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Physical characteristics and mineral composition of two pepper cultivars under organic, conventional and soilless cultivation

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ABSTRACT

The present study aims to compare pepper quality and mineral composition in two different cultivars (Almuden and Quito) under organic or conventional management (experiment 1) and under soil or soilless cultivation (experiment 2). This work falls into the category of "research center studies", which compare cropping systems under identical environmental conditions. The effect of the experimental factors – cropping system (CS), harvesting time (HT) and cultivar (CV) – and their interactions were studied. In general, conventional management led to larger, firmer and thicker peppers than observed in organic fruits, with a similar greenish colour but lower colour intensity. However, some exceptions were recorded since the effect of CS on most fruit quality parameters depended on the HT and/or CV. Conventional peppers showed higher concentrations of N and P than organic fruits and also, only in the case of Almuden, a higher NO_3^- concentration. Peppers grown under the soilless system showed higher NO_3^- and lower Ca concentrations and were less greenish (lower hue) than those grown in soil. Significant two-way and/or three-way interactions between CS and the other experimental factors were detected for weight, firmness and flesh thickness. The results obtained for fruit weight in Quito showed this cultivar to be the less suitable for soilless cultivation.

1. Introduction

The quality of fruits and vegetables for fresh consumption is a complex issue. While their nutritional composition is a primary factor for defining food quality, the external appearance of fruits, particularly their colour and properties such as firmness and pericarp thickness, also play an important role in the quality evaluation, especially as far as consumer acceptance is concerned (Abbott, 1999). In addition, fruits and vegetables are excellent dietary sources of minerals, although little attention has been paid to this issue. In particular, pepper is a good source of potassium, magnesium, phosphorus and calcium, all essential minerals for human health (Wang et al., 2008). Potassium, the most abundant mineral in fruits and vegetables, helps reduce the risk of stroke (Joshipura et al., 1999). Magnesium is important in protein synthesis and it is critical for proper heart functioning (Douban et al., 1996). Phosphorus is essential for skeletal mineralization and the correct functioning of multiple cellular functions (DiMeglio et al., 2000). Finally, calcium is essential for bone formation and the prevention of osteoporosis (Cohen and Roe, 2000).

The physical properties and chemical composition of fruits and vegetables have been shown to be highly influenced by agricultural management practices, and organic vegetables, in particular, are usually considered to have higher mineral content and to be more nutritious and safer than conventionally grown vegetables (Jolly, 1991).

Soilless cultivation, the most intensive production method in today's horticulture industry, can also affect fruit quality and composition (Gruda, 2009). This system clearly presents high yields, even in areas with adverse growing conditions (Grillas et al., 2001), but the organoleptic properties of fruits grown in this way have received little attention and comparative studies about the effect of soil and soilless cultivation on fruit quality are scarce in the scientific literature. The studies that have compared organic and conventional production systems have provided inconsistent results as regard the organoleptic quality and nutritive value of fruits (Bourn and Prescott, 2002; Lester, 2006; Zhao et al., 2006). This is not surprising because comparing the effect of organic and conventional farming systems on fruit quality is inherently difficult due to the wide range of factors that can potentially affect crop composition such as climate, soil conditions, cultivar, soil type, planting date, harvesting time and growing seasons (Adam, 2001; Goldman et al., 1999; Magkos et al., 2003). To obtain conclusive results, comparative studies should be carried out from different perspectives. The present research falls into the category of "Research center

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studies", which compare different agricultural management system under identical environmental conditions (climate, soil type, etc.). According to Magkos et al. (2006), this study category is the most accurate and valid method of comparison since it allows the differences in the nutrient composition of food to be identified. However, this type of study does not realistically reflect commercial production systems and so should be regarded as complementary to "Farm studies", which involve exact production conditions. This study forms part of a larger research project in which a comparative farm study was carried out to assess the sensory quality, nutritional value of peppers cultivated under organic, conventional and soilless systems (Flores et al., 2009a,b). The aim of the present study is to assess the influence of the agricultural management system, including organic, conventional and soilless cultivation, on the sensory attributes and the mineral composition of two different pepper cultivars (Almuden and Quito).

Table 1
Initial soil characterization (after biosolarization, and before the beginning of the crop cycle).

	Experiment 1		Experiment 2
	Conventional	Organic	Soil
pH	7.6	7.9	7.7
EC (dS m^{-1})	15.4	11.7	17.1
Soluble Na	55.2	56.0	75.2
Cl (meq l^{-1})	82.1	60.6	100.5
SO_4^{2-} (meq l^{-1})	51.0	55.1	63.0
NO_3^- (meq l^{-1})	30.0	14.2	26.9
Assimilable P (mg l^{-1})	131.0	114.9	125.7
Soluble K (meq l^{-1})	19.5	19.8	16.9
Soluble Ca (meq l^{-1})	38.6	43.6	46.6
Soluble Mg (meq l^{-1})	53.1	44.9	57.7
Organic N (%)	0.18	0.20	0.20
Organic matter (%)	2.98	2.96	3.0

2. Materials and methods

2.1. Study site and experimental design

Two experiments were conducted on pepper (*Capsicum annuum* L.) grown in a polyethylene (800 G) greenhouse during two consecutive growing seasons; in the experimental farm "Torreblanca" located in Torre-Pacheco (Murcia), SE Spain. The experiments were based on three experimental factors: cropping system (CS), harvesting time (HT) and cultivar (CV). In the first trial, twelve treatments were obtained from the factorial combination of two CS, three HT and two CV. The CS were organic (O) or conventional (C) system; HT corresponded to 164 (H1), 186 (H2) or 223 (H3) days after transplantation; the CV were pepper cvs. Almuden and Quito. In the second experiment, 8 treatments were obtained from the factorial combination of two CS, two HT and two CV. The two CS were the soil (S) or soilless (SL) system; the two HT corresponded to 159 (H1) or 181 (H2) days after transplantation; the two CV were the same pepper cvs. Almuden and Quito. Plants were grown following a split-plot experimental design with two replicates: the cropping systems were assigned to the main plots and the cultivars were assigned to the elementary plots. In both experiments the two pepper cultivars, Almuden, a Lamuyo-type pepper and Quito, a California-type pepper, were grown for an entire crop cycle starting in December. Fifty four plants were randomly distributed in three rows per plot, spaced by 0.4 m along the row and by1.0 m between the rows.

2.1.1. Experiment 1: organic vs conventional

For conventional and organic farming, plants were grown in soil with a clay-loam texture. For both treatments, the soil was prepared by biosolarisation (Flores et al., 2008). As an amendment, a mix of ovine and chicken manure was applied at rate of 5 kg/m^2. Manure used for soil solarisation had the following characteristics: pH extracted at a 1:10 (w/v) = 7.4, electric conductivity (1:10) 8.7 dS m^{-1}, organic matter 41.0%, N 1.8%, P 0.2%, K 1.4%, Ca 7.1%, Mg 1.0%, Fe 0.2 ppm, Mn 76.8 ppm, Zn 49.3 ppm, Cu 12.5 ppm and C/N ratio = 13.2. Afterwards the soil was covered with a plastic film and the greenhouse was closed for 3 months during the summer season (August–October). Characterization of the soil from the organic and conventional plots is presented in Table 1.

Plots under organic cultivation had a previous history that involved three years under this agricultural management. The organic cultivation was managed following the corresponding European Regulation (EC) 834/2007, using fertilizers certified for organic crops: Ecoamin® (aminoacids with 3% of total N and 1.9% of organic N) and Basuras Pedrín® (N 1%, P 0.02%, K 1%, Ca 350 ppm, Mg 250 ppm, Fe 350 ppm, Mn 275 ppm, Zn 600 ppm and Cu 0.5 ppm). For the conventional cultivation, plants were fertilized with $Ca(NO_3)_2$, KH_2PO_4, NO_3NH_4, KNO_3 and $MgSO_4$, following low-input guidelines, at rate of 373 N; 56 P; 485 K; 65 Ca and 26 Mg kg/ha, respectively. For the soilless system, a modified Hoagland's solution was used, containing macronutrient concentrations (mM) as follow: 18 NO_3^-, 1 $H_2PO_4^-$, 1 SO_4^{2-}, 5.5 Ca, 6.5 K and 1.7 Mg. The micronutrient concentrations (ppm) were as follows: 2 Fe, 1 Mn, 0.1 Zn, 0.3 B, 0.1 Cu and 0.06 Mo. Pest control was performed according to the Integrated Production Protocol for pepper crops (B.O.R.M., 2007)

Pepper fruits were sampled in the green mature stage at three planned harvesting times (HT) during the growing season: 164 (HT1), 186 (HT2) and 223 (HT3) days after transplanting. Fruit showing full-size development and a homogeneous green colour (with no appreciable brown or red parts) were selected, and damaged fruits were discarded. At each HT, six samples per treatment were collected, each consisting of six subsamples from different plants. The physical parameters of weight, shape index, colour parameters (L^*, a^* and b^*), firmness and thickness were measured. After these determinations, peppers were washed with deionised water and the seeds were removed. Each fruit was cut into pieces and mixed with those of fruits belonging to the same replicate. Samples were dried in an oven at 60 °C and dry tissue was ground to determinate the mineral composition.

2.1.2. Experiment 2: soil vs soiless

For soil cultivation, plants were grown under identical conditions that those above specified for the conventional cultivation (experiment 1). Soil characterization is presented in Table 1. For the SL system, plants were grown in substrate containing perlite (30%) and coconut fibre (70%). The nutrient solution used for irrigation had the following macronutrient composition: NO_3^-, 18.0; $PO_4H_2^-$, 1; SO_4^{2-}, 1; Ca, 5.5; K, 6.5; and Mg, 1.7. The micronutrient concentration (ppm) was as follows: Fe, 2; Mn, 1; Zn, 0.1; B, 0.3; Cu, 0.1; and Mo, 0.06. Pepper fruits were sampled in the green mature stage at two planned harvesting times (HT) during the growing season: 159 (HT1) and 181 (HT2) days after transplanting. Fruit selection, sampling and analysis were carried out as in experiment 1.

2.2. Morphological and physical attributes

The colour of the fruits of each of the samples was measured by reflectance using a Minolta CR-200 (Minolta, Ramsey, NJ) colorimeter through direct reading in three different areas of the surface of randomly selected fruit, taking the mean of the three measurements as the definitive. Colour data are provided as CIE $L^*a^*b^*$ coordinates. L^* indicates lightness (0, black; 100, white) and a^* (+, red; −, green) and b^* (+, yellow; −, blue) are the chromaticity