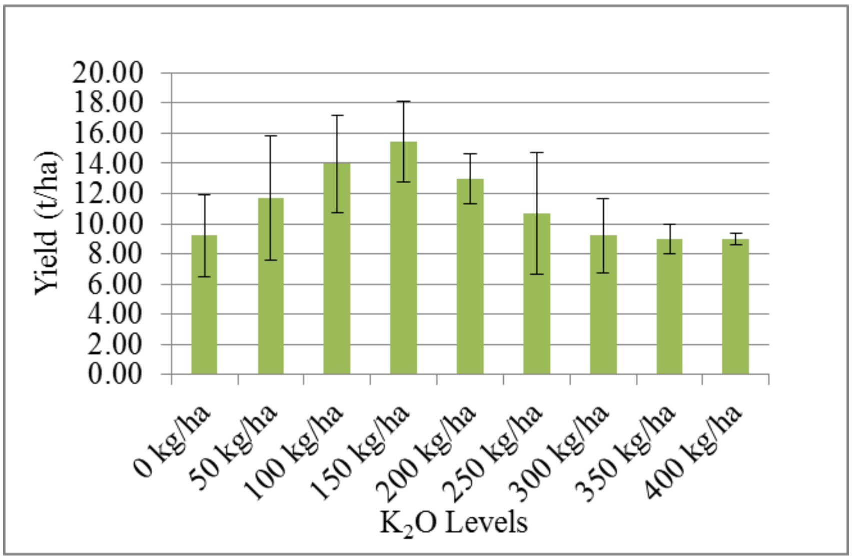

Figure 3 Effect of potassium yield of tomato (t/ha)

3.2 Quality parameters

Total soluble solids of tomato are predominantly sugars, which determine flavor and other fruit quality characteristic. The result presented in Figure 4 indicates that TSS was significantly influenced by potassium levels. The highest value (3.84^o brix) was recorded from 150 kg K_2O/ha while the lowest (3.05^o brix) was obtained with application of 400 kg K_2O/ha. Similarly Javaria *et al*., (2012) found that TSS was significantly influenced by the application of K. TSS showed increment when K doses were increased up to 375 kg K_2O/ha the author added. The increase of TSS in the fruits with the increase of K levels confirms that

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K played an important role in the configuration of quality profile in tomato fruits (Caretto *et al*., 2008). Besides, Wuzhong, (2002) reported that an increase of K fertilizer application increased sugar content of tomato fruit which in turn, a higher import and accumulation of sugar may enhanced TSS content in tomato fruits (Balibrea *et al*., 2006). In contrary to the current findings Al-Moshileh *et al*., (2017) reported that k application did not have significant effect on TSS of tomatoes.

The influence of K application on specific gravity was found to be significant. Specific gravity had shown gradual increment with increasing potassium levels up to 150 kg K_2O/ha then after decreased. Maximum value (1.46) was obtained from application of 150 kg K_2O/ha while plots treated with 400 kg K_2O/ha gave the lowest (1.10) mean value (Figure 5). Consistent to the current results, Zelelew and Ghebreslassie (2016) reported that application of K fertilizer had significant influence on specific gravity of potato tubers and maximum (1.11) was obtained from 150 kg K_2O/ha. Similarly application of 150 kg K_2O/ha yielded highest fruit size and fruit weight per plant (Figures 2 and 3) which might have a positive effect on specific gravity which is closely correlated with fruit size and weight (Tigist *et al*., 2012). Application of sufficient K also decreases dark respiration leading to more deposition of photosynthates in the sink (Bergmann, 1992 and Havlin *et al.*, 2005) that ultimately increased fruit size and specific gravity of tomato fruits.

Fruit dry matter content had increased significantly with increasing K application up to 150 kg K_2O/ha and then decreased (Figure 6).The highest and lowest dry matter content (5.68 % and 4.53 %) were obtained from applications of 150 and 400 kg K_2O/ha, respectively. In line to the current result decreased in dry matter content of tomato and sweet pepper fruits was reported when potassium was applied above 225 Kg/ha (Wuzhong, 2002). On potassium deficient soils, dry matter percentage increases with increasing K doses but it is only up to the rate required for optimum yield (McNabnay *et al*., 1999). Likewise soil fertility of the current experimental field was deficient in K content (Table 2) resulted for positive response up to 150 kg K_2O/ha which might be the optimum level for that particular area. The result was supported by Panique *et al*., (1997) who reported that reductions in dry matter content occurred only if high rates of potash are applied.

With regard to fruit moisture content, potassium treatment was found to have statistically significant effect. Opposite to fruit dry matter content, fruit moisture content had increased more in the range of 150 - 400 kg K_2O/ha. Maximum fruit moisture content (95.47%) was obtained from the application of 400 kg K_2O/ha (Figure 7). The result of this current experiment is supported by the findings of (Bergmann, 1992) who reported that with the application of potassium, the water contents of the plasma volume were found to be influenced, thus increased the water contents of fleshy storage tissues as to reduce the dry matter content. This could be due to the vital role K in water use efficiency of crops, maintaining the turgidity of plant cells and amount of water in plant cells so as to increase the amount of water in plant organ like fruits (Abd El-Latif *et al*., 2011).

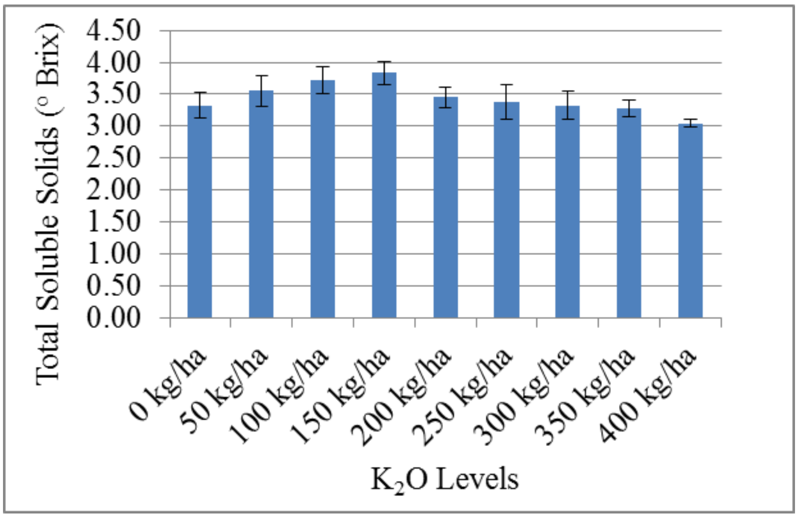

Figure 4 Effect of potassium on Total soluble solids (^{o} Brix)

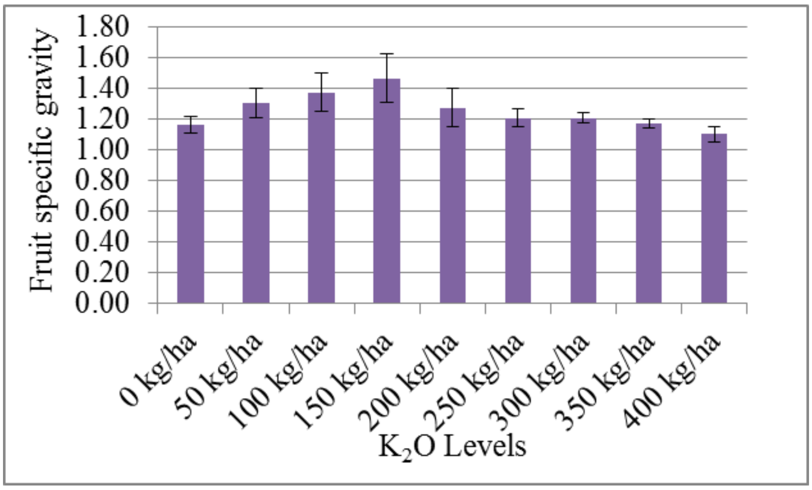

Figure 5 Effect of potassium on fruit specific gravity

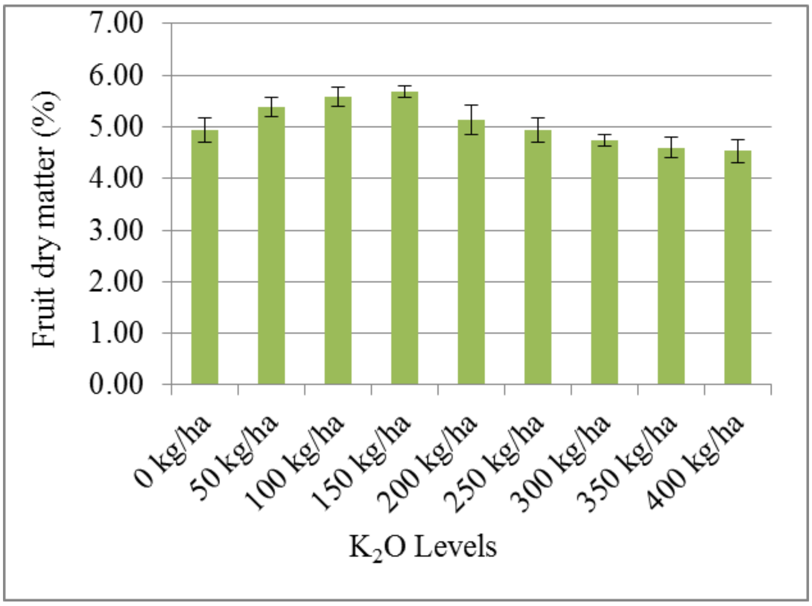

Figure 6 Effect of potassium on fruit dry mater content (%)

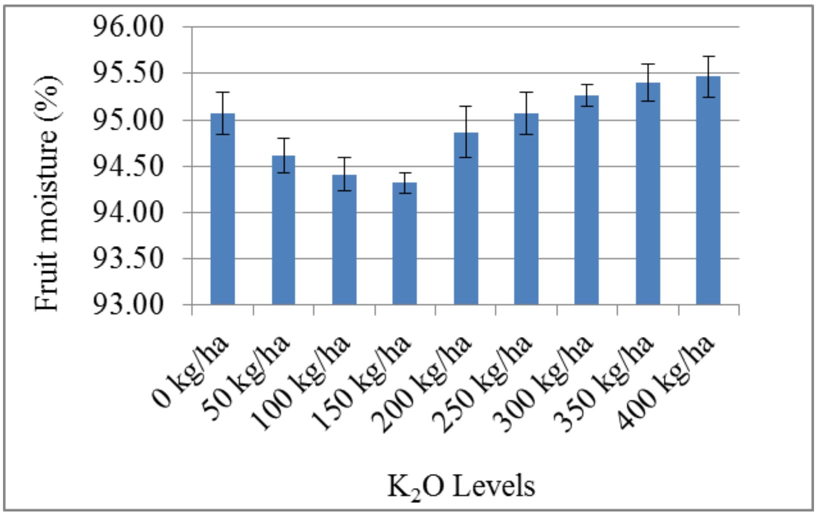

Figure 7 Effect of potassium on fruit moisture content (%)

3.3 Correlation among Potassium, Yield and Quality Parameters

Correlation analysis result revealed that, K had positive and significant correlation with fruit diameter ($r = 0.066$), fruit weight per plant ($r = 0.315$) and total fruit yield ($r = 0.315$). Similar positive correlation of K with fruit weight per plant and fruit diameter was reported by (Amjad *et al*., 2014). This indicates that increasing K levels results an increase on fruit diameter; fruit weight per plant and total fruit yield. This is due to the significant role of K in carbohydrate formation and transformation and movement of photosynthates from sites of production to storage organs (Cakmak *et al*., 1994, Abd El-Latif *et al.*, 2011 and Patil, 2011). Fruit diameter was also positively correlated with fruit weight per plant ($r = 0.599$) and total fruit yield (r =

0.599). These positive correlations implies that for every addition of tomato fruit size there was an increase on fruit weight produced per plant and then ultimately increased overall fruit yield. Likewise, total fruit yield was found to be positively correlated with TSS (r = 0.577), fruit specific gravity (r = 0.667) and fruit dry matter (r = 0. 688). The result further proved that potassium application had positive correlation with TSS (r = 0.441), fruit specific gravity (r = 0.395) and fruit dry matter (r = 0. 600). This could be due to the active role of K in increased sugar content of tomato fruit Wuzhong, (2002) which in turn a higher import and accumulation of sugar may enhanced TSS content in tomato fruits (Balibrea *et al*., 2006).

4. Conclusion

It is concluded that application of K fertilizer has significant and positive influence on yield and fruit quality parameters of tomato. There were positive correlations among K, yield and fruit quality parameters. Highest fruit weight (1.39 kg/plant), fruit yield (15.45 t/ha), total soluble solids (3.84 ^{o} Brix), specific gravity, (1.46) and fruit dry matter (5.68) were recorded from 150 K_2O kg/ha. It is therefore recommended that fertilizer package policy of the country need to be revised, K fertilizers should be introduced and balanced NPK fertilizers should be applied to improve yield and quality of tomato produce.

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