Mineral Content and Quality Parameters of Tomato Fruits as Affected by Different Potassium Fertilization Treatments and Cultivar Specifics

Veselina H. Vasileva, Nikolai S. Dinev

ABSTRACT

Background: Potassium is one of the essential nutrients for optimal plant growth and development, related to higher yield and improved crop quality. Split potassium fertilization achieved maximum nutrient efficiency and improved the available potassium status in the root zone. The purpose of this study was to determine the extent to which the split potassium application affects the mineral content and the quality parameters of various tomato cultivars.

Methods: A pot experiment was undertaken to investigate the impact of single dose and split potassium fertilization treatments on nutrient content and quality traits of tomato fruits. Seven high yielding, early and mid-early tomato cultivars and hybrids were planted on Fluvisol and subjected to separate single dose and split potassium fertilization treatments (1. N\textsubscript{200-250}-P\textsubscript{300-350}-K\textsubscript{300}; 2. N\textsubscript{300-350}-P\textsubscript{150}-K\textsubscript{300-350}) as K\textsubscript{2}SO\textsubscript{4}, at constant nitrogen (NH\textsubscript{4}NO\textsubscript{3}) and phosphorus (Ca(H\textsubscript{2}PO\textsubscript{4})\textsubscript{2}-H\textsubscript{2}O) fertilization rates.

Result: Results revealed that mineral content in tomato fruits was significantly affected by cultivar, while the potassium fertilization type did not have a statistically proven effect. Positive relationships between potassium content and lycopene and sugars in tomato fruits were present. Highest mineral content was measured in fruits of “Sheena F.” and “Nikolina F.”, which also stand out with high biochemical attributes - lycopene, ascorbic acids, sugars and dry matter content. All tested biochemical parameters defining tomato fruit quality (except for acidity) were significantly affected by split potassium fertilization treatments.

Key words: Biochemical attributes, Lycopene, Mineral content, Potassium fertilization, Vitamin C.

INTRODUCTION

Tomatoes (Solanum lycopersicum) are amongst the most widely grown and consumed crops across the World (Narolia and Reddy, 2010). They are essential component of the human diet and an excellent source of nutrients and secondary metabolites, supporting human health: acids, sugars, potassium, Vitamin C and E, flavonoids, β-Caroten and lycopene (Hegde et al., 2007; Perkins-Veazie and Roberts, 2003).

According to Dorais et al. (2010), sugar and acid content determine the flavor qualities, while the mineral, vitamin and carotenoid content are related to the nutritional qualities of the tomato fruit. The significant beneficial effect of consuming tomato fruits (high in biochemical compounds such as lycopene and ascorbic acid) to human health, have been subject of numerous studies (Clinton, 1998; Naidu, 2003; Rao and Rao, 2007) and led to breeding of new tomato cultivars and hybrids with improved nutritional and organoleptic characteristics. Along with the cultivar specifics, environmental factors and fertilization practices also affect the biological value of tomato production (Mitova, 2007; Mitova, 2016; Thompson et al., 2000). Potassium, the most abundant element in soil particularly important in crop physiology, as it is involved in enzyme activation, transport of assimilates and managing the water balance of the plants (Kanai et al., 2007; Singh and Singh, 2013). The positive effect on tomato plants is expressed in higher yield, extended shelf life and improved fruit quality parameters - increased dry matter content, Vitamin C, β-Carotene, lycopene, total sugars and acidity (Bidari and Hebsur, 2011; Fanasca et al., 2006; Hartz et al., 2005). There is a need for increased awareness about the importance of potassium in agriculture for nutrient balance and efficiency, top crop yields and quality and farmer profitability (Hasan, 2002). The most widely adopted practice is to apply the full dose of potassium basally, but competition between microorganisms and crop plants, luxury consumption, leaching losses and fixation processes reduce the available potassium at the critical plant growth stages (Annadurai et al., 2000). According to Hartz (2007), potassium fertilization proved to be most effective on tomato plants, if applied before bloom, at 1.5-inch fruit diameter, until 10% of red fruits. Split potassium fertilization...
achieved maximum nutrient efficiency, minimal nutrient leaching losses and improved the available potassium status in the root zone (Tiwari et al., 1992). Split potassium fertilization achieved maximum nutrient efficiency, minimal nutrient leaching losses and improved the available potassium status in the root zone (Tiwari et al., 1992). The purpose of our study was to determine the extent to which the split potassium application affects the mineral content and the quality parameters of various tomato cultivars and hybrids.

**MATERIALS AND METHODS**

A greenhouse pot experiment under controlled conditions was carried out on Fluvisol (FAO, ISRIC World Soils) at the experimental station of Institute of Soil Science, Agrotechnologies and Plant Protection “Nikola Poushkarov” in 2017. The soil had the following characteristics: neutral to low alkaline pH (pH_H2O=7.1, pH_KCl=6.20), low hummus content and high content of mobile nitrogen (NH4-N-70.2 mg kg⁻¹, NO3-N-7.5 mg kg⁻¹) and P2O5 and K2O values of 76.2 mg P 100g⁻¹ and 40.4 mg K 100g⁻¹.

Seven high yielding, early and mid-early tomato cultivars with determinate growth habitat were tested at single and split potassium fertilization treatments (1. N200+P200+K225, 2. N300+P200+K325) in the form of K2SO4 at constant nitrogen and phosphorus fertilization rates (Ca(H2PO4)2.H2O). At 1. N200+P200+K225, the entire phosphorus and potassium and half of the nitrogen was applied at sowing. Remaining nitrogen was applied at flowering and fruit forming stage. At 2. N300+P200+K325, the entire phosphorus, half of the nitrogen and half the potassium was applied at sowing and the remaining nitrogen and potassium was applied at flowering and fruit forming stage. The experiment was staged with 3 replications.

Fruit dry matter content was weighted after drying the samples at 65°C with initial fixation at 105°C. Potassium and phosphorus content in fruits was determined using a spectrophotometer, total nitrogen was measured via Kjeldahl method (Horneck and Miller, 1998; Mincheva and Brashnarova, 1975). Ascorbic acid was determined reflectometrically (ROflex® Merck) after reaction with molybdophosphoric acid to phosphomolybdenum blue, total sugars was measured according to Shoorl-Regenbogen, acidity was determined reflectometrically by direct titration of juice with 0,1 n NaOH, lycopene was measured via Manuelyan method with some modification (Genadiev et al., 1969; Jones and Scott, 1983; Manuelyan, 1991).

All collected data was subjected to multi-factor ANOVA (Analysis of variance at 95% confidence level) and Duncan’s multiple range test (P≤5%) using STATGRAPHICS Centurion software package.

**RESULTS AND DISCUSSION**

**Mineral content**

Although minerals represent a small fraction of fruit dry matter, they play an important role in the nutritional composition and fruit quality. It has been determined that the consumption of fresh fruits and vegetables could meet 35% of Potassium, 24% of Magnesium, 11% of Phosphorus and 7% of Calcium of the recommended daily nutritional values (Levander, 1990). The total N, P2O5, K2O, Ca and Mg content in the tomato fruits, measured with our experiment are comparable to those reported by Mukta et al. (2016).

Mineral content, measured in fruits subjected to split-potassium fertilization was higher compared to those that received a single dose treatment, but not statistically significant (Table1). ANOVA analysis revealed that potassium fertilization (both single and split treatments) is not significantly correlated to mineral content in fruits, as

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|---|---|---|---|---|
| **Table 1:** Mineral content in tomato fruits as affected by cultivar and potassium fertilization. | | | |
| Fertilization | N | P2O5 | K2O% | Ca | Mg |
|---|---|---|---|---|---|
| Split | 2.54a | 0.8a | 4.96a | 0.1a | 0.12a |
| Single | 2.62a | 0.62a | 5.11a | 0.12a | 0.13a |
| LSD>95% | 0.029 | 0.041 | 0.189 | 0.021 | 0.01 |
| Tomato cultivars | | | | | |
| Bersola F | 2.25a | 0.56a | 4.8b | 0.1abc | 0.12bc |
| Atak | 2.32ab | 0.51a | 4.88b | 0.07a | 0.11ab |
| Sadeen F | 2.9c | 0.57a | 5.05bc | 0.09ab | 0.13bc |
| Sheena F | 2.85bc | 0.68b | 5.15bc | 0.19d | 0.15d |
| 3593 | 2.35ab | 0.5a | 4.43a | 0.07a | 0.09a |
| 3093 | 2.44abc | 0.69bc | 5.25c | 0.12bc | 0.13cd |
| Nikola F | 2.98c | 0.76c | 5.73d | 0.14c | 0.15d |
| LSD<95% | 0.056 | 0.076 | 0.354 | 0.039 | 0.018 |
| Main effects | A | 0.0324* | 0* | 0* | 0* |
| B | 0.565NS | 0.2066NS | 0.1154NS | 0.0898NS | 0.1937NS |
| Interactions | AB | 0.0324NS | 0.003* | 0.0001* | 0.0005* | 0.095NS |

Single - N200+P200+K225; Split - N300+P200+K325; A - Tomato cultivars; B - Fertilization.

Means within each column followed by the same letter are not significantly different at P<0.05.

NS, * - Non significant or significant at p<0.05.
opposed to the cultivar, which had a significant effect (P≤5%). Highest total N content was measured in the fruits of “Nikolina F₁”, and “Sadeen F₁” hybrids, highest P₂O₅ and K₂O - in “Nikolina F₁”, highest Ca in “Sheena F₁”, and highest Mg content was measured in “Sheena F₁” and “Nikolina F₁” (Table 1). According to Fanasca et al. (2006), the concentrations of fruit mineral elements are mainly affected by the nutrient solution composition and to a lesser degree are due to cultivar specifics.

**Fruit quality parameters**

Importance of potassium for tomato plant nutrition is well studied. It is involved in numerous physiological processes that control plant growth, yield and quality parameters such as sugars, titratable acidity, total soluble solids, taste, colour and firmness (Lester et al., 2005). In this study, the effect of split potassium fertilization on all measured quality parameters was statistically significant except for acid contents, where highest values were measured in tomato fruits, subjected to single potassium fertilization treatment (Table 3). These results contradict previous findings of Afzal et al. (2015), according to whom splitting the potassium treatment did not affect the yield and quality parameters.

In terms of cultivar specifics, our research confirmed their significance on the biological value of tomato fruits, as previously observed by other authors (Taber et al., 2008; Thompson et al., 2000).

Lycopene content values were ranging from 4.81 to 11.72 mg 100⁻¹, which is consistent to what was measured by Rath et al. (2009). The antioxidant properties of lycopene define the high interest towards lycopene-rich tomato fruits, but its content is a genotypically determined characteristic. According to literature, potassium fertilization, aimed at increasing antioxidant content shows different results on different tomato cultivars (Hartz et al., 2005; Henry et al., 2008). Similar findings were observed with our experiment, where plants subjected to split potassium fertilization measured highest lycopene concentration in fruits (P≤5%) for “Sadeen F₁”, “3093” and “Nikolina F₁” (Table 2). According to Kosinski (1996), there is a linear correlation between lycopene concentrations and potassium content in tomato fruits. In his research, maximum lycopene was measured in fruits, where potassium content was over 4.5% of dry matter, which is confirmed by our study as well (Table 1, Table 3). The correlation between potassium and lycopene in fruits was also graphically represented (Fig 1a). Analogical results (positive correlation between potassium and lycopene content) were reported by Afzal et al. (2015), who concluded that increased potassium resulted in increased lycopene contents in tomato fruits.

Potassium played a key role in increasing ascorbic acid concentration in tomato fruits as per Perkins-Veazie and Roberts (2003) research. “Bersola F₁”, “Atak”, “Sheena F₁”, “3093” and “Nikolina F1” measured higher Vitamin C content at split potassium fertilization compared to single dose treatment, but significant increase was identified for “Bersola

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**Table 2:** Tomato fruit quality parameters as affected by potassium fertilization only.

| Fertilization | Tomato cultivars | Lycopene mg 100g | Vitamin C mg 100g | Total acidity % | Sugar % | Dry matter % | Sugar-acid ratio |
|---------------|------------------|-----------------|-------------------|----------------|---------|-------------|-----------------|
| Single        | Bersola F₁       | 5.68a           | 26.13a            | 0.49a          | 3.67a   | 6.77a       | 7.48a           |
| Split         |                  | 6.32a           | 31.33b            | 0.48a          | 4.13b   | 6.87a       | 8.62b           |
| LSD 95%       |                  | 0.861           | 1.535             | 0.036          | 0.307   | 0.472       | 0.759           |
| Single        | Atak             | 6.23a           | 25.57a            | 0.73a          | 5.13a   | 5.47a       | 7.04a           |
| Split         |                  | 6.94a           | 31.43b            | 0.67a          | 5.37a   | 6.00a       | 7.97b           |
| LSD 95%       |                  | 0.777           | 1.047             | 0.059          | 0.262   | 0.585       | 0.784           |
| Single        | Sadeen F₁        | 5.83a           | 25.63a            | 0.75a          | 4.83a   | 5.83a       | 6.48a           |
| Split         |                  | 7.07b           | 23.57a            | 0.62b          | 5.77a   | 6.63b       | 9.32a           |
| LSD 95%       |                  | 0.229           | 3.027             | 0.106          | 1.915   | 0.763       | 3.047           |
| Single        | Sheena F₁        | 11.13a          | 26.33a            | 0.56a          | 5.20a   | 5.97a       | 9.26a           |
| Split         |                  | 11.72a          | 30.23b            | 0.55a          | 5.43a   | 6.87b       | 9.84a           |
| LSD 95%       |                  | 0.849           | 2.343             | 0.083          | 0.370   | 0.571       | 1.483           |
| Single        | 3830             | 5.00a           | 26.87a            | 0.46a          | 4.17a   | 5.90a       | 9.25a           |
| Split         |                  | 4.81a           | 24.97a            | 0.45a          | 4.43b   | 6.53a       | 9.95a           |
| LSD 95%       |                  | 0.631           | 3.010             | 0.110          | 0.207   | 0.774       | 2.438           |
| Single        | 3093             | 5.85a           | 24.43a            | 0.51a          | 4.53a   | 6.03a       | 8.97a           |
| Split         |                  | 7.07b           | 26.37a            | 0.52a          | 4.77a   | 6.47b       | 9.12a           |
| LSD 95%       |                  | 1.026           | 3.048             | 0.098          | 0.614   | 0.262       | 1.225           |
| Single        | Nikolina F₁      | 9.40a           | 26.07a            | 0.58a          | 5.80a   | 6.90a       | 10.00a          |
| Split         |                  | 10.08b          | 28.10a            | 0.55a          | 6.10a   | 6.97a       | 11.02b          |
| LSD 95%       |                  | 0.359           | 6.627             | 0.029          | 0.453   | 0.293       | 0.724           |

Single - N225×225P2O5K2O; Split - N150×225P2O5K2O. Mean within each column followed by the same letter are not significantly different at P≤5%.
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Table 3: Tomato fruit quality parameters as affected by cultivar and potassium fertilization.

| Fertilization | Lycopene mg 100g | Vitamin C mg 100g | Total acidity % | Sugar % | Dry matter % | Sugar-acid ratio |
|---------------|------------------|-------------------|-----------------|--------|-------------|-----------------|
| Single        | 7.02a            | 25.82a            | 0.58b           | 4.76a  | 6.12a       | 8.4a            |
| Split         | 7.72b            | 28.73c            | 0.49ab          | 3.9a   | 6.82c       | 8.1a            |
| LSD≥95%       | 0.203            | 0.945             | 0.022           | 0.226  | 0.157       | 0.48            |
| Tomato cultivars |                |                   |                 |        |             |                 |
| Bersola F1    | 6b               | 28.73c            | 0.49ab          | 3.9a   | 6.82c       | 8.1a            |
| Atak          | 6.58c            | 28.5c             | 0.7d            | 5.25c  | 5.73a       | 7.5a            |
| Sadeen F1     | 6.45c            | 24.6a             | 0.69d           | 5.3c   | 6.23b       | 7.9a            |
| Sheena F1     | 11.42e           | 28.28c            | 0.56c           | 5.32c  | 6.42b       | 9.5b            |
| 3830          | 4.91a            | 25.77ab           | 0.45a           | 4.3ab  | 6.22b       | 9.6b            |
| 3093          | 6.46c            | 25.4ab            | 0.52b           | 4.65b  | 6.25b       | 9b              |
| Nikolina F1   | 9.74d            | 27.08bc           | 0.57c           | 5.95d  | 6.93c       | 10.5c           |
| LSD≥95%       | 0.379            | 1.768             | 0.042           | 0.422  | 0.294       | 0.9             |
| Main Effects  | A 0               | 0.0001*           | 0*              | 0*     | 0*          | 0*              |
|              | B 0               | 0.0001*           | 0.0077*         | 0.0018*| 0*          | 0.001*          |
| Interactions  | AB 0.0134*        | 0.0002*           | 0.0433*         | 0.5936NS| 0.0454*    | 0.115NS         |

Single - N$_{300}$ P$_{150}$ K$_{450}$; Split - N$_{200}$ P$_{300}$ K$_{300}$; A - Tomato cultivars; B - Fertilization.
Means within each column followed by the same letter are not significantly different at P≤5%.
NS, * - Non significant or significant at p<0.05%.

F1, “Atak” and “Sheena F1,” only, that also measured highest content with values of 31.33 mg 100g$^{-1}$, 31.43 g 100g$^{-1}$ and 30.23 mg 100g$^{-1}$, respectively (Table 2, Table 3). It was also clearly demonstrated that splitting the potassium fertilization significantly increased Vitamin C content (0.945, LSD$≥95%$), as opposed to Ahmad et al. (2015). He experimented with various potassium treatments and although measured highest ascorbic acid content at fruits with split-in-two (30.33 mg 100g$^{-1}$) treatment, this was not statistically proven.

Sugar and organic acid content are key components affecting tomato fruit quality. Forming 60% of dry matter content, they define consumer preferences and are essential to flavour intensity (Kader, 2008). Concentration of sugars and total acid content is in agreement with previous findings (Davies et al., 1981; Dorais et al., 1999) who reported sugar content range of 1.5-7.6%, depending on cultivar and environmental factors and average acid content of 0.4%. Total acidity was the only parameter that measured lower values in tomato fruits, subjected to split potassium fertilization (0.022, LSD$≥95%$) (Table 3).

Split potassium fertilization had a significant effect on total acidity (decreased) for “Sadeen F1,” fruits only. The rest of the cultivars exhibited similar, but statistically not significant trend (Table 2). Our results indicate that splitting the potassium fertilization treatment as a factor had a pronounced effect on sugar content (0.226, LSD$≥95%$) (Table 3) and is also positively correlated to potassium content and sugars in fruits ($R^2 = 0.3134$) (Fig 1b).

According to Davies and Winsor (1967) tomato flavour is a subjective characteristic, dependent on the consumer sense only. For that reason, the term “sugar-acid ratio” was
The cultivar specifics on tomato fruit quality, treated by split potassium fertilization, significantly affected by the fertilization. The effect on dry matter content was significant on “Nikolina F1”, “Sheena F1” and “3093”, P ≤ 0.05% (Table 2).

Dry matter content in tomato fruits is an important parameter for the processing industry, total soluble solids and sucrose content is considered to be correlated to flavour and processing characteristics of tomatoes (Davies et al., 1981). All dry matter content values obtained within this study were within the optimal range of 5% to 7%, defined by literature (Heuvelink, 2018). Highest dry matter content was measured in “Nikolina F1” (6.97%), but they were not significantly affected by the fertilization. The effect on dry matter content was significant on “Sadeen F1”, “Sheena F1”, and “3093”, P ≤ 0.05% (Table 2).

CONCLUSION
Positive effect of splitting the potassium fertilization treatments and the cultivar specifics on tomato fruit quality was reported. However, split potassium fertilization did not show significant effect on the accumulation of minerals, compared to the cultivar as factor. A positive correlation was found between potassium and lycopene and sugars content in tomato fruits. All tested biochemical parameters defining tomato fruit quality (except for acidity) were significantly affected by split potassium fertilization treatments.

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