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FOLIAR APPLICATION OF POTASSIUM IMPROVES FRUIT QUALITY AND YIELD OF TOMATO PLANTS

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Abstract. Tomato is well known regarding its quality and nutritional value in all over the world but imbalances of fertilizer nutrients severely affect the quality of tomato. To investigate the specific contribution of potassium to yield and quality of tomato, a field experiment was conducted on two tomato cultivars, Nagina and Roma. Foliar application with varying levels (0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0%) of potassium solutions was applied to the plants and compared with control (without K). Exogenous application of 0.6% K significantly improved plant height, lycopene content, potassium, fruit weight and diameter. Exogenous application of 0.5, 0.6 and 0.7% K maximally improved ascorbic acid contents of both tomato cultivars whereas 0.4 and 0.8% did not improve ascorbic acid contents. Due to positive correlation between K nutrition and fruit quality attributes, exogenous application of an appropriate K level can contribute to higher yield and better quality of tomato fruits. Among all potassium levels, 0.5–0.7% K maximally improved performance of tomato plants of both cultivars.

Key words: *Lycopersicon esculentum*, exogenous application, potassium nutrition, fruit quality

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is an important vegetable crop of the world. Tomato is widely used as salad as well as for cooking purposes. It is well known for its nutritional importance as it is the rich source of nutrients Na, K, Fe, vitamin A and C and antioxidants especially lycopene and salicylate [Afzal et al. 2013]. Lycopene is an antioxidant which protects the cells from oxidative damage, so it decreases the risk of

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chronic diseases such as coronary heart diseases and cancer diseases [Giovannucci 2002, Taber et al. 2008]. The mode of action is tentative, but they are believed to reduce cancer risk by successfully trapping oxygen and intermediates of free oxygen radical. Lycopene is soluble in fat and it is the precursor of β-carotene. It has at least two folds antioxidant capacity of β-carotene [Taber et al. 2008]. Lycopene concentration in tomato fruit depends upon maturity, genetics, environmental conditions, cultivation techniques and production methods. The environmental conditions like temperature, light, fertility and others affect fruit lycopene [Robertson 1995, Kanai et al. 2007].

Potassium (K) is a key nutrient for enhancing productivity of vegetable crops and its content in vegetables has significant positive relationship with quality attributes [Bidari and Hebsur 2011]. Potassium has significant contribution in photosynthesis, enzyme activation, cell turgor maintenance and ion homeostasis [Marshner 1995]. Additionally, it is also involved in the enrichment of lycopene contents of tomato fruit through synthesis of pigments or carotenoids [Bedari and Hebsur 2011]. Inside plant, K is found in ionic form only; it is co-factor of many enzymes. Major role of K in plant is osmotic adjustment. Under K deficient conditions, the fruit will be small in size, lack in red color and at early stage. Red color of fruit and ripening disorders closely related with K content of fruit [Perkins-Veazie and Robert 2003]. It is reported that the K application above the optimum level reduces the tomato fruit color disorders [Hartz et al. 1999].

Foliar spray is the ideal method of application of nutrients for intensive and profitable cultivation of tomato crop [Oded and Uzi 2003]. Potassium nutrition is a low-cost approach to maximize fruit lycopene production. Lycopene is an important health promoting agent; as a result more importance is being given to those cultivars with high lycopene contents. Potassium nutrition is among those factors influencing the lycopene contents of tomato fruit [Lester et al. 2005, 2007]. Foliar nutrition is rapidly utilized by the crop plants; it improves the fruit color [Borkowski and Szwonek 1986, Kowalska 2003]. Potassium plays the most important role in fruit quality and flavor. The amount of vitamin C in tomato also depends upon K nutrition [Perkins-Veazie and Robert 2003]. In a ripened fruit, the more red parts contain more K, acids and sugars [Adams and Ho 1995]. This research was undertaken to provide insights in the relationship of K nutrition and fruit quality of tomato cultivars.

MATERIALS AND METHODS

Seeds of tomato (*Lycopersicon esculentum* Mill.) cv. Nagina and Roma were obtained from the Vegetable Research Institute, Faisalabad, Pakistan and had initial seed moisture contents of 8.23 and 8.13% respectively on a dry weight basis.

The experiment was conducted in research area of Department of Crop Physiology, University of Agriculture Faisalabad (31.41ºN latitude and 73.08ºE longitude, Faisalabad, Pakistan). Two tomato cultivars Nagina and Roma were transplanted on beds using Randomized Complete Block Design (RCBD) design with factorial arrangement. There were 11 potassium treatments including control and 66 experimental units. The dimension of one experimental unit plot size is 5 × 5 feet. Each treatment was repeated 6 times (6 replications). Fertilizers (NPK) were applied at 90, 65, 65 kg ha^{-1} using urea, sulphate of potash and diammonium phosphate respectively. Whole phosphorus and potash and one third of the nitrogen were applied at sowing. Remaining nitrogen was applied at flowering initiation and fruit setting stages. The experimental soil was clay loam with 0.72% of organic matter, pH 7.9, total exchangeable salts 1.59 dS m^{-1}. Regarding macro and micronutrients, 8.12 mg kg^{-1} Olsen P, 0.016 $mmol_c$ L^{-1} K^+, 0.85 mg kg^{-1} DTPA extractable Zn, 17.65 $mmol_c$ L^{-1} Na^+, 20.98 $mmol_c$ L^{-1} SO_4^{2-} and 8.7 $mmol_c$ L^{-1} $Ca^{2+} + Mg^{2+}$ were present in the soil. Monthly average temperature ranged between 12 and 25ºC, relative humidity ranged between 54 and 83%.

Exogenous application of potassium. The role of foliar applied potassium on physiological, biochemical and yield attributes of tomato was carried out under field conditions. Five sprays with one-week interval were practiced throughout the whole period of research. Muriate of Potash (MOP) was used as source of K due to its cost effectiveness and availability in the local market. Different treatment combinations of K concentration used in this experiment were ranges from 0.1, 0.2, 0.3, 0.4….. 1.0%. The control combination was left without foliar application. Three plants were selected from each replication randomly for data analysis. The data on plant height, fruit size and yield per plant was taken. At breaker stage (fruit blossom end turning pink, < 10% color change), fruits were tagged and were harvested seven days later.

Agronomic traits. Three plants were selected at random from each experimental unit and plant height at maturity was measured with measuring tape and average height in cm was computed. At each harvest, diameter of three selected fruits from each replication was measured with the help of vernier caliper and average was calculated in cm. Fresh fruit weight of randomly selected plants was recorded at each harvest with the help of single pan digital balance and the data of each harvest was added to get cumulative yield per plant.

Determination of Lycopene contents. Tomato fruits were tagged at breaker stage in each replication (plot) for the analysis of lycopene. After 7 days of tagging, fully ripened tomatoes were harvested. The lycopene contents were determined by a method described by Davis et al. [2003]. Uniform tomato sample (0.6 g) was taken in falcon tube having 5 ml of 0.05% (w/v) butylated hydroxyltoluene in acetone, 5 ml of 95% ethanol and 10 ml of hexane. After centrifugation at 180 rpm for 15 min on ice, the supernatant (upper layer) was taken in cuvette and the absorbance was measured at 503 nm with UV-visible spectrophotometer.

Determination of ascorbic acid (AsA). Ascorbic acid contents of each replication were determined according to a method described by Ruck [1961]. 10 ml tomato juice was taken in 100 ml volumetric flask and volume was made up to the mark by 0.4% oxalic acid solution and filtered. Then 5 ml filtered solution was taken and titrated against 2,6-dichlorophenolindophenol dye, until light pink end point.

Determination of K contents of tomato fruit. Fruits were sliced in to small pieces and dried in shade before oven drying at 85ºC. After oven drying, 0.5 g sample was digested with 10 ml solution of nitric acid and perchloric acid (2:1). After digestion of samples, K contents were determined by flame photometer (Sherwood, UK, Model 360).

Statistical analysis. The experiment was laid out in Randomized Complete Block Design (RCBD) with two factors (cultivars × potassium foliar sprays) factorial arrangement. Analysis of variance of the data from each attribute was computed using the STATISTICA Computer Program. The Least Significant Difference test at 5% level of probability was used to test the differences among mean values.

RESULTS

Foliar application of potassium had significantly ($P < 0.05$) affected plant height of both cultivars of tomato (tab. 1). Foliar application of potassium with 0.5, 0.6, 0.7% maximally improved this attribute but Nagina responded less to potassium application regarding enhancement of plant height. In case of Roma, fruit diameter and fruit weight were maximally improved with application of 0.6% potassium whereas Nagina responded less to potassium application. Similarly 0.6% potassium also improved fruit yield of Roma. Moreover 0.5, 0.6 and 0.7% potassium maximally improved fruit yield of Nagina however higher dose of potassium did not improve fruit yield of both tomato cultivars.

Table. 1. Effect of foliar application of potassium nutrition on yield and yield related traits of tomato cultivars grown under field conditions

Tomato cultivars	Potassium application (%)	Plant height (cm)	Fruit weight (g)	Fruit diameter (cm)	Yield (kg plant^{-1})
Nagina	control	67.33 gh	25.70 e	3.22 d	0.94 a–d
	0.1	65.33 h	26.49 e	3.23 d	0.74 a–e
	0.2	70.0 f–h	20.38 e	3.24 d	0.93 a–d
	0.3	70.33 f–h	26.49 e	3.13 d	0.87 a–e
	0.4	71.0 e–h	26.23 e	3.21 d	1.19 ab
	0.5	73.33 d–h	26.61 e	3.27 d	1.27 a
	0.6	73.33 d–h	26.90 e	3.31 d	1.27 a
	0.7	74.0 d–h	27.60 e	3.32 d	1.23 a
	0.8	65.33 h	26.43 e	3.28 d	0.96 a–c
	0.9	64.0 h	26.16 e	3.27 d	0.92 a–d
	1.0	67.0 gh	25.57 e	3.24 d	0.93 a–d
Roma	control	60 .0 c–h	57.30 cd	4.40 c	0.47 c–e
	0.1	84.66 a–d	68.12 ab	5.32 ab	0.53 c–e
	0.2	83.66 a–d	64.16 a–d	4.67 bc	0.28 e
	0.3	80.0 b–f	62.50 a–d	5.32 ab	0.79 a–e
	0.4	83.0 a–e	66.98 a–c	5.25 ab	0.73 a–e
	0.5	94.33 a	65.80 a–c	4.90 a–c	0.77 a–e
	0.6	91.33 ab	72.53 a	5.43 a	0.95 a–d
	0.7	88.0 a–c	67.14 a–c	5.37 ab	0.69 a–e
	0.8	82.0 b–f	58.50 b–d	4.92 a–c	0.57 b–e
	0.9	78.33 c–g	55.28 d	4.51 c	0.32 de
	1.0	81.33 b–f	59.89 b–d	4.96 a–c	0.53 c–e
	LSD at 0.05	12.32	10.35	0.71	0.62

For each tomato cultivar, means within a column followed by the same letters are not significantly different at $P \leq 0.05$.

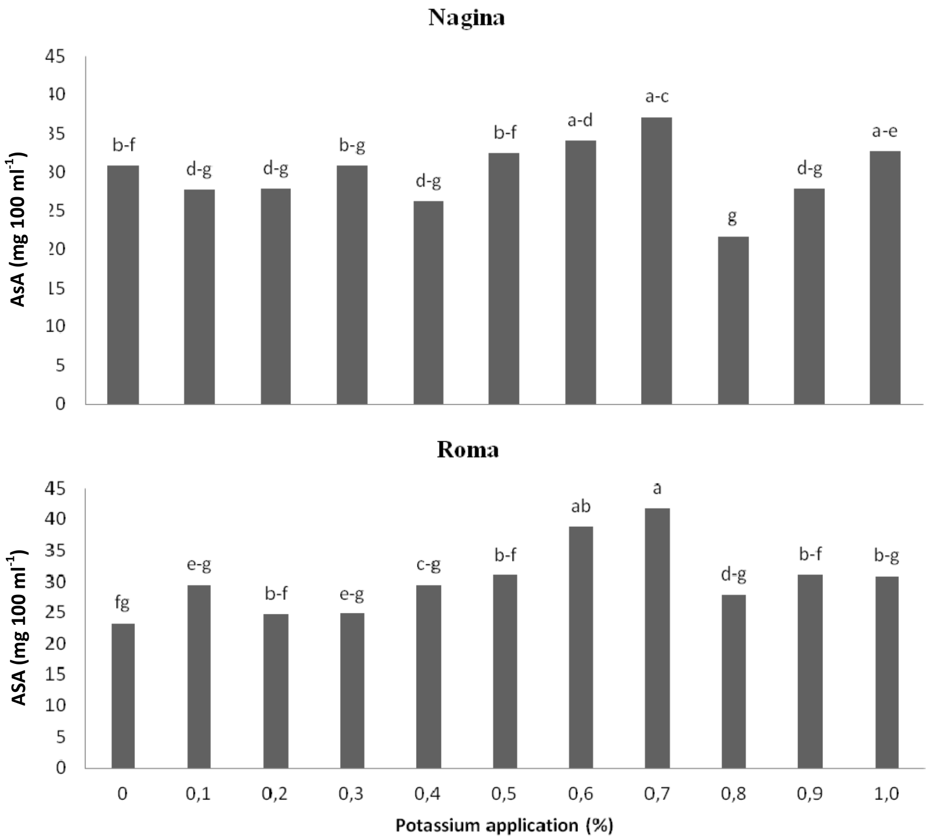


Fig. 1. Effect of foliar application of potassium nutrition on fruit ascorbic acid contents of two tomato cultivars grown under field conditions

Potassium nutrition significantly improved ascorbic acid contents of both tomato cultivars (fig. 1). Among foliar treatments, 0.5, 0.6 and 0.7% maximally improved ascorbic acid contents of both tomato cultivars whereas 0.4 and 0.8% did not improve ascorbic acid contents. Among cultivars comparison, higher ascorbic acid contents were recorded in Nagina than Roma. Maximum lycopene contents with exogenous application of 0.6% potassium in Nagina and 0.7% in Roma were recorded. In both tomato cultivars almost same lycopene contents were recorded (fig. 2). Moreover, potassium concentration in tomato fruit was not improved substantially. Albeit, 0.7% potassium applications maximally improved potassium contents in tomato fruits of Nagina (fig. 3).

Correlation studies. There was a positive correlation between lycopene contents and fruit yield (fig. 4a) and lycopene contents and potassium contents of tomato fruit (fig. 4b).

DISCUSSION

The importance of potassium (K) in plant nutrition and agricultural crop production has been well documented and foliar spray is being considered an ideal method of its application for improvement of tomato production [Oded and Uzi 2003, Bidari and Hebsur 2011]. Previous studies indicate that K has pivotal contribution to fruit weight, color, dry matter content and final yield of tomatoes [Anac et al. 1994]. In present study, exogenous application of K significantly affected growth, yield and quality attributes of tomato crop (tab. 1 and figs 1–3). It may be due to reason that K has increased the foliage and indirectly increased the photosynthesis and thus ultimately enhanced the plant height of tomato [Majumdar et al. 2000]. Nanadal et al. [1998] also reported that application of 120 kg ha^{-1} SOP has registered highest plant height. Adequate K nutrition has also been linked with increased yields addressed by Lester et al. [2005] and Kanai et al. [2007] which further confirm our findings that foliar application of K with 0.5–0.7%

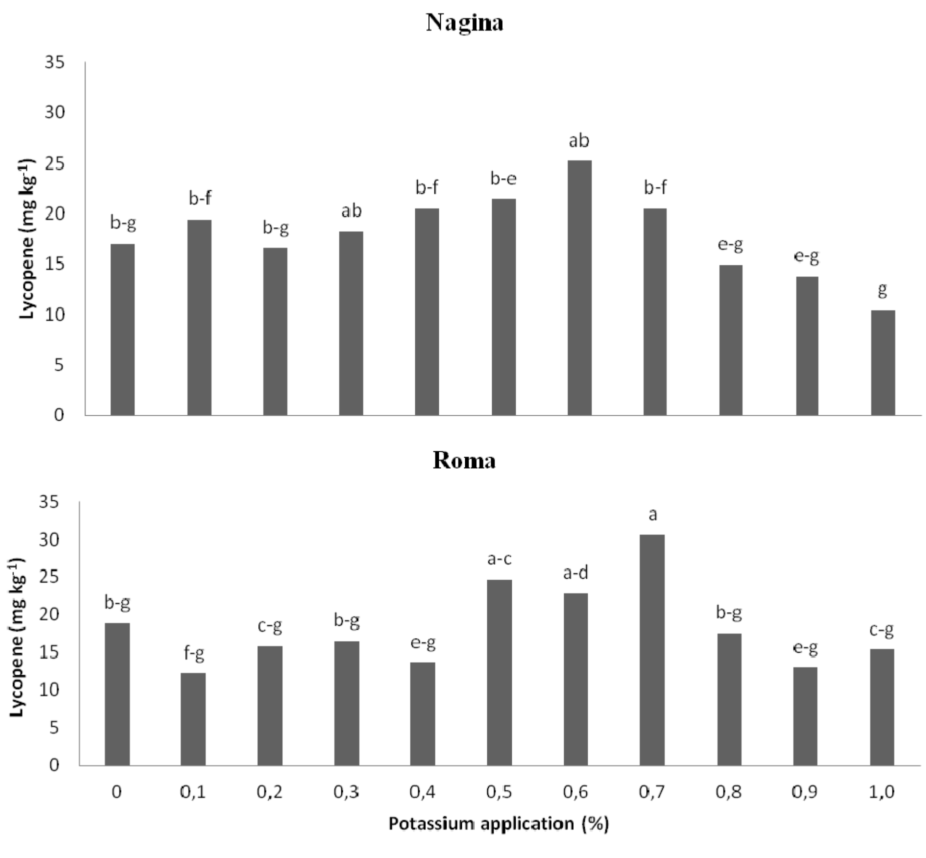


Fig. 2. Effect of foliar application of potassium nutrition on fruit lycopene contents of two tomato cultivars grown under field conditions

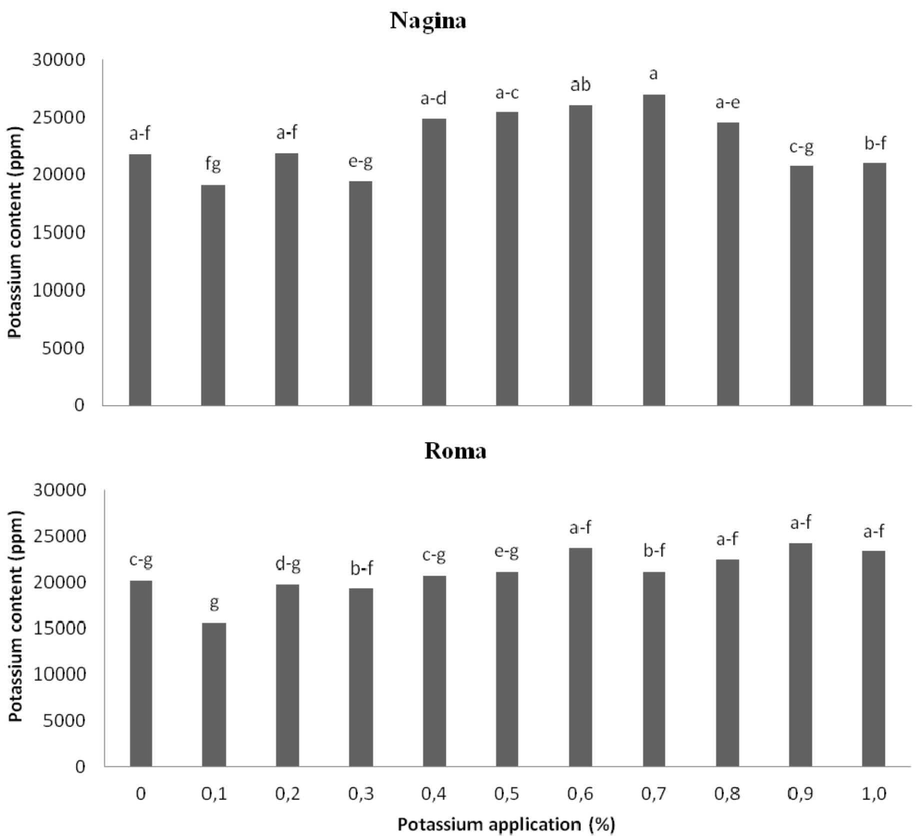
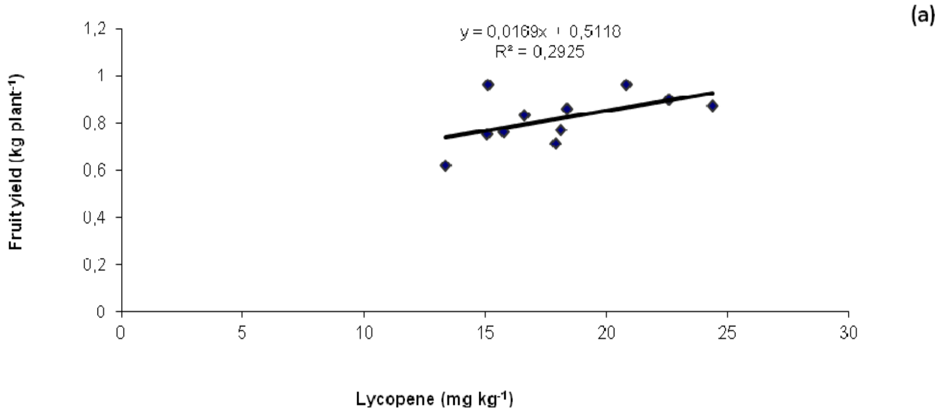


Fig. 3. Effect of foliar application of potassium nutrition on fruit potassium contents of two tomato cultivars grown under field conditions

has markedly increased yield of tomatoes (tab. 1). This increased fruit yield with K supply might be due to phloem loading, unloading efficient translocation of assimilates towards sink tissues [Zhao et al. 2001]. Chapagain and Wiesman [2004] also noticed the increase in tomato fruit weight by foliar application of K was significant that enhanced the concentration of K content under field conditions. Hariprakash and Subramanian [1991] also observed an increase in the yield of tomato fruits with increased levels of potassium. Less fruit yield in control or plants sprayed with low K level in our study is due to destabilization of source-sink relationship [Kanai et al. 2007].

Fruit quality is directly affected by potassium supply [Zhao et al. 2001, Lester et al. 2005]. If soil-applied fertilizer K was compared to foliar K applications, the second approach consistently resulted in improved number of fruits and quality attributes i.e. lycopene contents and ascorbic acid content [Demiral and Koseoglu 2005, Jifon and Lester 2009]. Generally reduced upake of K along with root activity was observed du-



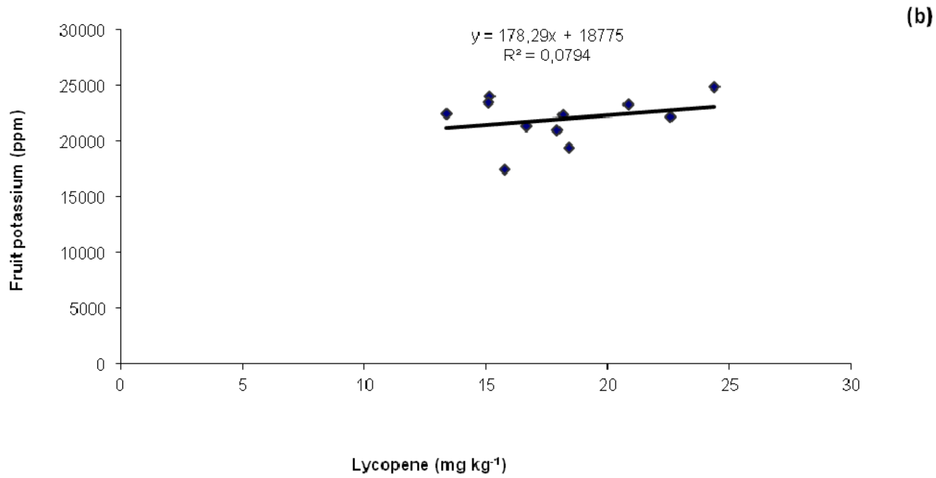


Fig. 4. Relationship among lycopene contents fruit yield and fruit potassium contents of two tomato cultivars

ring the reproductive phase of crop development. Additional foliar K applications during fruit development and maturation improves fruit marketable and human health quality by increasing sugar content, ascorbic acid, beta-carotene, and K levels [Lester et al. 2007]. Similarly our results also indicate an improvement in ascorbic acid, lycopene and K concentration with foliar application of an appropriate K level (figs 1–3). Positive correlation between fruit lycopene content and yield of tomato fruits further suggests that K nutrition remarkably improves fruit yield by improving fruit lycopene contents (fig. 4a). An improvement of fruit quality due to appropriate K nutrition might be due to improved photosynthates assimilation, their translocation from leaves to fruit and increased enzyme activation [Kanai et al. 2007]. Similar results i.e. potassium has a vital role in increasing vitamin C concentration in tomato fruits was also reported previously

[Oded and Uzi 2003, Perkins-Veazie and Roberts 2003]. Positive correlation between fruit potassium and lycopene contents also confirms the statement that increased potassium resulted in increased lycopene contents in tomato fruit (fig. 4b).

CONCLUSION

Potassium content in tomato crop indicates significant positive association with quality attributes. Obviously, exogenous application of an appropriate K level can contribute to higher yield and better quality of tomato fruits. Among all potassium levels, 0.5–0.7% K maximally improved performance of tomato plants of both cultivars. This study also indicates that growers can adopt this simple management tool for improving quality and yield of tomato in the world.

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DOLISTNE ZASTOSOWANIE POTASU POPRAWIA JAKOŚĆ OWOCÓW I PLON ROŚLIN POMIDORA

Streszczenie. Pomidor to dobrze znane na całym świecie źródło składników odżywczych, ale brak równowagi substancji odżywczych w nawozach wpływa na jego jakość. Doświadczenie polowe przeprowadzono na dwóch odmianach pomidora, Nagina i Roma, w celu zbadania wpływu potasu na plon i jakość pomidora. Roztwory potasu w różnych dawkach (0,1; 0,2; 0,3; 0,4; 0,5; 0,6; 0,7; 0,8; 0,9 oraz 1,0%) zastosowano dolistnie i porównano z kontrolą (bez K). Egzogenne zastosowanie 0,6% K istotnie poprawiło wysokość roślin, zawartość likopenu, zawartość potasu, a także wagę i średnicę owoców. Egzogenne zastosowanie 0,5, 0,6 i 0,7% K maksymalnie poprawiło zwartość kwasu askorbinowego w obydwu odmianach, natomiast zastosowanie 0,4 i 0,8% nie wywołało takiego efektu. Ze względu na pozytywną korelację między odżywianiem K a jakością owoców, egzogenne zastosowanie właściwego poziomu K może przyczynić się do wyższego plonu i lepszej jakości owoców pomidora. Spośród wszystkich poziomów potasu, 0,5–0,7% K w sposób maksymalny poprawiał wydajność roślin pomidora obu odmian.

Słowa kluczowe: *Lycopersicon esculentum*, zastosowanie egzogenne, odżywianie potasem, jakość owoców

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