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Mineral uptake by tomato cultivars as affected by organic and inorganic potassium amendments

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Abstract

The study was conducted to investigate the response of various combinations of potassium from organic and inorganic sources on the mineral profile of two tomato cultivars i.e. Falcon and Rio Grande for two years. The response of tomato cultivars was assessed to six combinations viz. 0-0, 100-0, 75-25, 50-50, 25-75 and 0-100% of poultry manure (PM) and Sulphate of Potash (SOP). All the factors (K source, cultivar and year) alone and in combination significantly ($P \leq 0.05$) affected the mineral profile of tomato fruit. The lowest mineral content of potassium (28.13 g kg^{-1}), zinc (19.20 mg kg^{-1}), copper (10.97 mg kg^{-1}), boron (16.39 mg kg^{-1}) and iron (206.03 mg kg^{-1}) was examined in Falcon cultivar in control treatment during 2009. However, lowest Ca content (453.28 mg kg^{-1}) was recorded in fruits of Rio Grande in control treatment during 2009. The treatment 75-25 resulted in highest contents of Ca (590.50 mg kg^{-1}) and Cu (15.12 mg kg^{-1}) in Rio Grande cultivar during 2010. Similarly highest concentration of K (44.27 g kg^{-1}), Zn (29.20 mg kg^{-1}) and B (28.02 mg kg^{-1}) was recorded for Rio Grande at treatment 50-50 of PM and SOP respectively. Whereas, the highest Fe (293.25 mg kg^{-1}), was recorded in cultivar Rio Grande at a treatment of 100-00 of PM and SOP. It was concluded that a combination of PM and SOP at 75-25 and 50-50 ratio may be used as an optimum fertilization dose for obtaining higher mineral contents of tomato crop.

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Introduction

Tomato (*Solanum lycopersicon* Mill) is widely cultivated crop in Pakistan. There has been a progressive increased in the area and production of tomato in Pakistan. Despite a steady increase in tomato yield ha^{-1}, Pakistan is still lagging behind in the production of the required quantity and quality of tomato as compared to developed countries. There are many factors responsible for the low production that includes the unavailability of high yielding cultivars, costly planting materials and lack of awareness in the use of integrated nutrients and pest management practices. The major factors that influence fertility include crop rotation and proper use of organic and inorganic fertilizers. Whereas the use of chemical fertilizers has detrimental effects on soil quality, water and air, the consumers have realized the importance of nutritious and safer foods (Jolly, 1996). The alternative to chemical fertilizer is organic manures especially poultry manure which provide a portion, or all, of the plant mineral requirements (John *et al*., 1999). It contains N, P and K and trace elements in higher quantity (Bolan *et al.,* 2010) and other minerals such as Cu, Ca and Zn etc (Bolan *et al*., 2010; Leytem *et al*., 2007). Potassium is present more abundantly in the soil than phosphorus but requires in large amounts by plants, being the second most concentrated nutrient in plant leaves and shoots after nitrogen. Potassium plays an important role in tomato fruit quality by involves in metabolic processes, such as the enzyme activation, synthesis of proteins, membrane transport processes and the generation of turgor pressure (Dorais *et al*., 2001). Furthermore, it involves in the translocation of photosynthates from sources to sinks (Cakmak *et al*., 1994). As tomato plant grows, the absorption of potassium increases to a relatively greater extent than that of other nutrients (Voogt and Sonneveld, 1997). The removal of nutrients by crops and the addition of nutrients to soil from fertilizers or manure plays key role in the nutrient balance of a cropping system (Blaise *et al.,* 2005). However, the application of chemical fertilizers has detrimental effects on soil, water and air quality (Allen *et al.,* 2006). The organic manure is very helpful in supplying potassium to soils on long term basis (Lin, 2010) and the combine application of poultry manure and potassium fertilizer increased the nutrients uptake from soil (Mottaghian *et al*., 2008). The use of both sources increases K utilization by transition in phloem vascular and growth stimulating material and increases cell division (Tabatabaii *et al*., 2011). The application of manure not only supplies the potassium but also add organic matter (Ouda and Mahadeen, 2008). By contrast, organic manure adds organic matter to soil, improves soil structures, promotes soil moisture and nutrients retention (Deksissa *et al*., 2001). The poultry manure is a cheaper source of fertilizer (Rahman, 2004) and may fulfill a portion, or all of the plant mineral requirements (John *et al*., 1999). Poultry manure also helps in maintaining the soil in optimum physical and chemical condition, a primary requirement for plant growth (Yafan and Barker, 2004). The organic fertilizer supply the nutrients in long run as compared to inorganic fertilizer which are readily available and cannot sustained for long time (Vernon, 1999). Thus, organic manure is an integral part of fertilizers management to sustain high crop productivity and profitability as well as minimize environmental degradation (John *et al*., 2004) and integrated nutrient management is recommended in agricultural and horticultural production systems (Moore Jr. *et al*., 2006).

Previous studies have shown that the combine application of commercial organic manure and chemical fertilizers enhanced the quantity and quality of vegetables (Kong and Ni, 2006; Qin *et al*., 2005). These observations allowed us to hypothesize that there might have been a synergistic influence of organic and inorganic K sources on the yield and mineral contents of tomato fruit. Therefore, this study was conducted to investigate the effect of poultry manure and SOP amendments on the yield and mineral profile of Rio Grande and Falcon tomato cultivars.

Materials and methods

Experimental site and soil characterization

The study was conducted in district Swat during summer 2009 and repeated in 2010. The climatic condition of the site was temperate to warm with low monthly average rainfall (9 mm) in 2009 and adequate (154 mm) in 2010 during the cropping season. The main chemical characteristics of the poultry manure and soil for both year are presented in the below paragraph.

Poultry Manure (2009-10): OM (3.45-3.25%), N (3.36-3.15%), P (1.80-1.74%), K (2.65-2.91%) and soil pH (7.5-7.44).

Soil (2009-10): OM (0.69-1.14%), N (0.034-0.055%), P (0.0086-0.0094%), K (0.019-0.021%) and soil pH (6.91-6.82).

Experimental design and crop fertilization

The experiment was laid in Randomized Complete Block Design (RCBD) with three factors and replicated four times. The factors included K-source (PM and SOP), cultivar (Falcon and Rio Grande) and two consecutive years of cultivation. The tomato cultivars were fertilized with PM and SOP in various combinations viz. 0-0 (control), 100-0, 75-25, 50-50, 25-75, 0-100 in percent. Each of these combinations provided 60 kg/ha of K to the crop. The experimental plot was ploughed and disked three times, and the beds were prepared manually. The PM was applied one month before seedling transplantation, while the SOP was applied at the time of seedling transplantation. The seedlings were transplanted on both sides of two-meter wide and five meter long beds with a distance of 60 cm on the bed. The plants were irrigated just after seedling transplantation and further irrigation were made as per plant requirement during the whole cropping season. The N and P requirements of the crop was fulfilled from PM, Urea and Triple Super Phosphate. Weeds were controlled manually in all plots. Corrective measures were taken for the control of pest and diseases. At each harvest the fruit were analyzed for mineral contents.

Minerals Analysis

For minerals analysis an acid digest of each dried sample was prepared according to AOAC, (2000). For the determination of elements such as Ca, Fe, Zn and Cu the method of Sandell (1959) and O'Dell *et al.* (1972), modified for macro-levels was employed using double beam Atomic Absorption Spectrophotometer (PerkinElmer Model A Analyst 200) equipped with laminar flow burner using an air acetylene gas and hollow cathode lamps. Whereas B content in tomato fruit was determined by Azomethine-H method developed by Basson *et al.* (1969).

Statistical analysis

The data calculated on different parameters were subjected to analysis of variance (ANOVA) technique to observe the differences among the treatments and their interactions. In cases of significant differences the means were separated using Least Significant Difference (LSD) test. Statistical computer software Statistix 8.1 was used for computing the ANOVA and LSD (Jan *et al.*, 2009).

Results

Fruit Potassium content

The tomato fruit potassium content was significantly ($P \leq 0.05$) affected by tomato cultivars fertilizer treatments and years, whereas the interactions among cultivars, fertilizer application and years were non-significant (Table 1).

The results (Fig 1) indicated that higher potassium content (44.27 g kg^{-1}) was recorded in fruits of Rio Grande cultivars with the application of 50-50 PM and SOP during 2010 closely followed by K content (41.50 g kg^{-1}) with 25-75 PM and SOP respectively. However the lowest K content (28.13 g kg^{-1}) was observed in Falcon cultivar in unfertilized plants during 2009.

Fruit Zinc content

The fruit Zn content was significantly ($P \leq 0.05$) affected by all the factors viz. K-source, cultivars and years (Table 2). While there was no significant interaction found among N-source, cultivars and years. Rio Grande cultivar contained higher Zn concentration than Falcon fruits (Fig 2). The higher fruit Zn content (29.20 mg kg^{-1}) followed by (28.95 mg kg^{-1}) was recorded with the application of K-source at ratio 50-50 and 75-25 from PM and SOP respectively in cultivar Rio Grande during 2010. However the lowest Zn concentration (19.20 mg kg^{-1}) was noted in fruits of Falcon cultivar in control treatment during 2009.

Table 1. Analysis of Variance for the effect of potassium sources on fruit potassium content (g kg^{-1}) of tomato cultivars.

Source	df[a]	Mean Square	P value
Year (Y)	1	145.632	0.0000
Cultivars (C)	1	350.753	0.0000
C x Y	1	14.061	0.1532
Treatment (T)	5	165.797	0.0000
Y x T	5	1.551	0.9480
C x T	5	0.538	0.9951
Y x C x T	5	4.138	0.6893
Error	66	6.736	
Total	95		

[a] df: degree of freedom.

Fruit Copper content

The fruit Cu concentration significantly (P≤0.05) responded to K-source, cultivars and years (Table 3). Fruit Cu content significantly responded to either source of potassium. Increased the K-source PM from 0 till 75% significantly improved the fruit Cu content in both cultivars. The data (Fig 3) indicated that Rio Grande cultivar contained the higher Cu concentration (15.12 mg kg^{-1}) with the application of K-source 75-25 ratio of PM and SOP during the year 2010. The unfertilized plants resulted in lower Cu concentration (10.97 mg kg^{-1}) in Falcon cultivar during 2009.

Table 2. Analysis of Variance for the effect of potassium sources on fruit zinc content (mg kg^{-1}) of tomato cultivars.

Source	df[a]	Mean Square	P value
Year (Y)	1	76.684	0.0049
Cultivars (C)	1	53.700	0.0001
C x Y	1	0.184	0.8042
Treatment (T)	5	71.426	0.0000
Y x T	5	1.937	0.6603
C x T	5	3.355	0.3529
Y x C x T	5	0.421	0.9817
Error	66	2.967	
Total	95		

[a] df: degree of freedom.

Fruit Calcium Content

The analysis of variance (Table 4) indicated that all the three factors K-source, cultivars and year significantly (P≤0.05) affected the fruit calcium content. The Falcon cultivar was noted superior in terms of Ca content in tomato fruit as compared to Rio Grande. The figure 4 clearly showed that higher PM ratio improved the Ca concentration in tomato fruit and reached maximum with the application of nitrogen 75% from PM. The results indicated that the maximum fruit Ca content (617.40 mg kg^{-1}) followed by (613.08 mg kg^{-1}) was noted with the application of K-source 75% from PM and 25% from SOP in Falcon cultivar during 2010 and 2009 respectively. However the minimum Ca concentration was (453.28 mg kg^{-1}) was observed in Rio Grande cultivar during 2009.

Fruit Iron content

A significant (P≤0.05) variation was observed in all the individual factors i.e. K-source, cultivars and years regarding fruit Fe content (Table 5). The results (Fig 5) indicated that N-source PM significantly increased the Fe content in the tomato fruit. The data showed that the K-source 75-25 PM and SOP significantly increased fruit Fe content (293.25 mg kg^{-1}) in Rio Grande cultivar during 2010. However the untreated plants resulted in lower Fe concentration (206.03 mg kg^{-1}) in fruits of Falcon cultivar during 2009.

Table 3. Analysis of Variance for the effect of potassium sources on fruit copper content (mg kg^{-1}) of tomato cultivars.

Source	df[a]	Mean Square	P value
Year (Y)	1	9.096	0.0006
Cultivars (C)	1	14.735	0.0000
C x Y	1	1.244	0.0516
Treatment (T)	5	15.434	0.0000
Y x T	5	0.097	0.9070
C x T	5	0.479	0.1982
Y x C x T	5	0.114	0.8750
Error	66	0.317	
Total	95		

[a] df: degree of freedom.

Table 4. Analysis of Variance for the effect of potassium sources on fruit calcium content (mg kg^{-1}) of tomato cultivars.

Source	df[a]	Mean Square	P value
Year (Y)	1	2128.638	0.0062
Cultivars (C)	1	28612.594	0.0000
C x Y	1	52.733	0.8272
Treatment (T)	5	24718.453	0.0000
Y x T	5	14.658	0.9999
C x T	5	565.345	0.7638
Y x C x T	5	45.480	0.9990
Error	66	1097.274	
Total	95		

[a] df: degree of freedom.

Fruit Boron content

K-source, cultivars and years significantly (P≤0.05) influenced the B content of tomato fruit (Table 6). The cultivars considerably varied regarding B content and showed that Rio Grande contained the higher B content than Falcon in both cropping seasons (Fig 6). The results showed that B content (28.02 mg/kg) followed by (27.08 mg/kg) was higher in Rio Grande cultivar with the application of K-source 50-50 and 75-25 ratio of PM and SOP in the year 2010. However, the control treatment resulted in lowest B content (16.39 mg/kg) in fruits of Falcon cultivar during 2009.

Discussion

The Rio Grande cultivar contained higher K, Zn, Cu, Fe and B contents in tomato fruit as compared to Falcon cultivar. However the fruit Ca content was higher in the fruit of cultivar Falcon. The variation in tomato fruit mineral composition contents might be due to genetic variability and better acquisition of soil nutrients or improved translocation and utilization of the nutrient within plants (Ci *et al.*, 2010; Grant *et al.*, 2008). Similarly the Falcon as high yielding cultivar might have diluted most the mineral nutrients therefore contained lower mineral composition (Kader, 1988).

Table 5. Analysis of Variance for the effect of potassium sources on fruit iron content (mg kg^{-1}) of tomato cultivars.

Source	df[a]	Mean Square	P value
Year (Y)	1	3564.844	0.0161
Cultivars (C)	1	8516.434	0.0000
C x Y	1	54.300	0.6806
Treatment (T)	5	7367.877	0.0000
Y x T	5	65.612	0.9586
C x T	5	405.238	0.2849
Y x C x T	5	52.577	0.9743
Error	66	317.623	
Total	95		

[a] df: degree of freedom.

Table 6. Analysis of Variance.

Source	df[a]	Mean Square	P value
Year (Y)	1	176.557	0.0090
Cultivars (C)	1	192.185	0.0000
C x Y	1	23.651	0.1260
Treatment (T)	5	100.227	0.0000
Y x T	5	8.413	0.5164
C x T	5	4.257	0.8245
Y x C x T	5	2.726	0.9242
Error	66	9.846	
Total	95		

for the effect of potassium sources on fruit boron content (mg kg^{-1}) of tomato cultivars

[a] df: degree of freedom.

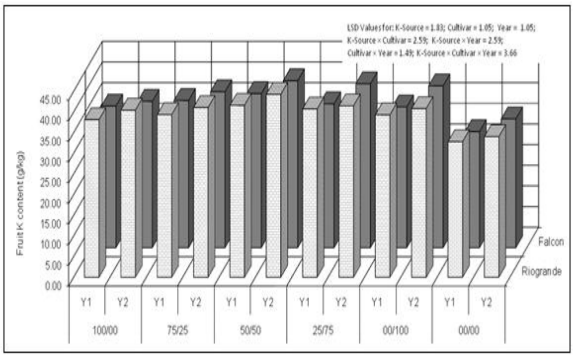

Fig. 1. Fruit K content (g kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

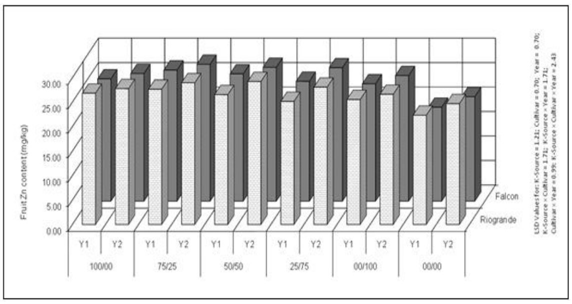

Fig. 2. Fruit Zn content (mg kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

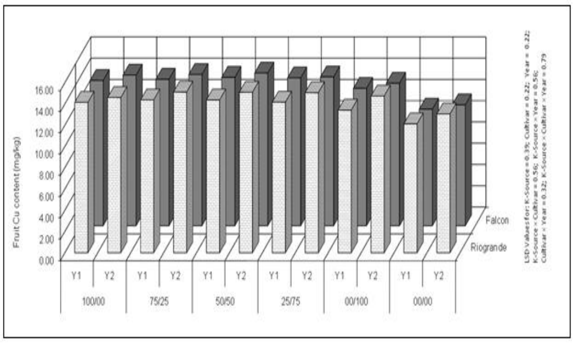

Fig. 3. Fruit Cu content (mg kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

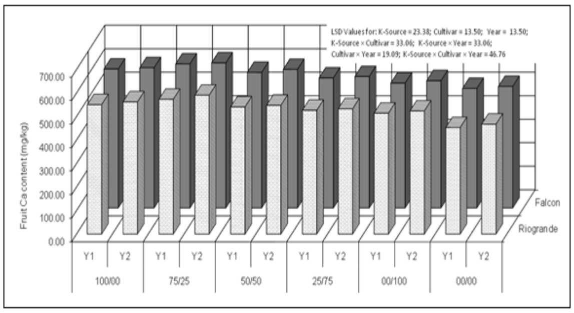

Fig. 4. Fruit Ca content (mg kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

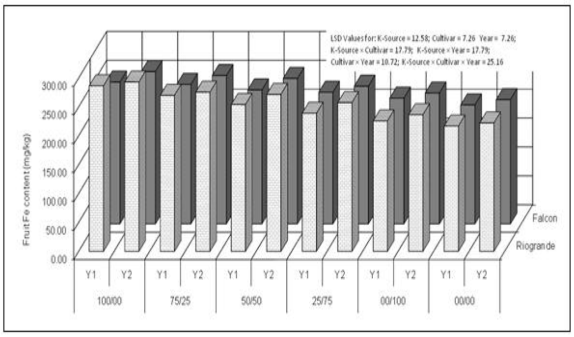

Fig. 5. Fruit Fe content (mg kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

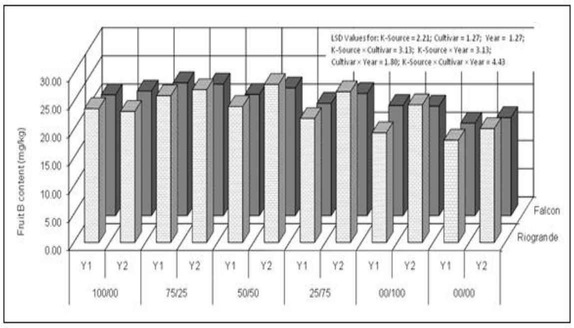

Fig. 6. Fruit B content (mg kg^{-1}) as affected by the organic and inorganic potassium amendments on tomato cultivars. Y1 and Y2 represent 1st and 2nd year of cultivation, respectively.

The results regarding fertilizer treatments showed that the higher ratio of poultry manure application significantly increased mineral composition of tomato fruits in both years. Poultry manure contained many plant nutrients which were supplied as part of their diet and are added to feed stuffs as growth promoters (Uprety *et al*., 2009) and excreted unchanged (Gupta and Gardner, 2005) while its application to soil might have increased the soil mineral status. Similarly the addition of poultry manure changed the concentration of available nutrients by improved soil physical and chemical structures and water holding capacity, resulted in extensive root development and enhanced micro flora, which could helped in increasing the availability of micronutrients (Zeidan, 2007). As compared to chemical fertilizer which contained specified element while the organic manure contained most of the plant required nutrients (Worthington, 2001). The results regarding year variation indicate that mineral nutrients were higher during 2010 as compared to 2009 due to the high soil organic matter and moisture content that helped in mobilization of mineral nutrients (Fageria and Zimmermann, 1998).

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