The Journal of Animal & Plant Sciences, 22(4): 2012, Page: 1081-1085
ISSN: 1018-7081

EFFECT OF POTASSIUM ON CHEMICAL AND SENSORY ATTRIBUTES OF TOMATO FRUIT

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ABSTRACT

Fruit quality is a crucial factor in the production of tomato and potassium is the only mineral element known as the quality nutrient because of its vital role in building up of metabolites and activation of enzymes which ultimately improve chemical and sensory attributes of tomato fruit. In the present investigation effect of different rates of potassium fertilizer on chemical and sensory attributes of tomato were studied through pot experiment conducted during crop season of 2009. The pots were treated with K_2O @ 0, 75, 150, 225, 300, 375, 450 Kg K_2O ha^{-1} along with basal doses of N and P (100 Kg N and 80 Kg P_2O_5 ha^{-1}, respectively). Treatments were arranged in complete randomized design. The result showed that total solids, sugars & titratible acidity increased significantly with increasing rates of potassium but contrary to above attributes the pH decreased. Similarly, lycopene, vitamin C and total soluble solids increased significantly with increased application of K_2O up to 375 kg but thereafter decreased when K_2O was applied @ 450 Kg K_2O ha^{-1}. Significant relationships were apparent between fertilizer rates and surface redness, tissue redness, firmness, crispness, mealinss, sweetness, sourness and flavor. Moreover, several masking effects were observed between taste active components and chemical components of tomato fruit. A positive linear correlation of flavor with sugar, total solids, titratible acidity; surface redness with lycopene & firmness with total solids while negative correlation between flavor and pH was observed. It was concluded that increasing K concentration resulted in improved quality parameters of tomato fruit and application of K_2O @ 375 Kg K_2O ha^{-1} along with recommended doses of N and P was found to be the best dose for high quality tomato fruit.

Key words: Potassium fertilizer, tomato quality, chemical composition, sensory attributes

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is a nutritious and popular product all over the world. Tomatoes are grown over about 53.1 thousand hectares in Pakistan with an average yield of about 10.1 tons ha^{-1} (Anonymous, 2008). However, much higher tomato yield has been reported in other countries of the world e.g., 73.87 t ha^{-1} in USA, 63.55 t ha^{-1} in Spain, 88.91 t ha^{-1} in California and 146 t ha^{-1} in the Netherlands (Bradley, 2006). One of the reasons of low yield in Pakistan is imbalanced fertilizer use; nitrogen 250 kg N and phosphorus 125 kg P_2O_5 ha^{-1} are being used commonly, while the use of potash and micronutrient are negligible. Potash use in Pakistan is only about 2 kg ha^{-1} (Khan, 2006)

Potassium is one of the essential mineral nutrients in the plant food and one of the three those are taken up by roots from the soil solution in its ionic form. It is involved in numerous physiological processes that control plant growth, yield and quality parameters such as sugars, titratible acidity (TA), soluble solids (SS), total soluble solids (TSS), taste, color, firmness and meliness (Wuzhong; 2002 and Lester *et al*., 2005). Potassium (K) is the most efficient cation for tomato plants and according to several authors, it plays a key role in the improvement of several quality traits in tomato fruits and in almost all vegetables (Cakmak, 2005; Chapagain and Wiesman, 2004; Dorais *et al*., 2001). Unlike nitrogen, phosphorus, and sulfur, K is not a constituent of the organic matter, but its physiological functions in plants include enzyme activation, osmoregulation, photosynthesis, and translocation of photosynthates into sink organs (Marschner, 1995). Plants receiving K applications matured earlier and had significantly higher soluble solid concentration, total sugar, ascorbic acid (vitamin C), and beta-carotene content than fruits from plants without receiving any K application (Lester *et al*., 2005). It has been reported that acid and reducing sugar contents in tomato, often correlated with K application, influence not only sweet and sour taste attributes, but also different flavor traits (Auerswald *et al*., 1999; Chapagain and Wiesman, 2004). It also affects the nutritional quality of tomato as it increases lycopene which may protect against certain cancers such as prostate cancer and add in redness of fruit (Etminan *et al*., 2004).

Most of the work published on the taste-active components of tomato are of limited use for relating the chemical composition, organolyptic characteristic of whole fruit and effect of fertilizer on it. The present study was conducted to search the effect of potassium fertilizer levels on the quality of tomato and also to evaluate taste active compounds and nutrients present in tomato by adjusting potassium fertilizer along with recommended doses of nitrogen and phosphorous.

MATERIALS AND METHODS

Growing system: A pot experiment was conducted during 2009 cropping season at the research area of Faculty of Agriculture, Gomal University D.I.Khan, Pakistan. The pots were kept in open. The maximum and minimum temperature was 35 °C and 11°C, respectively and annual rainfall was about 7 inches (Pakistan Meteorological department D.I.Khan, 2009).

The soil was thoroughly prepared and analyzed for its physico-chemical characteristics which are given in table 1.

Table 1: Physico-chemical characteristics of soil

Characteristics	Values	Units
Textural class	Sandy loam	-
pH	7.8	-
Organic matter	0.92	%
ECe	1.4	dSm^{-1}
$CaCO_3$	2.05	%
CEC	3.25	meq/100 g
Total Nitrogen	0.04	%
Available phosphorous	12	µg/g soil
Available potassium	102	µg/g soil
Available Zn	4.012	µg/g soil
Available Cu	5.012	µg/g soil

Galia variety of tomato was used as test crop. One month old seedlings raised in seed bed were transplanted to the pots in the last week of November. Each pot was filled with 21 Kg soil and then treated with Potassium sulphate fertilizer @ 0, 75, 150, 225, 300, 375, 450 Kg K_2O ha^{-1} along with recommended doses of N and P (100 Kg N ha^{-1} in the form of urea and 80 Kg P_2O_5 ha^{-1} in the form of single super phosphate). Quantities of fertilizers for a pot were calculated by the method described by Yellamanda and Sankara (2002) (Table 2).

Table 2: Quantity of fertilizers applied per pot

Manures/ Fertilizer used	Dose of NPK (Kg ha^{-1})	Dose of NPK pot^{-1}
Control	--	--
Nitrogen	100 Kg ha^{-1}	1.35 g pot^{-1}
Phosphorous	80 Kg ha^{-1}	2.48 g pot^{-1}
Potassium	75 Kg ha^{-1}	0.93 g pot^{-1}
	150 Kg ha^{-1}	1.86 g pot^{-1}
	225 Kg ha^{-1}	2.80 g pot^{-1}
	300 Kg ha^{-1}	3.73 g pot^{-1}
	375 Kg ha^{-1}	4.60 g pot^{-1}

Doses of K and P were applied to the pots at the time of transplantation of seedlings while N was applied in 2 splits, half at the time of transplantation and half with 8^{th} irrigation. Irrigation was done at an interval of 4 days after transplantation of tomato plants until March and then daily up to the time of harvesting. Each treatment was replicated 4 times and the experiment was arranged in a complete randomized design.

Assessment of Chemical attributes of tomato fruit: In the last week of March, when the tomatoes reached the table ripe stage of maturity as determined visually USDA (1975), they were halved, one half was further divided into wedges for sensory analysis. The remaining halves for each treatment were blended and subjected to chemical analysis. Vitamin C was extracted and estimated by the method as described by David (1986). Lycopene was detected and estimated by the method of Lidia *et al;* (2007). Total soluble solids, titratible acidity, pH, total solids and total sugars of fruit were estimated by the method of Awan (2001).

Sensory evaluation: A group of ten assessors was trained in descriptive analysis according to guidelines in ISO (1993). Samples of half a tomato from each treatment were served on white plates coded with a 3-digit number in arbitrary order to each assessor. Two evaluations of the samples were carried out per day. The assessors developed a list of profiling attributes and agreed on: redness of the surface skin, redness of the fruit tissue evaluated as the 1 cm layer just below the skin, firmness, crispness, sourness, sweetness, mealiness and tomato flavor. The panel was trained for 4–5 h in the profile with respect to reproducibility and aptitude to categorize. The evaluation was carried out using a 18-cm unstructured line scale with affix points 'none' on the left side and 'very much' on the right side. While choosing the panelists following criteria were kept in mind,

i) Don't have allergy from tomatoes
ii) Their ages were between 21-60 years
iii) Able to pass a flavor acuteness test

Between samples' sensory analysis panel was guided to clean their mouths with a piece of bread and mineral water to vanish the effect of taste of previous sample

Statistical analysis: The instrumental/chemical data were analyzed with Analysis of variance (ANOVA) according to Russell (1991) at $p \leq 0.05$. LSD was used to assess the location of the significant differences. Regression and correlation analysis of sensory data were statistically analyzed by Microsoft excel XP spreadsheet as described by Gomez and Gomz (1984).

RESULTS AND DISCUSSION

Chemical attributes: Increased levels of potassium had shown significant effect in increasing the ascorbic acid (vitamin C) content of tomatoes (Table 3). The highest ascorbic acid content (31.14 mg /100 g) was recorded in the treatment (T_6) that received 375 kg K_2O ha^{-1} as sulphate of potash and was found to be superior over control (18.70 mg /100g). However, with further increase of K_2O @ 450 Kg K_2O ha^{-1} (T7), a decrease of 23.32 % in vitamin C from T6 was noted. The reason of increased ascorbic acid might be that potassium plays a key role in proper carbohydrate metabolism and close relationship between carbohydrate metabolism and formation of ascorbic acid has been reported by Majumdar *et al.* (2000) and Ananthi *et al.* (2004). Results obtained are in conformity with the findings of Wuzhong (2002) and Bose *et al*. (2006) who reported positive correlation between enhanced potassium doses and ascorbic acid content.

Fruit lycopene was significantly influenced by potassium levels. There was 52.54% increase in lycopene content over control (Table 3). The increased lycopene value might be because of the key role of potassium in accelerating enzymatic activities that enhanced lycopene production in tomato fruit. The results are in conformity with findings of Hartz *et al*. (2000). However, these results contradicted with the findings of Paulo *et al*. (2000) who reported that K fertilizer rate had no effect on lycopene content of tomato fruit. However, further increase in potassium level decreased lycopene, as lycopene production is sensitive to the exact potassium concentration in cytoplasm. Henry *et al*; (2008) concluded that overdose of potassium decreased lycopene concentration in tomato fruit.

Total sugars are significant components of flavor in tomatoes. In the present study potassium fertilizer enhanced sugars over control by 11.03% (Table 3). The reason of enhanced sugar content could be the participation of potassium in biosynthesis and transfer of sugars as concluded by Karam *et al*., (2009). The results are however, in contrast with those reported by Ehsan *et al*; (2010) who found no significant effect of enhanced potassium fertilizer on total sugar content of tomato. These contrasting results may be ascribable to cultivar differences in absorption and response to K fertilization as well as environmental factors such as light, water and nutrient supply which always result in different outcomes (Paulo *et al,* 2000).

Fruit pH plays an important role in processing of tomato. If it is low, it would help to increase shelf life of tomato and improve its flavor Panagiotopoulos and Fordham (1995). In present study as the potassium levels increased pH was decreased (6.35%) over control (Table 3). These results support the finding of Wuzhong (2002) and Lester *et al*., (2005).

Titratible acidity increased significantly with increase in potassium levels, an increase of 121.87% in titratible acidity over control was observed (Table 3). These results are in confirmatory with the results of Wuzhong (2002), who stated that potassium fertilizer have significant effect on titratible acidity and hence on taste of tomato fruit.

Total solids and soluble solids are closely related to each other and these are important attributes which determine mineral nutrition status and shelf life of raw and processed tomatoes. The statistically analyzed results in table 3 depicted that TS and TSS increased significantly over control by 27.44% and 101.23%, respectively with enhanced doses of potassium. Also, the content of tomato fruit was significantly affected by differing K levels. The maximum value of TS was observed in the treatment where K was applied @ 450 kg K_2O ha^{-1} while TSS was maximum in the treatment receiving 375 kg K_2O ha^{-1} and then decreased by 20.37 % with the highest K level (450 kg K_2O ha^{-1}). These results are in line with those reported by Cakmak (2005) and Wuzhong (2002). They reported an increasing trend of sugar contents as well as TS and TSS content in tomato fruit with K fertilizer application. These results are however, in contrast to those of Yagmur *et al*, (2004) who reported no positive effect of K fertilizer on solids of tomato. The difference in response of tomato to K fertilizer could be due to nature of tomato variety tested, soil and climatic condition etc. The experimental site in the present study is situated in low rainfall area with comparatively high temperature. It appears that the variety had preference for relatively similar environmental conditions.

Sensory attributes: There are 7 basis or general factors on which the consumers evaluate the quality of tomatoes. These are color, mealinss, firmness, crispness, sourness, sweetness and flavor. The effect of potassium on the sensory attributes of tomatoes is given in table 4. Significant effects of enhanced potassium fertilization were observed on sensory attributes those were correlated with chemical components (Table 4). Tomatoes grown with enhanced potassium doses had higher intensity in surface redness, tissue redness, firmness, sweetness, crispness and flavor ($P \leq 0.001$) while lower intensity for sourness and mealinss ($P \leq 0.001$).

Very different patterns of correlation between chemical and sensory attributes emerged as perceived by panelists. A strong positive correlation has been observed between trained panel response of flavor and total solid, sugars and titratible acidity and was negative to pH. Enhanced doses of potassium had significant effect on it as had on lycopene and surface redness. The studies of Shashidhara and Mathad (2008) affirmed these results. Correlation coefficients in respect to chemical and sensory characteristics were very high in terms of increased potassium levels (Table 5). These results are supported by the research conclusion of Ni-Wu *et al*; (2001) and Economakis and Daskalaki (2003).

Table 3: Quality attributes of tomato as affected by different levels of potassium fertilizer.

Treatments	Vitamin C mg /100 gm	Lycopene mg /100 gm	Total sugars	Titratible acidity acidity (%)	pH	Total solids	TSS (Brix)
T_1 NP+ 0 kg K_2O ha $^{-1}$	18.70 f	3.10^f	3.12^f	0.35^e	4.87^a	10.75^f	5.0^e
T_2 NP+ 75 kg K_2Oha $^{-1}$	20.68 e	3.51^e	3.51^e	0.37^{de}	4.85^a	12.20^e	5.46^d
T_3 NP+ 150 kg K_2Oha $^{-1}$	25.89 d	4.05^d	3.68^d	0.40^d	4.72^b	15.82^d	6.02^c
T_4 NP+ 225 kg K_2Oha $^{-1}$	27.24 c	4.30^c	3.78^c	0.63^c	4.69^b	20.20^c	6.12^c
T_5 NP +300 kg K_2Oha $^{-1}$	28.20 c	4.60^b	3.82^c	0.65^c	4.64^c	21.76^b	6.42^b
T_6 NP +375 kg K_2Oha $^{-1}$	31.14 a	5.060^a	3.97^a	0.82^a	4.57^d	24.55^a	6.97^a
T_7 NP+450 kg K_2O ha $^{-1}$	29.33 b	4.88^a	3.90^b	0.72^b	4.60^{cd}	22.51^b	6.55^b
LSD ($P \leq 0.05$)	1.016	0.230	0.055	0.046	0.048	1.390	0.270

Means bearing different superscripts in column differ significantly (P<0.05)

Table 4: Chemical & Sensory aspects of tomato as affected by different levels of Potassium fertilizer.

Treatments	Redness surface	Tissue redness	Firmness	Crispness	Mealinss	Sourness	Sweetness	Flavor
T1 NP+ 0 K ha $^{-1}$	8.0	6.5	6.8	6.5	1.9	9.0	3.0	5.0
T2 NP+ 75 K ha $^{-1}$	8.5	6.6	7	6.7	1.8	8.9	3.3	5.6
T3 NP+ 150 K ha $^{-1}$	8.6	7.5	7.2	7.1	1.6	8.7	3.6	5.8
T4 NP+ 225K ha $^{-1}$	8.8	8.0	7.6	7.6	1.2	8.5	4.3	6.0
T5 NP +300 K ha $^{-1}$	9.2	8.5	8.0	8	1.1	8.3	5.6	6.2
T 6 NP +375 K ha $^{-1}$	10	10	8.5	8.6	1.0	6.7	6.3	6.3
T7 NP+450 K ha $^{-1}$	9.7	9.8	9.0	8.9	0.6	6.0	6.8	6.8
Regression equation	y = 0.005x +8.34	y = 0.012x + 6.675	y = 0.007x + 6.883	y = 0.007x + 6.715	y = -0.003x + 1.761	y = -0.010x + 9.349	y = 0.013x + 3.133	y = 0.003x + 5.574
r^2	0.961	0.982	0.978	0.971	0.927	0.908	0.935	0.962

Table 5: Correlation coefficients between chemical and sensory attributes of tomato fruit.

Sensory and chemical characteristics of tomato	Correlation coefficients
Surface redness-Lycopene	0.96
Firmness-Total Solids	0.80
Flavor- Sugar	0.88
Flavor-pH	-0.91
Flavor- Total Solids	0.82
Flavor-Titratible Acidity	0.94

Recommendation: Based on the findings of this experiment it is recommended that for improvement of yield, quality and maximization of nutritive value of tomato, application of potassium at the rate of 375 Kg K_2O ha^{-1} along with recommended dose of N and P (100 Kg ha^{-1} N and 80 Kg P_2O_5 ha^{-1}) would be passable for acquiring nutritionally satisfying processing tomatoes under the prevailing agro-climatic conditions of D.I.Khan.

Acknowledgment: The authors are heartily thankful to the Higher Education Commission, Pakistan for financial assistance to conduct the research.

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