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EFFECT OF POTASSIUM FOLIAR NUTRITION ON CHANGES IN THE CONTENT OF CAROTENOID PIGMENTS AND ON SOME PARAMETERS OF THE NUTRITIONAL VALUE OF TOMATO FRUIT

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Summary

The aim of the study was to investigate the effect of potassium foliar nutrition on changes in the content of carotenoid pigments and on some parameters of the nutritional value of tomato fruit. The experiments were conducted on three tomato cultivars: Faustine F_1, Atut F_1 and Magnus F_1. All trial plots with plants were additionally fertilized with 0.3% Final K and 0.3% Kalisol whilst in the control plots no foliar nutrition with potassium was applied. The chemical composition of tomato fruit depended on two factors: tomato cultivar and fertilization method and differed from year to year of investigation. In 2005 neither the cultivar nor the foliar fertilization affected the level of β-carotene while the fertilization with Final K resulted in the increase of lycopene content compared with the control. In 2006 and 2007 the fruits from treatments fertilized with Kalisol had significantly higher content of β-carotene and lycopene in compareson with those treated with Final K. The obtained results do not clearly show the effect of potassium foliar fertilization on the increase of dry matter, sugars or acids contant in tomatoes. Foliar fertilization with Kalisol increased the content of L-ascorbic acid in tomatoes in 2005 and 2007. In 2006 the content of this acid in fruit treated with Kalisol was at the same level as untreated plants but higher in plants treated with Final K. The effect of foliar nutrition with potassium had a variable influence on the level of the investigated macroelements (K, P, Ca, Mg). The content of β-carotene was positively correlated with the content of phosphorus and negatively correlated with the acidity of fruit.

key words: tomato, potassium, lycopene, β-carotene, nutritional value

INTRODUCTION

Tomato is one of the most popular vegetable species both in Poland and all over the world. Many factors among which are: great taste, dietary value, wide use both for direct consumption and in food industry and

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high adaptability cause that tomato is grown in different climatic zones. The health promoting values of tomato also contributed to the consumption increase. Ripe tomatoe fruit are a good source of carotenoids. According to Podsędek (2007) tomato fruit contains 1.1-15 mg·1000 g^{-1} α-carotene; 2.1-8.9 mg·1000 g^{-1} β-carotene; 31-114 mg·1000 g^{-1} lycopene; and 0.8-4.3 mg·1000 g^{-1} luteine and zeaxanthine. The well known attribute of β-carotene is the highest activity of vitamin A. Numerous studies show that carotene prevents the proliferation of cancer cells in the human organism and at the same time improves the intercellular communication (Horbowicz & Saniewski 2000, Ruiz *et al*. 2001, Guz *et al*. 2007). Lycopene is beneficial to human health although it does not show the activity of vitamin A. It is the most effective antioxidant in the carotenoid compounds and helps to detoxify free radicals. Diets with a rich content of lycopene are associated with the reduction of some diseases, including the lung, bladder, cervical and skin cancer as well as digestive tract disorders (Lugasi *et al*. 2003). Due to the valuable health promoting properties of lycopene an increased attention is paid to cultivars with a higher content of this pigment. The level of potassium is one of many factors influencing the content of lycopene in tomato fruit (Babik 1997).

It has also been proved that L-ascorbic acid is an agent of great importance in the human organism. The most important roles it plays are: the participation in the synthesis of collagen and in hemabsorption, as well as the enhancement of the resistance of organisms. Its antioxidative potential is also suggested and hence its role in the prevention and control of early stages of cancer development (Sosnowska 2007). Tomatoes contain 23 mg% ascorbic acid on average (Saltveit 2005), while according to Babik (1997) its content can reach up to 42 mg%. The content of L-ascorbic acid changes during the ripening of fruit and depends on the solar radiation (Saltveit 2005; Sosnowska 2007) as well as on potassium fertilization (Mengel & Kirkby 1983).

Sugars and titratable acids are important constituent part of tomato flavour. They exert their effect mainly through the ratio. Fruit rich both in acids and in sugars have an excellent flavour (Saltveit 2005).

Foliar nutrition with potassium plays an important role also in other agrotechnical procedures. Potassium foliar nutrition is a treatment which can be quickly applied to plants and hence can contribute to the fuller utilization of yield potentiality (Szewczuk & Michałojć 2003), can improve the colour of fruit and can also intensify the development of numerous organic compounds (Borkowski & Szwonek 1986, Kowalska 2003). Potassium is found in the composition of organic compounds, it occurs in cells only as an ion and in this form it takes part in over 60 enzymatic reactions. It is active in the biosynthesis of high-molecular compounds and has a pronounced effect on the water economy of plants. Plants containing sufficient amount of this element suitably economize their water resources and are more resistant to frost damage as well as to fungal and bacterial infections (Mengel & Kirkby 1983). Potassium is the most important nutrient in rela-

tion to fruit quality and flavour. In evenly ripened fruit, the blotchy green tissue contains lower concentrations of K, acids and sugars than red parts (Adams & Ho 1995).

The aim of the investigation was to determine the effect of foliar nutrition with potassium on changes in the content of carotenoid pigments and some parameters of the nutritional value of fruit of three tomato cultivars.

MATERIAL AND METHODS

The investigation was carried out in 2005-2007 in Mydlniki near Krakow as a field trial on brown soil. The experiment was established in a two-factor randomized design in four replications. The first factor was the cultivar and the second factor was the method of foliar nutrition. The control combination was left with no foliar fertilization while the other combinations were fertilized with 0.3% Final K and 0.3% Kalisol once a week in the period of fruit maturation (July 4 - August 16). Final K is a liquid fertilizer composed of amide nitrogen 4.7% and potassium 47.0% K_2O. Kalisol is composed of water soluble potassium oxide (50% K_2O), water soluble sulphur (17%) and chlorides (max. 1%). Three tomato cultivars of large fruit but of various potential of growth were compared: the indeterminate Faustine F_1 and Atut F_1 and the determinant cultivar Magnus F_1. These greenhouse cultivars are also recommended for growing in the field. Tomato seedlings were planted on May 11 in 90 x 60 cm spacing, in 10.8 m^2 large plots. During the vegetation period the procedures recommended for indeterminate tomato cultivars were carried out, i.e. plant cutting and topping above the fifth cluster.

The basic soil fertilization was adjusted to the results of soil analysis, available forms of mineral constituents being supplemented to the level of ($mg \cdot dm^{-3}$) 120 N; 80 P; 250 K; 80 Mg. Single foliar fertilization with lime saltpeter 100 mg · 10 dm^{-3} water was carried out in last days of July.

Fully matured tomato fruits from the third cluster were taken for analyses. The following constituents were taken into consideration: sugars (using the anthrone method); vitamin C (Tillmans' method); total acidity (according to Pijanowski); dry matter (desiccation method) and carotenoid pigments such as lycopene and ß-carotene (using column chromatography with hexane and acetone). For the determination of macroelements Ca, K and Mg fruits were washed, sliced, air-dried and ground. In the next step the material was ashed in a muffle furnace at 500^oC and then dissolved in 20% HNO_3. The macroelements were measured using atomic absorption method in a Varian (Spectr AA-20) spectrophotometer. Phosphorus was determined using colorimetric method (Specol spectrophotometer). The obtained results were subjected to statistical elaboration using analysis of variance. Separation of means was performed with the Fisher's least significant difference test with P=0.05.

RESULTS AND DISCUSSION

The chemical composition of tomato fruit depends on numerous factors such as the cultivar and environmental factors, fertilization, growing method, stage of maturity as well as postharvest treatment (Johjima &

Matsuzoe 1995, Saltveit 2005, Brandt 2006). These factors can significantly influence the nutritional quality of tomatoes what was confirmed in the latest research by Dorais (2008). In the presented investigation the chemical composition of tomatoes depended on the cultivar and the method of foliar nutrition. Considerable differences were also found between the investigated parameters of fruit in consecutive years of the investigation.

In the investigated fruit samples the content of β-carotene varied from 2.40 to 5.33 mg·kg^{-1} fresh matter and the content of lycopene was at the level of 16.29 to 43.83 mg·kg^{-1} fresh matter (Tables 1 & 2). In 2005 neither the cultivar nor potassium fertilization influenced the level of β-carotene while the application of Final K caused the significant increase in the content of lycopene in comparison with the control combinations. In 2006 and 2007 years fruit samples from plots fertilized with Kalisol had a higher content of both carotenoid pigments compared with those fertilized with Final K. This content corresponded to the amounts of pigments in control plots. In 2006 the foliar nutrition with the two potassium fertilizers increased the content of lycopene compared with the control fruit cv. Magnus F_1. In case of cv. Atut F_1 the significant effect was only found with Kalisol application. The content of pigments also depended on the cultivar. The highest content of both pigments in fruit was found in 2006 in cultivar Magnus F_1 however in 2007 in cv. Faustine F_1.

Table 1. ß-carotene content in tomato fruits (mg·kg^{-1}d.w.) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	3.20 a*	3.27 a	3.17 a	3.21 a
Atut F_1	3.56 a	3.31 a	3.00 a	3.29 a
Magnus F_1	3.43 a	3.65 a	3.62 a	3.57 a
Mean	3.40 a	3.41 a	3.26 a	-
2006				
Faustine F_1	4.74 de	3.49 ab	3.99 bc	4.07 b
Atut F_1	3.57 ab	3.24 a	4.40 cd	3.74 a
Magnus F_1	4.45 cd	5.03 ef	5.33 f	4.93 c
Mean	4.25 b	3.92 a	4.57 b	-
2007				
Faustine F_1	4,29 d	4.23 d	4.27 d	4.26 c
Atut F_1	3.86 cd	3.08 b	3.65 c	3.53 b
Magnus F_1	3.10 b	2.40 a	3.01 b	2.83 a
Mean	3.75 b	3.24 a	3.64 b	-
Mean for years and cultivars	3.80 a	3.52 a	3.82 a	-

Note: *Statistical analysis concerning cultivar and the kind of potassium foliar nutrition was done each year separately.
Means with the same letter do not differ significantly at P=0.05

Table 2. Lycopene content in tomato fruits (mg·kg^{-1} d.w.) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	24.05 a	38.18 d	35.94 bcd	32.72 b
Atut F_1	29.23 ab	29.48 abc	26.01 a	28.24 a
Magnus F_1	36.30 cd	36.12 bcd	34.29 bcd	35.57 b
Mean	29.86 a	34.59 b	32.08 ab	-
2006				
Faustine F_1	31.19 bc	22.64 a	28.00 b	27.27 a
Atut F_1	31.73 c	22.28 a	37 87 d	30.63 b
Magnus F_1	39.52 d	43.83 e	41.08 de	41.48 c
Mean	34.15 b	29.58 a	35.64 b	-
2007				
Faustine F_1	39.75 fg	42.61 g	34.02 e	38.79 c
Atut F_1	24.33 bc	16.29 a	29.18 d	23.27 a
Magnus F_1	36.59 ef	20.85 ab	26.17 cd	27.87 b
Mean	33.56 c	26.59 a	29.79 b	-
Mean for years and cultivars	32.51 a	30.25 a	32.50 a	-

Note: see Table 1

The content of dry matter in tested tomatoes varied from 3.37 to 6.33% (Table 3) and it was strongly connected both with cultivar and foliar nutrition. The highest dry matter content was noted in fruit of cv. Faustine F_1. In 2005 and 2007 fruit samples taken from plots treated with Kalisol had lower dry matter content when compared with those taken from control plots as well as those taken from plots treated with Final K. However in 2006 a reverse dependence was recorded. The obtained results do not confirm previous studies proving that the uptake of K directly relates to dry matter accumulation in fruit (Borkowski & Szwonek 1986, Adams & Ho 1995). Borkowski & Szwonek (1986) found that with the rates of potassium increasing from 200, 400, and 600 to 1000 mg·dm^{-3} the highest level of dry matter in tomato fruit was obtained at the highest rate of K. The lower content of dry matter in treatments with an additional foliar nutriation with potassium probably resulted from the fact that the fertilization did not affect an increase in the content of potassium in fruit (Table 7).

In the presented experiment the content of L-ascorbic acid in fruit depended on the year of the investigation and changed in the different treatments from 17.83 to 25.23 mg% (Table 4). No differences in the content of L-ascorbic acid were found between the cultivars except for the first year of the investigation. Foliar nutrition with Kalisol resulted in the increase of L-ascorbic acid content of 17% in 2005 and of 19% in 2007. In 2006 the content of this acid was at the level equal to the control and exceeded that in the plots treated with Final K. Observations made by Mengel and Kirkby (1983) in pot experiments confirm that the potassium fertilization affects an increase in the content of L-ascorbic acid in vegetables.

Table 3. Dry matter content in tomato fruits (%) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	4.97 d	5.01 d	3,90 b	4.63 b
Atut F_1	4.58 cd	4.40 c	3.37 a	4.12 a
Magnus F_1	4.42 c	4.29 bc	3.84 ab	4.18 a
Mean	4.67 b	4.57 b	3.70 a	-
2006				
Faustine F_1	6.04 de	5.80 c	6.28 f	6.04 c
Atut F_1	5.76 c	6.07 e	5.90 cd	5.91 b
Magnus F_1	5.29 ab	5.16 a	5.39 b	5.28 a
Mean	5.70 a	5.68 a	5.86 b	-
2007				
Faustine F_1	6.19 e	6.07 d	6.33 f	6.19 c
Atut F_1	5.61 b	6.08 d	5.42 a	5.70 a
Magnus F_1	6.31 f	5.76 c	5.57 b	5.88 b
Mean	6.03 c	5.97 b	5.77 a	-
Mean for years and cultivars	5.46 a	5.40 a	5.11 a	-

Note: see Table 1

Table 4. L-ascorbic acid content in tomato fruits (mg% f.w.) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	20.30 ab	23.50 c	24.23 c	22.68 b
Atut F_1	23.18 bc	24.68 c	24.23 c	24.03 b
Magnus F_1	17.83 a	17.83 a	23.27 c	19.64 a
Mean	20.43 a	22.00 a	23.91 b	-
2006				
Faustine F_1	23.30 bcd	20.93 a	24.48 d	22.90 a
Atut F_1	23.60 cd	21.95 ab	23.13 bcd	22.89 a
Magnus F_1	22.25 abc	22.63 bc	23.28 bcd	22.72 a
Mean	23.05 b	21.83 a	23.63 b	-
2007				
Faustine F_1	21.16 b	18.35 a	24.95 c	21.48 a
Atut F_1	21.28 b	19.31 a	22.30 b	20.96 a
Magnus F_1	18.66 a	18.03 a	25.23 c	20.64 a
Mean	20.37 b	18.56 a	24.16 c	-
Mean for years and cultivars	21.28 a	20.97 a	23.90 b	-

Note: see Table 1

In the presented experiment the cultivar Faustine F_1 was characterized by a higher content of sugars compared with the remaining cultivars in the first two years of the investigation (Table 5). In 2007 a higher content of sugars was found in fruit of cultivar Magnus F_1. The results in 2005 and

2007 showed the highest content of sugars in fruit from the control treatments whereas only in 2006 year an increased content of sugars was found in fruits additionally fertilized with potassium, both with Final K and Kalisol. The obtained results do not confirm results obtained by Mengel & Kirkby (1983). Authors investigated the effect of fertilization on fruit quality in pot experiments. They found that in conditions of insufficient potassium supply the fruits were small and the content of sugars was at the low level.

Organic acids constitute only 0.4% of the fresh fruit, however, they are an important attribute of the taste. According to Saltveit (2005) a distinct variation in acid content occurs between cultivars. In the presented research the acidity of fruit did not depend on the cultivar while the applied potassium fertilization had a divers effect on this parameter in the different years of the experiment (Table 6).

Table 5. Reducing sugars content in tomato fruits (mg%) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	2.67 d	2.62 d	2.39 cd	2.56 c
Atut F_1	2.54 d	2.06 ab	1.93 a	2.18 b
Magnus F_1	2.25 bc	1.92 a	1.86 a	2.01 a
Mean	2.49 b	2.20 a	2.06 a	-
2006				
Faustine F_1	2.31 bc	2.42 cd	2.53 d	2.42 c
Atut F_1	2.21 b	2.38 c	2.34 c	2.31 b
Magnus F_1	1.88 a	1.97 a	1.92 a	1.92 a
Mean	2.13 a	2.25 b	2.26 b	-
2007				
Faustine F_1	2.86 e	2.38 a	2.74 de	2.66 b
Atut F_1	2.53 abc	2.64 bcd	2.45 ab	2.54 a
Magnus F_1	3.32 f	2.60 bcd	2.70 cde	2.87 c
Mean	2.90 b	2.54 a	2.63 a	-
Mean for years and cultivars	2.51 a	2.33 a	2.32 a	-

Note: see Table 1

The effect of foliar fertilization with potassium on the level of macroelements (K, P, Mg and Ca) varied in the different years of the investigation (Table 7). Foliar fertilization with Final K and Kalisol did not increase the amount of macroelements in fruit with one exception - year 2007. The higher content of phosphorus was observed in plants fertilized with Final K in comparison with control plants. The obtained results differ from the observations noted by Borkowski and Szwonek (1986). They have recorded a strong favourable effect of foliar fertilization on the level of potassium, phosphorus and magnesium in tomato fruit. The lack of influence of additionally used potassium foliar fertilization on the content of phosphorus and magnesium in fruit was observed by Komosa

(1990). This author however recorded a favourable effect of foliar fertilization with potassium on increased amounts of potassium and calcium.

Table 6. Total acidity content in tomato fruits (mg%) of different cultivars and foliar K nutrition

Cultivar	Control	Final K	Kalisol	Mean
2005				
Faustine F_1	0.47 c	0.38 a	0.38 a	0.41 a
Atut F_1	0.41 abc	0.40 ab	0.39 ab	0.40 a
Magnus F_1	0.40 ab	0.44 bc	0.38 a	0.41 a
Mean	0.42 b	0.41 ab	0.38 a	-
2006				
Faustine F_1	0.33 b	0.33 b	0,32 a	0.32 a
Atut F_1	0.36 c	0.41 e	0.38 d	0.38 b
Magnus F_1	0.32 a	0.31a	0.33 b	0.32 a
Mean	0.34 a	0.35 b	0.34 a	-
2007				
Faustine F_1	0.37 a	0.34 a	0.35 a	0.35 a
Atut F_1	0.36 a	0.39 a	0.36 a	0.37 a
Magnus F_1	0.36 a	0.37 a	0.34 a	0.36 a
Mean	0.36 a	0.37 a	0.35 a	-
Mean for years and cultivars	0.38 a	0.37 a	0.36 a	-

Note: see Table 1

Table 7. Macroelements content in tomato fruits (mg·100 g^{-1} d.w.) treated with different foliar K nutrition (mean for cultivars)

Microelements	Year	Control	Final K	Kalisol
Potassium	2005	148.56 b	150.71 b	120.69 a
	2006	183.41 b	168.49 a	182.07 b
	2007	182.58 c	170.75 a	175.12 b
	Mean for years	171.52 a	163.43 a	159.30 a
Phosphorus	2005	16.55 b	15.73 b	13.46 a
	2006	21.35 b	20.68 a	21.54 b
	2007	17.25 a	19.02 b	17.25 a
	Mean for years	18.38 a	18.48 a	17.42 a
Calcium	2005	10.34 b	9.49 b	7.54 a
	2006	12.43 a	12.40 a	12.37 a
	2007	13.10 a	12.26 a	12.02 a
	Mean for years	11.99 a	11.38 a	10.65 a
Magnesium	2005	6.26 b	6.43 b	5.37 a
	2006	7.61 b	7.12 a	7.43 b
	2007	7.93 a	7.85 a	7.71 a
	Mean for years	7.27 a	7.13 a	6.84 a

Note: see Table 1

On the basis of the obtained correlation coefficient a significant dependence was only found between the content of β-carotene and the content of phosphorus in fruit (Table 8). At the same time the acidity of fruit was in a reverse correlation with the content of β-carotene.

Table 8. Correlation coefficient between carotenoids content and other parameters of the nutritional value of tomato fruits

Parameter	ß-carotene	Lycopene
Dry matter	0.25	-0.09
L-ascorbic acid	0.22	0.06
Reducing sugars	-0.35	-0.24
Total acidity	**-0.50***	-0.20
Potassium	0.32	0.06
Phosphorus	**0.46***	0.20
Magnesium	0.23	-0.05
Calcium	0.20	-0.21

* – r significant at $P<0.05$

CONCLUSIONS

1. Foliar fertilization with Kalisol resulted in the increase of β-carotene and lycopene content in tomato fruit compared with those treated with Final K.
2. The results do not clearly show the effect of potassium foliar fertilization on the increase of three factors in tomatoe samples: dry matter, sugars and acids.
3. Both tested potassium fertilizers increased the content of L-ascorbic acid but not the content of macroelements in fruit.
4. The content of β-carotene was positively correlated with the content of phosphorus and negatively with the acidity of fruit.

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OKREŚLENIE WPŁYWU DOLISTNEGO NAWOŻENIA POTASEM NA ZMIANY ZAWARTOŚCI BARWNIKÓW KAROTENOIDOWYCH ORAZ INNYCH PARAMETRÓW WARTOŚCI ODŻYWCZEJ OWOCÓW POMIDORA

Streszczenie

Badano wpływ dolistnego nawożenia potasem na zmiany zawartości barwników karotenoidowych oraz innych parametrów wartości odżywczej owoców trzech odmian pomidora (Faustine F_1, Atut F_1 oraz Magnus F_1). Porównywano kontrolę bez dolistnego nawożenia potasowego, oraz obiekty dodatkowo nawożone 0,3% Finalem K oraz 0,3% Kalisolem. Skład chemiczny owoców pomidora zależał od odmiany oraz sposobu nawożenia dolistnego i zmieniał się zależnie od roku badań. W 2005 roku nie stwierdzono wpływu odmiany ani nawożenia potasowego na poziom ß-karotenu, a zawartość likopenu istotnie wzrosła w stosunku do zawartości z obiektów kontrolnych pod wpływem Finalu K. W pozostałych latach owoce z obiektów kontrolnych oraz nawożonych Kalisolem odznaczały się istotnie wyższą zawartością obydwu barwników karotenoidowych w porównaniu do owoców traktowanych Finalem K. Nie stwierdzono jednoznacznego wpływu dolistnego nawożenia potasowego na zawartość suchej masy, cukrów i kwasowości w owocach pomidora. Dolistne nawożenie Kalisolem spowodowało wzrost zawartości kwasu L-askorbinowego w owocach w latach 2005 oraz 2007. W 2006 roku zawartość kwasu L-askorbinowego w obiektach traktowanych Kalisolem utrzymywała się na poziomie obiektu kontrolnego i była wyższa niż w obiektach nawożonych Finalem K. Wpływ dolistnego nawożenia potasem na poziom badanych makroelementów (K, P, Mg, Ca) był zróżnicowany w poszczególnych latach badań. Stwierdzono pozytywną korelację pomiędzy zawartością ß-karotenu a ilością fosforu w owocach oraz negatywną pomiędzy ilością ß-karotenu a kwasowością owoców.