Research Findings

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Increases in Yield and Vitamin C Levels of Tomato Grown on K_2HPO_4-enriched Zeolite in an Inert-Sand Substrate

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Introduction

Plant nutrition research is highly useful in tackling low soil fertility, low levels of available mineral nutrients in soil and improper nutrient management. Removing these constraints improves the sustainability of food security and well-being of humans without harming the environment (Cakmak, 2002).

As far as mineral nutrition of tomato is concerned, the effect of potassium (K) and phosphorus (P) are well established. K plays a vital role in growth, plant productivity, metabolism, ionic balance, activation of several enzymes and plant defense systems (Marschner, 1995). K is the most prominent inorganic plant solute and is the only mineral nutrient that is not a constituent of organic structures. It plays a primary role in osmoregulation, the maintenance of electrochemical equilibria in cells and its compartments, and the regulation of enzyme activities (Hsiao and Läuchli, 1986). K is crucial to the energy status of the plant, translocation and storage of assimilates, and maintenance of tissue water status. K is of outstanding importance for crop quality as it improves fruit size and stimulates root growth. It is necessary for the translocation of sugars and formation of carbohydrates and provides resistance against pest and diseases and drought, as well as frost stresses (Marschner, 1995). Several studies have

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shown that K content during the growth period has a profound effect on sugars and acids. The involvement of K in quality formation can, to a large extent, be attributed to its function in stimulating transport of soluble assimilates such as amino acids and sugars to storage organs (grains, tubers and roots), and to activate their conversion into starch, proteins, vitamins, etc. K nutrition strongly influences acid concentrations (Wien, 1997) and especially ascorbic acid (vitamin C) levels.

Fresh tomato fruits are an important source of vitamin C hence production practices, including adequate plant K fertilization, are important to determine how levels can be increased. Vitamin C must be ingested in food form because the human body is unable to synthesize it (Lee and Kader, 2000). Byers and Perry (1992) indicate that vitamin C prevents cancer by inhibiting creation of nitroso compounds in the stomach and stimulation of the immune system. This vitamin also contributes to many others aspects of human health, such as immune response, pulmonary function, and iron absorption, preventing free radical-induced damage to DNA, and also lowering the risk or even preventing chronic diseases, such as CHD (Coronary Heart Disease) and cataracts (Weber *et al.*, 1996, Kalt *et al.*, 1999).

According to Balliu and Ibro (2002), nearly 70 percent of the total K uptake in tomato plants during harvest is located in the fruit and 16 percent in the leaves. The K uptake is rapid and fairly constant during vegetative growth and fruit expansion. Fruits of K deficient plants are not fleshy, their ripening is uneven and their appearance is blotchy. The dry matter content of the ripe tomato fruit is about 5-7.5 percent of the total weight, a high proportion of this dry matter consisting of sugars and organic acids, both of which contribute to the taste of the fruit. The organic acid content, mainly citric and malic acids, increases during fruit development. The importance of P as a plant nutrient in tomato plants in general is less well recognized than that of K, even though P and K are both essential plant nutrients. The main reason for this is that lower amounts of P (in the form of phosphate) are taken up by plants and tomato is particularly responsive to K application by increased growth and raised quality. In tomato, the P content of fruit and vegetative tissue is less than one tenth that of K. After uptake, phosphate can remain as free inorganic phosphate as well as being bound with organic constituents of major importance, including sugar phosphates. With nitrogen (N) bases, P makes up the life transmitting RNA and DNA molecules, and with adenine and ribose it forms adenosine triphosphate (ATP) (Marschner, 1986). This high energy compound, although present in only small concentrations in the plant, is essential in providing the energy required in numerous metabolic reactions. One such example is the transfer of sugars from the leaves in their transport to the fruits; P - like K - is highly mobile in the plant. When tomato plants are P deficient, foliage size is greatly reduced and P is transferred preferentially to the roots, photosynthesis is depressed, and the smaller leaves become a darker green. In extreme cases, the underside of the leaves become purple as a consequence of anthocyanin accumulation.

The experiment

The evaluation of K and P addition to a zeoponic substrate for growth of tomato (*Lycopersicon esculentum* L. cv. Finestra; Bernardi *et al.*, 2007, 2010), showed positive effects on fruit yield, quality and dry matter (DM) yield. The zeoponic system was termed by Mumpton (1999) as the growth of plants in synthetic soils consisting of zeolites with or without peat or vermiculite.

As decribed by Monte *et al.* (2010), zeolite mineral was concentrated by a gravitational process and dispersed into solution (NaCl 0.5 mol L^{-1}) to saturate the negative charges. This homoionic material was dispersed into a K_2HPO_4 1.0 mol L^{-1} solution and then centrifuged, filtered and dried. Concentration of P and K in zeolite were 11,289 and 41,925 mg kg^{-1} respectively.

Bernardi *et al.* (2007, 2010) tested four levels (20, 40, 80 and 160 g per pot) of K_2HPO_4-enriched zeolite in an inert-sand substrate. All other nutrients were supplied by nutrient solution. Fig. 1 illustrates the tomato fruit and DM production in relation to K and P concentration in the growth substrate. Results of these experiments indicate that enriched zeolite was an adequate slow-release source of nutrients to the plants. Tomato fruit and DM increased with the higher availability of K in the substrate. Higher fruit and DM yields (786 and 66 g per pot) were obtained with a mean dose of 6.57 g per pot. Nanadal *et al.* (1998) also

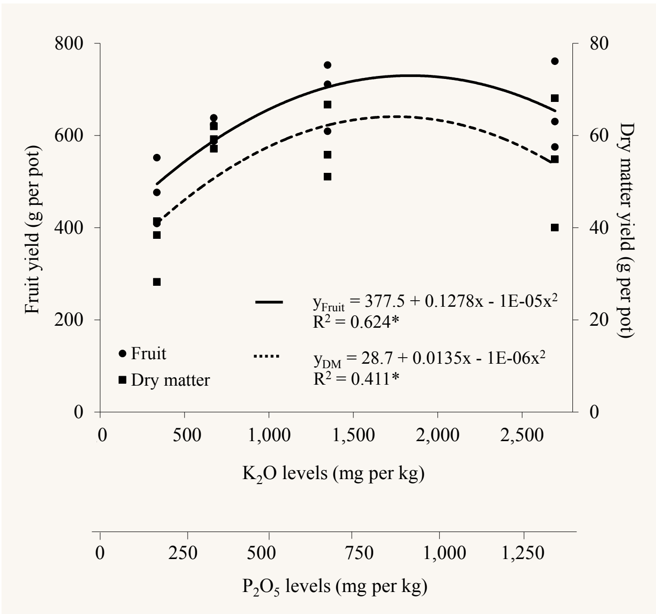

Fig. 1. Fruit and DM yield of tomato in relation to K and P levels in the substrate. Adapted from Bernardi *et al.*, 2007, 2010.

reported increased tomato yields with higher availability of P and K in the substrate.

Significant differences of vitamin C content in fresh tomato fruit, evaluated according to Ashoor *et al.* (1984), were also found in relation to K and P supply (Fig. 2). Dumas *et al.* (2003), in reviewing several papers, stated that the content of this vitamin in tomatoes could increase with the supply of combined fertilizers. As observed in our study, the highest level of 26 mg vitamin C 100 g^{-1} fresh tomato was obtained at 2.5 and 1.3 g of K_2O and P_2O_5 mg kg^{-1} substrate. Our values are consistent with those described in the literature, where the concentrations of vitamin C in tomatoes grown under greenhouse conditions ranged from 7 to 23 mg 100 g^{-1} of fresh fruit (Dumas *et al.*, 2003), and from 17 to 22 mg 100 g^{-1} in different cultivars under field conditions (Abushita *et al.*, 2000). Likewise, Sampaio and Fontes (2000), investigating yield and chemical composition of tomato in relation to K fertilization, obtained values of 20 mg 100 g^{-1} with applications of 180 kg ha^{-1} of K.

Increases in the concentration of vitamin C with increased availability of K has also been reported by Solubo and Olorunda (1977), Anac and Colcoglu (1995), Nanadal *et al.* (1998), Sampaio and Fontes (2000) and Balliu and Ibro (2002). On the other hand, Fontes *et al.* (2000) found no differences in the values of this vitamin as a function of varying doses of K.

As Vitamin C is a lactone of an acid-sugar, the higher concentrations in the fruits in the treatments of greater K and P availability of nutrients, probably relate to stimulated carbohydrate synthesis and transport of photosynthetic sugars. Both nutrient elements play an essential role in the loading and transport of sugars from leaves to fruits (Marschner, 1995).

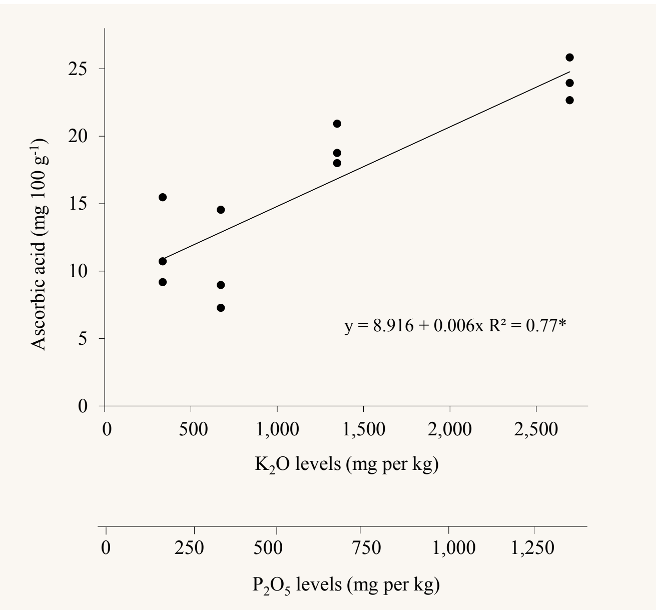

Fig. 2. Concentration of ascorbic acid (vitamin C) in fresh tomato fruits in relation to K levels in the substrate. Adapted from Bernardi *et al.*, 2007, 2010.

Conclusions

K functions in numerous ways at both cellular and whole plant levels, including acting as an enzyme cofactor in the synthesis and stability of proteins and synthesis of carbohydrates. Increasing levels of K and P supply to tomato plants, by addition to a zeoponic substrate in a pot experiment, raised fruit and total DM yields. Additionally, the concentration of vitamin C in the fruits was also raised by higher levels of K and P in the substrate. A maximum value of 26 mg vitamin C 100 g^{-1} FW was obtained with 2.5 and 1.3 g of K_2O and P_2O_5 mg kg^{-1} substrate, a value which is in accordance with other researchers' findings.

These results provide an example confirming that adequate mineral nutrient supply is a major contributor to enhancing crop production, maintaining soil productivity, as well as raising the quality of a crop product, thereby contributing to human nutrition.

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