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Calcium, Iron, Potassium, Phosphorus, and Vitamin C Content of Organic and Hydroponic Tomatoes

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***Abstract*. Two tomato (*Lycopersicon esculentum* Mill.) cultivars were grown in two organic and two inorganic media to evaluate the effects upon the levels of Ca, Fe, K, P, and vitamin C in the fruit. 'Platense' tomato was grown in a glasshouse, on sand or peat–perlite (hydroponic substrates) irrigated with a complete solution of macro and microelements, or on 100% vermicompost or 50% vermicompost–50% soil (organic substrates) irrigated with water. Fruit were harvested at physiological maturity, and levels of P, K, Ca, Fe, and vitamin C were determined. Fruit grown on organic substrates contained significantly more Ca and vitamin C and less Fe than did fruit grown on hydroponic media. Phosphorus and K content did not differ between fruit from organic and hydroponic substrates.**

The intensive nature of vegetable production necessitates fertilizer management aimed at maximizing yield and quality (Huett and Rose, 1988). There is great interest in organic crop production (Montagu and Goh, 1990), particularly in adding organic matter to the soil, which liberates nutrients in a gradual and controlled way, allowing a greater production of vegetables with a minor environmental impact (Premuzic and Iorio, 1996; Premuzic and Nicolossi, 1995). Organic wastes should be applied to soil after being processed to obtain a mature and stabilized compost (Senesi, 1989). Earthworms act on organic wastes to form vermicompost, which releases nutrients slowly (Brandjes, 1984; Ferruzi, 1994).

To compare substrate effect on the levels of P, K, Ca, Fe, and vitamin C in the fruit, tomatoes were grown on two hydroponic substrates irrigated with a nutrient solution (Premuzic et al., 1996) and on two organic (vermicompost) substrates irrigated with water.

Materials and Methods

'Platense' tomatoes were grown in a naturally lighted glasshouse with average maximum–minimum temperatures of 24–16 °C, using 3-L black opaque polyethylene pots. Seed was directly sown in pots filled with one of four substrates. Two substrates were hydroponic: purified sand (S) (Hewitt,1966) and peat–perlite (P–P), both irrigated with a solution complete in macro and microelements (Table 1) (Premuzic et al., 1996), taking into account the nutrient requirements of tomato in an open hydroponic system (Cheng and Dube, 1976; Cooper, 1976; Hoagland and Arnon, 1950; Martinez-Caldevilla and Garcia-Lozano, 1993; Pardossi et al., 1987; Sonnenveld, 1985). The other substrates were organic: 100% vermicompost (V100) and 50% vermicompost : 50% soil (V50) (Table 2), irrigated with water. All four substrates were irrigated daily, early in the morning and late in the afternoon. The experimental design was completely randomized with three replications and four treatments (substrates). Fruit were harvested at physiological maturity and dried for 48 h at 70 °C for determination of P by molecular absorption spectrophotometry (Iorio et al., 1992), K by flame photometry, and Ca and Fe by atomic absorption. Vitamin C (Official Methods of Analysis of the Association of Analytical Chemists, 1980) content was measured on fruits frozen at –18 °C for 60 d. The data were analyzed by analysis of variance, and when F values were significant, by comparison of means with Tukey's test (Tukey, 1950).

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Results and Discussion

Phosphorus and K levels of fruit did not differ significantly among the four substrates. The mean levels of P (0.083%) were below, and the mean levels of K (3.31%) were similar to those previously reported (Auclair et al., 1995; Magalhaes and Wilcox, 1983a, 1983b; Sobulo et al., 1975).

Calcium concentration (Fig.1A) was significantly higher for fruit grown in the organic than in the hydroponic substrates, and the levels were higher than previously reported (Agui et al., 1979; Maher, 1976; McMurtry et al.,1993; Muller-Haslach et al., 1986). There were no significant differences in Ca content between fruit from V50 and V100 or between fruit from S and P–P. Iron concentration (Fig. 1B) was significantly higher in the fruit grown hydroponically, but did not differ between V50 and V100 or between S and P–P.

Vitamin C concentration (Fig. 1C) was higher in fruit grown on vermicompost than in fruit grown on the hydroponic substrates, but did not vary significantly between fruit from V50 and V100 or between fruit from S and P–P. Fruit with greater vitamin C concentration have greater nutritional value (Bangerth, 1976; Gull et al., 1978; Lopez-Andreu et al., 1988; Silva and Scotti, 1973). Vitamin C levels were similar to those previously reported (Adams et al., 1978; Ketsa and Wongveerakhan, 1987; Klein and Perry, 1982; Muller-Haslach et al., 1986), although a little lower, as they were measured in frozen fruit (Barowski et al., 1981).

The higher concentration of Ca and vitamin C in the organic tomatoes suggests a positive correlation of Ca and vitamin C levels, in agreement with Bangerth (1976). According to the values presented in the USDA Food Agricultural Handbook (1963), the fruits grown organically had an adequate level of nutrients.

The quality of food and its composition are being scrutinized more critically than ever before by the consumer (Goh and Vitykon, 1986). The nutritional value of tomato consists essentially of carotene (provitamin A), lycopene, and vitamin C (Lopez-Andreu et al., 1988; Muller-Haslach et al., 1986). Most research indicates that fruit quality is affected not only by adequate amounts of N, P, and K, but also by the balance between the levels of these nutrients (Varis and George, 1985). The relationship between fertilizer application and vitamin C content in fruit has been discussed by various authors. Sharma and Mann (1971) noted a positive correlation between N and P fertilization and level of vitamin C. Mengel (1972) reported that higher rates of N increase

Table 1. Composition of the nutrient solution employed for irrigation of the hydroponic substrates. $CaCo_3$ ($0.42 g·L^{-1}$) and $MgCO_3$ ($0.17 g·L^{-1}$) were added directly to the hydroponic solution.

Nutrient	Stock solution ($g·L^{-1}$)	Stock solution used in hydroponic solution ($mL·L^{-1}$)
NH_4NO_3	21.50	21
NaH_2PO_4	63.00	4
KCl	19.00	33
Na_2SO_4	50.00	13
$FeSO_4$	26.20	5
$MnSO_4$	0.80	12
H_3BO_3	0.34	2
$CuSO_4$	0.63	1
Na_2MoO_4	0.15	1
$ZnSO_4$	0.40	1

levels of amino acids and vitamin C at the expense of carbohydrate. A negative correlation between fertility and vitamin C was cited by both Montagu and Goh (1990) and Muller-Haslach et al. (1986). High rates of fertilizers promote foliar growth and shading of the developing fruit, especially in glasshouse- grown tomatoes. This would affect vitamin C, as its synthesis depends on exposure to light (Venter, 1977).

In our experiment, tomatoes grown with vermicompost as the nutrient supply had a higher concentration of vitamin C, which could be related to the shading effect, as foliage development was greater on the hydroponic substrates (Premuzic and Iorio, 1996). Higher Ca levels in organically grown tomatoes were associated with reduced levels of other cations such as Na, Mg, and K, which are usually more abundant in substrates irrigated with nutrient solutions (Matev and Stanchev, 1979). Another important factor is that the fruit grown on organic substrate received nutrients in a slow-release fashion, optimizing the nutrient availability during fruit growth, when the uptake of nutrients is more important (Huett and Dettman, 1988).

Composting is an environmentally safe means of converting a waste product into an acceptable source of organic matter (Sterrett et al., 1983). Compost prepared from biogenic waste is an excellent material for use in intensive vegetable production, as it improves yield and nutritional and storage quality of the product (Vogtmann et al., 1993).

The results of our experiment and of others may lead to increased organic production of high-quality, contaminant-free food and contribute to the use of biogenic wastes in crop production, while reducing environmental impact.

Table 2. Chemical properties of the soil and the organic substrate

Properties	Soil	Vermicompost
Total N (%)	0.12	1.30
pH	5.80	7.00
OM (%)	2.80	13.20
Ca ($g \cdot kg^{-1}$)	0.36	0.46
Mg ($g \cdot kg^{-1}$)	0.34	0.60
K ($g \cdot kg^{-1}$)	0.54	1.75
Na ($g \cdot kg^{-1}$)	0.13	0.11
Fe ($mg \cdot kg^{-1}$)	----	43.00
P ($mg \cdot kg^{-1}$)	5.00	350.00

Method used for exchangable cations: NH_4CH_3COO; pH = 7.

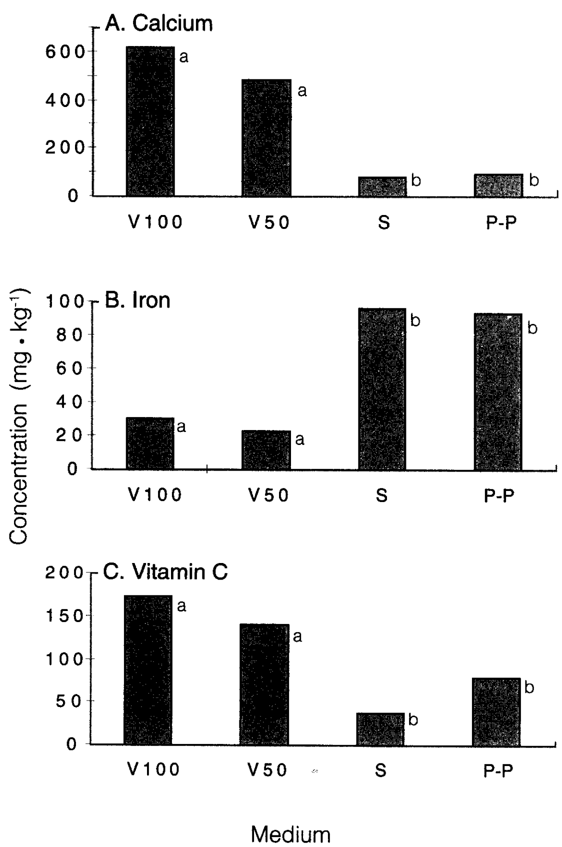

Fig. 1. Effects of media on concentrations of Ca, Fe, and Vitamin C in tomato fruit. Media used were 100% vermicompost (V100), 50% vermicompost–50% soil (V50), sand (S), and peat–perlite (P–P). Three replications per treatment with mean separation by Tukey's test ($P \leq 0.05$).

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