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Ionomic Concentration and Metabolomic Profile of Organically and Conventionally Produced 'Rojo Brillante' Persimmon

Nariane Q. Vilhena [1], Alejandra Salvador [1,*], Julia Morales [2], Almudena Bermejo [3] and Ana Quiñones [2,*]

[1] Postharvest Department, Valencian Institute for Agricultural Research, 46113 Valencia, Spain; quaresma_nar@gva.es
[2] Center of Sustainable Agricultural Development, Valencian Institute for Agricultural Research, 46113 Valencia, Spain; morales_jul@gva.es
[3] Center of Citriculture and Plant Production, Valencian Institute for Agricultural Research, 46113 Valencia, Spain; bermejo_alm@gva.es
* Correspondence: salvador_ale@gva.es (A.S.); quinones_ana@gva.es (A.Q.)

Abstract: This study evaluates mineral concentrations, biocomponents contents and fruit quality attributes in 'Rojo Brillante' persimmon grown under organic and conventional managements. During two seasons, the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and boron (B) were determined in leaves and fruits. Weight, color, firmness, and total soluble solids (TSS) were also evaluated in fruits. Moreover, in the second season, organic acids (citric, succinic, and fumaric acids), main sugars (sucrose, glucose, and fructose), carotenoids (β-carotene, β-cryptoxanthin, violaxanthin, lutein, and zeaxanthin), phenolic compounds (gallic and ρ-coumaric), and ascorbic acid concentrations were determined in fruit flesh. The crop yield in the conventional plots was bigger than that for organic crops. Nevertheless, the highest agronomic efficiency was found in organic management. In general, the greater nutrient supply in the conventional compared to in the organic system did not result in higher concentrations of macro- and microelements in leaves and fruits. The organic fruit had higher color values and lower firmness values than the conventional fruit. The concentrations of malic acid, β-cryptoxanthin, and ascorbic acid were higher in the organic compared to in the conventional fruit, while no crop system effect was found in the other evaluated biocompounds.

Keywords: *Diospyros kaki*; macronutrients; nutritional compounds; fruit quality; organic crop

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1. Introduction

Persimmon (*Diospyros kaki* Thunb.) is an important fruit crop in Spain, with a production area covering around 17.600 ha and centered mainly on the 'Rojo Brillante' cultivar [1]. Persimmon fruit is highly appreciated for its nutritional quality and for the presence of bioactive and antioxidant compounds such as polyphenols, carotenoids, and tannins. The 'Rojo Brillante' cultivar is highly valued for its good quality and is commercialized with a crunchy texture, a large size, and good flavor [2].

Nowadays in Spain, most plots employed for persimmon cultivation respond to conventional agriculture practices and, therefore, include the use of synthetic pesticides and herbicides, as well as chemical fertilizers [3]. Nevertheless, persimmon production performed by organic farming practices has been increasing in recent years. At present, almost 300 ha is used for organic persimmon production [4]. Organic matter from composts and manures is a direct source of slow-release nutrients and can increase nutrient uptake due to an improved cation/anion balance and nutrients availability through improved microbiological activity [5,6]. Lack of synthetic pesticides in organic farming can also lead to positive results in the production of natural defense substances, such as phenolic compounds, due to plants being more exposed to biotic stresses [7].

It is noteworthy that final fruit quality can be affected by plant nutrients supply, which is determined by production management (conventional or organic) [8]. Organic foods are generally perceived as being healthier, tastier and more nutritious than conventionally produced foods. However, there is little evidence to confirm this assumption, because comparative data from production systems are inconsistent [9,10]. For persimmon, very few studies have compared the nutrient uptake and quality of organic and conventional fruit. A study with the cv. Rama Forte reported that organic fruit contained larger amounts of Zn while Mg, P, Na, and K concentrations were higher in conventional fruit [11]. Cardoso et al. [10] found higher vitamin C content in this cultivar when it was conventionally produced than in those organically cultivated. Previous studies on 'Rojo Brillante' have shown that management can affect persimmon macronutrient fruit composition, which depends on both harvest moment and the evaluated flesh area [12]. However, more information about the mineral and nutritional compositions of persimmon fruit grown in different management systems is needed.

Hence, the objective of this work is to compare the fruit and leaf mineral concentrations (macro- and micronutrients), fruit biocomponents contents, and quality attributes of organically and conventionally grown 'Rojo Brillante' persimmons.

2. Materials and Methods

2.1. Plant Material

This experiment was carried out in six orchards of 'Rojo Brillante' persimmon trees located in Alcudia (Valencia), Spain (lat. 39°11′18.7″ N, long. 0°32′6.2″ W), at an altitude of 42 m above sea level during 2 growing seasons. Three plots were subjected to organic management in the last ten years, and the other three were subjected to conventional management. This region has a Mediterranean climate with 400–500 mm of mean annual rainfall and average annual temperatures of 15–17 °C. The soil characteristics of both growth management systems are presented in Table 1.

Table 1. Soil physico-chemical characteristics.

Parameter	Conventional Orchards	Organic Orchards
Sand (%)	28.1	22.4
Silt (%)	37.1	54.9
Clay (%)	34.8	22.7
USDA Classification	Clay loam	Silty loam
pH	8.4	7.6
OM (%)	0.94	3.14
Norg (%)	0.05	0.14
C/N	11.47	13.05
Soluble P_{Olsen} [1] (ppm)	15.2	18.0
Ca_{sse} [2] (meq/L)	6.81	7.43
Mg_{sse} [2] (meq/L)	2.89	2.43
K_{sse} [2] (meq/L)	0.31	0.35

[1] POlsen, available phosphorus; [2] sse, soils saturation extract.

Trees were subjected to drip irrigation employing four commercial emitters per tree (4 L h^{-1}), aiming to achieve an approximate 33% wetting area at a depth of 20 cm, following the methodology outlined by Keller and Karmelli [13]

The quantity of water applied to each tree was calibrated to match the total seasonal crop evapotranspiration (ETc) [14]. The weekly water volume administered to each tree was computed using the formula:

$$ETc = ETo \times Kc$$

where ETo represents the reference crop evapotranspiration under standard conditions, and Kc is a crop coefficient. ETo was determined utilizing the Penman–Monteith method, as detailed by Allen et al. [15]. Kc values were derived from information provided by Castel and Buj [16], which takes into account crop-specific influences on overall crop water requirements based on canopy size and leaf properties.

The fertilization plans for the orchards under assessment are elucidated in Table 2.

Table 2. Nutrient fertilization on the studied crops.

Management	Season	Chemical Compound							
		N	P_2O_5	K_2O	Ca	Fe	Mn	Zn	B
		kg year^{-1} ha^{-1}				mg year^{-1} ha^{-1}			
Conventional	1	170	74	155	0.3	2190	1535	1093	120
	2	167	62	113	3.6	720	1650	650	120
Organic	1	27	1	27	0.7	150	120	420	0
	2	20	1	27	0.0	150	31	332	0

Fluidogama was used to provide fertilizers units in organic management (2.8% organic N, 3.1% K_2O, and 40% organic matter) through fertigation.

All pest control, weed management, and other relevant practices were implemented in accordance with common guidelines for both conventional and organic plots.

In each plot, 12 trees, of which 4 were one replicate, were previously marked to carry out subsequent leaf and fruit samplings. In two consecutive seasons, leaf and fruit samples were taken, when fruit were considered commercially mature (the earliest commercial harvest moment): on October 16 and October 28 during the first and second seasons, respectively. On each sampling date, 8 leaves were collected from the summer flush of each tree, with the third or fourth leaf from the axilla of reproductive sprouting, placed in the four orientations, to totalize 32 leaves per replicate. In addition, 36 fruit were collected per replicate by taking 9 fruits from each tree from the same reproductive sprouting.

Leaf and fruit samples were transported to the Valencian Institute for Agricultural Research (IVIA), where the ionomic analysis, physico-chemical determination, and biocomponents analysis were performed.

2.2. Ionomic Analysis

The concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and boron (B) were determined in both leaves and fruits. Prior to the macro- and microelements determinations, leaves and fruits were washed with deionized water. Five fruits per replicate were longitudinally cut into four parts, and two opposite parts were peeled. Samples were dried in a forced air oven at 65 °C for a minimum 72 h period, ground in a water-refrigerated mill (IKA M20, IKA-Werke GmbH & Co. KG, IKA Labortechnick, Staufen, Germany). Nutrient extraction was carried out by wet digestion in a digestor FOSS Tecator (Foss Analytics, Hilleroed, Denmark). For that purpose, 0.2 g of the pulverized samples was weighed, and 4 mL of Milli-Q, 4 mL of nitric acid (HNO_3), and 2 mL of hydrogen peroxide (H_2O_2) were added to each sample. The tubs were kept at 200 °C for 15 to 20 min. The extracts were diluted in a 25 mL beaker to analyze the micronutrients concentrations. An aliquot of 0.5 mL was taken from the extraction solution to determine the macronutrients and made up to 10 mL with Milli-Q water. Both tubes were stored until further analysis.

The Kjeldahl method was used for the organic N analysis, performed in a Tecator^{TM} Line distiller (Kjeltec 8200, Foss Analytics, Hilleroed, Denmark). The concentrations of P, K, Ca, Mg, Fe, Mn, Zn, and B were determined by inductively coupled plasma optical emission spectrometry (ICP-OES iCAP 7000, Thermo Scientific, Waltham, MA, USA). The results of the macronutrient concentration were expressed as a percentage of dry weight (DW), and the micronutrient concentration was expressed as ppm (DW).

The agronomic efficiencies of the main applied macronutrients were calculated as the fruit yield (kg ha^{-1}) divided by the amount of N, P, or K (kg ha^{-1}) applied to each plot.

2.3. Determination of the Physico-Chemical Parameters

Weight, external color, and flesh firmness were individually measured on 20 fruits per replicate. Fruit weight was determined on a digital scale (PB3002-S/FACT, Mettler-Toledo, Greifensee, Switzerland). External color was measured on the two opposite sides of the equatorial zone of each fruit using a portable colorimeter (Minolta, mod. CR-400, Ramsey, NY, USA). The results were expressed as the color index (CI = 1000.a/L.bs, where L, a, and b are Hunter color parameters) [17].

Flesh firmness was evaluated on the equatorial zone of each fruit after removing skin by a texturometer (Instron Corp., mod. 4301, Canton, MA, USA) provided with an 8 mm-diameter punch. The results were expressed as the force in Newton (N) needed to break flesh.

For the total soluble solids (TSS) determination, samples of five fruits per replicate were taken. Fruits were cut into four longitudinal parts. Two opposite parts were peeled and placed inside an electric juice extractor, and the filtered juice was used to determine TSS content by a digital refractometer (model PR-1, Atago, Japan). To avoid tannins interfering with TSS measurements, their insolubilization was previously carried out according to Sugiura et al. [18]. The results were expressed as °Brix.

2.4. Biocomponents Analysis

The extraction and determination of sugars, organic acids, vitamin C, phenolic compounds, and carotenoids were conducted from the same juice samples used for the TSS determination.

Individual sugars extraction was carried out following the procedure as previously described by Bermejo et al. [19]. Compounds were analyzed by an HPLC device equipped with a refractive index detector (Waters, Barcelona, Spain) using a 5 µm Tracer Carbohydrate column (250 mm × 4.5 mm) (Teknokroma, Barcelona, Spain). The mobile phase was acetonitrile:water (75:25) at a flow rate of 1 mL/min. Compounds were identified by comparing their retention times to standards and were quantified using an external calibration curve with fructose (RT = 10.60 min), glucose (RT = 12.66 min), and sucrose (RT = 18.54 min). Sugars were obtained from Sigma (Sigma Co., Barcelona, Spain). The results were expressed as g kg^{-1}.

Organic acids extraction was performed according to the method described by Bermejo et al. [19]. Compounds were analyzed by HPLC-DAD and HPLC-MS under electrospray ion negative conditions. An ICSep ICE-COREGEL 87H3 column (Transgenomic, Omaha, NE, USA) was used with an isocratic mobile phase of 0.1% H_2SO_4 solution at a flow rate of 0.6 mL/min, and the injection volume was 5 µL. The temperature of samples was 5 °C, the column temperature was maintained at 35 °C, and UV−Vis spectra were detected at 280–400 nm. Compounds were identified by comparing their retention times and UV−Vis and mass spectral characteristics to the corresponding standards. Concentrations were determined using an external calibration curve with citric acid (RT = 8.01 min; $[M - H]^+$ 191 m/z), malic acid (RT = 9.41 min; $[M - H]^+$ 133 m/z), succinic acid (RT = 11.43 min; $[M - H]^+$ 117 m/z), and fumaric acid (RT = 13.60 min; $[M - H]^+$ 115 m/z). The standard compounds came from Sigma-Aldrich (Sigma Co., Barcelona, Spain). The results were expressed as mg 100 g^{-1}.

Ascorbic acid was extracted according to the method reported by Bermejo et al. [19]. DL-dithiothreitol (DTT) was used as the reducing reagent of dehydroascorbic acid to ascorbic acid. Ascorbic acid quantification was performed by HPLC-DAD (Waters, Barcelona, Spain) with a reverse-phase column C18 Tracer Excel 5 µm 120 OSDB (250 mm × 4.6 mm) (Teknokroma, Barcelona, Spain) and an isocratic mobile phase of methanol:0.6% acetic acid (5:95, v/v). Quantification was carried out at 245 nm by external standard calibration. L-ascorbic acid was obtained from Sigma (Sigma Co., Barcelona, Spain), and DTT was purchased from Fluka (Sigma Co., Barcelona, Spain). The results were expressed as mg 100 g^{-1}.

Phenolic compounds were extracted according to the procedure described by Novillo et al. [20]. They were analyzed by HPLC-DAD and HPLC-MS in a reverse-phase column C18 Tracer Excel 5 µm 120 OSDB (250 mm × 4.6 mm) (Teknokroma, Barcelona, Spain) under electrospray ion positive and negative conditions, with a gradient mobile phase consisting of acetonitrile (solvent A) and 0.6% acetic acid (solvent B) at a flow rate of 1 mL/min. The gradient change was as follows: 10% for 2 min, 10–75% for 28 min, 75–10% for 1 min, and held at 10% for 5 min. Compounds were identified by comparing their retention times and UV−Vis spectra and mass spectra data to authentic standards from Sigma-Aldrich, and all the employed solvents were of LC–MS grade. Concentrations were determined using an external calibration curve with gallic acid (RT = 4.61 min; $[M - H]^+$ 169 m/z) and p-coumaric acid (RT = 13.40 min; $[M - H]^+$ 163 m/z). The results were expressed as mg 100 g^{-1}.

Carotenoid extractions were carried out following the procedure described by González et al. [21] and were analyzed by HPLC-DAD and HPLC-MS in a reverse-phase column Agilent ZORBAX Eclipse XDB-C18 5 µm. The mobile phase was of water (A): acetonitrile−water−triethylamine (900:99:1) and (B) ethyl acetate at a flow rate of 1 mL/min. The gradient elution was: 0–5 min, 100% to 75% A; 5–10 min, 75% to 30% A; 10–13 min, 75% to 0% A; 13–14 min, 0% to 100% A; 14–15 min, 100% A, with a total run time of 15 min. Compounds were identified by comparing their retention times and absorption spectra characteristics. The quantification of carotenoids was achieved using calibration curves with commercially available authentic standards: violaxanthin, lutein, zeaxanthin, β-cryptoxanthin, and β-carotene from CymitQuimica (Barcelona, Spain). Their quantities were corrected for extraction efficiency based on the β-apo-8′-carotenal internal recovery standard. Concentrations were determined using an external calibration curve with violaxantin (RT = 4.60 min), lutein (RT = 6.65 min), zeaxanthin (RT = 6.80 min), β-cryptoxanthin (RT = 10.40 min), and β-carotene (RT = 12.50 min). The results were expressed as µg 100 g^{-1}.

2.5. Statistical Analysis

The statistical analysis was carried out using the Statgraphics Centurion XVII.I software application (Manugistics Inc., Rockville, MD, USA). Data were subjected to analyses of variance (ANOVA) and multiple comparisons between means at $p \leq 0.05$, with management and season as factors, determined by the least significant difference (LSD) test.

3. Results and Discussion

3.1. Crop Yield and Agronomic Efficiency

One of the drawbacks that is most often pointed out when comparing organic and conventional managements is the large difference in crop yield between both agriculture systems. Organic cultivation is often associated with poor performance in fruit productivity terms [22]. The higher productivity of conventional agriculture is associated mainly with high fertilization rates [23].

In the present study, the yield obtained for conventional management was similar for both seasons and was higher than those achieved with organic crops (Table 3). In organic farming, a decreased yield was recorded during the second season. It is known that crop yield variability among seasons can be influenced by a wide range of factors. In organic farming, one of the main yield-limiting factors is N availability [24]. Thus, in the present study, the lesser N input in organic management in the second year could be related to lower production.

Table 3. Average yields in conventional and organic crops in two harvest seasons.

Season	Yield (kg)/ha	
	Conventional	Organic
1	44,452 [a]	33,418 [b]
2	44,174 [a]	23,914 [c]

The mean values followed by different letters significantly differ when comparing both factors ($p \leq 0.05$).

Nevertheless, when comparing crop productivity to the fertilization rate of the main macronutrients, the agronomic efficiency of the organic crop was much higher than for the conventional agriculture in both study years (Table 4). These results indicate a better use efficiency of the nutrients applied in organic systems. Lin et al. [25] also found a better nitrogen use efficiency under organic farming systems (arable farming, improved arable farming and agroforestry) when compared to conventional system.

Table 4. Agronomic efficiencies of the main macronutrients in conventional and organic managements in two harvest seasons (kg fruit kg fertilizer $^{-1}$).

Management	Season	N	P_2O_5	K_2O
Conventional	1	261 [b]	600 [d]	286 [d]
	2	264 [b]	712 [c]	391 [c]
Organic	1	1237 [a]	33,418 [a]	1238 [a]
	2	1195 [a]	23,914 [b]	886 [b]

The mean values followed by different letters in a column significantly differ ($p \leq 0.05$).

3.2. Macro- and Micronutrients Concentrations

In both studied seasons, a higher N input in conventional management was applied, up to six times more than in organic farming (Table 2). However, differences in the leaf N concentration were observed between the conventional and organic managements, but only in the second year, when the lowest values were detected in the organic plots (Table 5). Nevertheless, the leaf N concentrations obtained for both managements fell within the optimal range established for 'Rojo Brillante' persimmon (1.33–1.50%) [26]. The N concentration in the conventional plots was slightly higher than 1.50%, which indicates that the amount of N added by fertilization could be reduced. The lower leaf N in the organic crop in the second season could be due to a lesser N input, which would result in an N concentration being at the threshold of the optimum values. These results corroborate more efficient N use in organic than in conventional fertilization [12]. Similar to that observed in leaves, no differences in the N concentration of the conventional fruit were observed between seasons, and values were similar to those of the organic fruit from the first season.

As shown in Table 2, the P and K inputs in the conventional plots were much higher than in the organic ones. Nevertheless, the concentrations of these macronutrients in both leaves and fruits were similar in the two management systems, with no differences between seasons (Table 5). The similar P concentrations in both crop systems could be explained by the effect of the applied organic matter, which reduces the rhizosphere's pH to favor the most available form of P [27]. According to Morales et al. [26], K leaf concentration was in the range considered optimal for this variety, showing the correct fertilization carried out in both managements, whereas P concentrations were higher; therefore, the P applications could be reduced under conventional management. Despite lack of Mg supply, the concentrations detected in leaves and fruit were also similar in both the conventional and organic crops, with values within the optimal range [26].

Table 5. Macronutrients concentrations in the leaves and fruit of the 'Rojo Brillante' persimmon cultivated by conventional or organic management in two harvest seasons.

	N (%)		P (%)	K (%)	Ca (%)		Mg (%)
Leaves							
Management (M)							
Conventional	-		0.14	1.27	3.77		0.87
Organic	-						
Season (S)							
1	-		0.14	1.27	4.21 ^{a}		0.87
2	-				3.33 ^{b}		
M × S	CV	OR	-	-	-		-
S1	1.52 ^{a}	1.48 ^{a}					
S2	1.52 ^{a}	1.32 ^{b}					
Significance							
M	**		NS	NS	NS		NS
S	*		NS	NS	***		NS
M × S	*		NS	NS	NS		NS
Fruits							
Management (M)							
Conventional	-		0.08	0.90	-		0.04
Organic	-				-		
Season (S)							
1	-		0.08	0.90	-		0.04
2	-				-		
M × S	CV	OR	-	-	CV	OR	-
S1	0.39 ^{a}	0.42 ^{a}			0.05 ^{a}	0.03 ^{b}	
S2	0.39 ^{a}	0.31 ^{b}			0.03 ^{b}	0.03 ^{b}	
Significance							
M	*		NS	NS	*		NS
S	***		NS	NS	NS		NS
M × S	**		NS	NS	*		NS

Significant correlation at $p \leq 0.05$ (*), $p \leq 0.01$ (**), and $p \leq 0.001$ (***). NS, not significant. M × S represents the interaction of factors. The means followed by different letters significantly differ ($p \leq 0.05$).

The Ca in leaves was not affected by crop system, although this concentration was lower in the second season (Table 5). It should be noted that the Ca input in the conventional plots was higher in the second season (Table 2). Nevertheless, in both seasons, Ca concentrations were higher than 2.7%. This value is considered optimum in leaves at harvest [26]. In the fruits harvested in the first season, the Ca concentration was higher in the conventional plots than in the organic ones. In the second season, however, no effect of crop system was found, which was related to a lower Ca concentration only in the conventional fruit. It has been reported that Ca application does not guarantee Ca assimilation by plants, because this depends on the applied Ca form [28,29].

Although Fe inputs were much higher in the conventional plots than in the organic plots, the Fe concentrations in both leaves and fruits were similar for both managements (Table 6). However, differences in the leaf Fe concentration were detected between seasons, which may be related to the lesser Fe application in the second season with conventional management, but this did not affect the fruit concentration.

Table 6. Macronutrients concentrations in the leaves and fruits of the 'Rojo Brillante' persimmon cultivated by conventional or organic management in two harvest seasons.

	Fe (ppm)	Mn (ppm)	Zn (ppm)			B (ppm)
Leaves						
Management (M)						
Conventional	55.97	271.09 ^{b}		-		53.87
Organic		340.46 ^{a}		-		
Season (S)						
1	67.88 ^{a}	305.78		-		53.87
2	44.06 ^{b}			-		
M × S	-	-		CV	OR	-
			S1	9.69 ^{c}	58.6 ^{a}	
			S2	11.46 ^{c}	47.58 ^{b}	
Significance						
M	NS	**		***		NS
S	***	NS		NS		NS
M × S	NS	NS		**		NS
Fruits						
Management (M)						
Conventional	4.64	5.10		3.50 ^{b}		15.17
Organic				5.08 ^{a}		
Season (S)						
1	4.64	5.10		5.05 ^{a}		11.74 ^{b}
2				3.53 ^{b}		18.60 ^{a}
M × S	-	-		-		-
Significance						
M	NS	NS		**		NS
S	NS	NS		**		*
M × S	NS	NS		NS		NS

Significant correlation at $p \leq 0.05$ (*), $p \leq 0.01$ (**), and $p \leq 0.001$ (***). NS, not significant. M × S represents the interaction of factors. The means followed by different letters significantly differ ($p \leq 0.05$).

Despite the lower Mn and Zn applications in the organic plots than in the conventional ones, higher concentrations of these elements in leaves were found for organic management (Table 6). It has been reported that higher organic matter content in organic farming can lead to better micronutrients assimilation compared to in conventional cultivation [30]. Moreover, in the organic crops, fungicide products based on Mn and Zn were applied at three different times in the warmest months (July–September). Despite the main purpose not being fertilization here, these applications could have also increased the concentrations of these micronutrients in organic leaves. The leaf Mn concentrations came close to the optimal values range in all cases (168.32–338.54 ppm), according to Morales et al. [26], while the Zn concentration in the conventional leaves was below the established optimal values (28.75–44.10 ppm). In fruit, no influence of the crop system on the Mn concentration was observed, while a lower Zn concentration was obtained in conventional farming compared to in organic farming. Cardoso et al. [11] also reported higher Zn content in the organic 'Rama Forte' persimmon fruit than its conventional counterpart. In their case, however, Zn sulfate was added to the organic plantation.

B was applied only to the conventional crops. However, a similar B concentration was found for the two management systems and also for both leaves and fruits (Table 6), which indicates a better assimilation of this micronutrient in the organic plots. Moreover, differences in the fruit B concentration were detected between seasons despite the similar amount of B applied in both years.

3.3. Fruit Physico-Chemical Parameters

In both seasons, fruits were harvested in October, when they reached their maximum weights and in the commercial maturity stage with homogeneous coloration. The crop system did not affect fruit weight during either season, although fruits were lighter in the second season (Table 7). Regarding the external color for both studied seasons, the fruits from organic farms showed higher coloration values, and differences between seasons were also observed (Table 7). Low N availability during the growing season often results in small-sized fruit, but with better coloration [31,32]. For some persimmon cultivars, high N supply is reported to delay external fruit coloration [33–35]. Thus, in the present study, the smaller fruit size and their more advanced coloration in the second season could be related to lower N supply (Table 2). In addition, the differences in fruit color between crop systems could also be explained by the lower N supply in the organic compared to in the conventional crop.

Table 7. Weights, color indices (CIs), firmness values, and total soluble solids contents (TSS) of the Rojo Brillante' persimmon grown by conventional and organic managements in two harvest seasons.

		Weight (g)	CI	Firmness (N)	TSS (°Brix)
Management	Conventional	216.94	0.54 [b]	51.92 [a]	15.05
	Organic		0.85 [a]	47.31 [b]	
Season	1	250.05 [a]	0.42 [b]	52.42 [a]	15.05
	2	183.83 [b]	0.96 [a]	46.80 [b]	
Significance	Management (M)	NS	**	***	NS
	Season (S)	***	***	***	***
	M × S	NS	NS	NS	NS

Significant correlation at $p \leq 0.01$ (**), and $p \leq 0.001$ (***). NS, not significant. M × S represents the interaction of factors. The means followed by different letters significantly differ ($p \leq 0.05$).

Fruit firmness is one of the most important quality parameters for 'Rojo Brillante', which is commercialized with a crisp texture. A strong negative correlation is known to exist between persimmon skin color and flesh firmness. This fact allows fruit firmness to be predicted from external color as a nondestructive measurement [36,37]. Thus, according to the obtained results of fruit external color, the firmness of the second season was slightly lower than for the first one. In addition, the organic fruit firmness was lower than for the fruit from the conventional plots during both seasons (Table 7). For both management types, however, firmness values were considered high enough to be commercialized [36]. Fruit softening is generally associated with the dissolution of the middle lamella and with changes in the composition, structure, and linkages between cell wall polysaccharides [38]. Ca seems to be associated with flesh firmness, because it is related to cell wall consistency by interacting with pectins to form a cross-linked polymer network that increases mechanical strength [39,40]. Accordingly, the higher firmness values observed in the present study for the conventional crop in the first season were accompanied by the higher Ca concentration in those fruits (Table 5). These results agree with our previous studies, in which a positive correlation of the Ca concentration and fruit firmness appears for 'Rojo brillante' persimmon [12]. Liu et al. [39] found positive effects on Ca treatment for maintaining cell wall structure integrity and for, thus, maintaining high 'Youhou' persimmon fruit firmness values.

The TSS content was not affected by either management system (Table 7). With persimmon, it is known that changes in fruit color and firmness occur during fruit maturation and are accompanied by slight variations in TSS content [36]. Indeed, TSS content is not considered a good maturity index for 'Rojo Brillante' persimmon.

3.4. Fruit Biocomponents Characterization

Different studies have been carried out to address the effect of production management on final fruit quality in different crops; however, the information available to support the idea that organic farming results in fruit with higher bioactive compounds than those conventionally produced is inconsistent [11,41,42].

In the present study, biocomponents characterization in the fruits grown according to conventional and organic practices was made in the second year. Of the studied organic acids, only malic acid, which is predominant in persimmon, was influenced by crop management, with a higher concentration in the fruits from the organic than the conventional plots (Table 8). The data available in previous reports on conventional and organic fruits do not allow us to conclude about a clear effect of the cultivation system on organic acids [43].

Table 8. Biocomponents concentrations in the 'Rojo Brillante' persimmon fruit cultivated by conventional or organic management.

Group	Compound	Management	
		Conventional	Organic
Organic acids (mg 100 g^{-1})	Malic	177.5 ^{b}	239.1 ^{a}
	Citric	164.8 ^{a}	161.7 ^{a}
	Succinic	97.4 ^{a}	87.5 ^{a}
	Fumaric	8.3 ^{a}	8.0 ^{a}
Individual sugars (g kg^{-1})	Sucrose	99.8 ^{a}	100.2 ^{a}
	Glucose	31.0 ^{a}	37.3 ^{a}
	Fructose	22.3 ^{a}	27.9 ^{a}
Carotenoids (µg 100 g^{-1})	β-carotene	91.0 ^{a}	115.0 ^{a}
	β-cryptoxanthin	373.6 ^{b}	581.3 ^{a}
	Violaxanthin	0.6 ^{a}	0.6 ^{a}
	Lutein	4.2 ^{a}	4.7 ^{a}
	Zeaxanthin	37.1 ^{a}	43.5 ^{a}
Phenolics (mg 100 g^{-1})	Gallic	2.2 ^{a}	2.2 ^{a}
	p-coumaric	0.32 ^{a}	0.34 ^{a}
Ascorbic acid (mg 100 g^{-1})		8.5 ^{b}	10.4 ^{a}

The means followed by different letters significantly differ ($p \leq 0.05$).

Sugars are one of the main constituents of taste in fruit [41]. The predominant sugar in this study was sucrose, followed by glucose and fructose, with values falling within the range previously reported for 'Rojo Brillante' persimmon (Table 8) [20,44]. A marked variability of the relative sucrose abundance in relation to other sugars has been reported in persimmon [44]. No influence of crop management on sugars was found, although slightly lower values were obtained in the conventional plots than in the organic ones.

Carotenoids are the major pigments present in persimmon fruit and contribute to both color and the nutritional value [45]. The individual carotenoids detected in persimmon flesh were β-carotene, β-cryptoxanthin, violaxanthin, lutein, and zeaxanthin (Table 8). β-cryptoxanthin was the main carotenoid, while violaxanthin came at the lowest concentration. This falls in line with the findings reported for most persimmon cultivars [20,45]. β-cryptoxanthin displayed higher concentrations in the fruits from the organic crop than from the conventional one, but no differences were observed for the other identified carotenoids between farming systems. In 'Rama Forte' persimmon, no differences were reported in the contents of certain carotenes (β-carotene and lycopene) between organic and conventional fruits [10]. For mandarin juice, Navarro et al. [46] revealed that organic farming has a positive effect on the total carotenoids content, with significantly higher concentrations for most of the identified carotenoids. However, this effect of organic farming on the different carotenoid biosynthesis was not proposed.

Phenolic compounds play important physiological roles in human health such as antioxidant, antimutagenic, and antitumor activities [47]. In the present study, gallic acid and ρ-coumaric acid were the main detected phenolic compounds (Table 8), which agrees with previous reports on persimmon [45,47]. Crop management did not influence the contents of these metabolites. Some studies have reported a higher concentration of phenolic compounds in organic fruits compared with in conventional fruits. This is related to lack of synthetic pesticide application in organic systems, which would induce an increase in plant defense mechanisms, such as the synthesis of phenolic compounds [41,48]. However, this aspect was not considered in the herein evaluated plots.

Ascorbic acid (vitamin C) is one of the essential nutritional attributes in fruit crops that is linked with several fundamental metabolic functions in the human body, including the stimulation of the immune system [48]. Many studies have indicated that fruits from organic crops have higher vitamin C contents than those from conventional crops. Other research works have found minor or no differences in vitamin C content in the fruit grown according to these two systems [9]. In the present study, the organic crop fruits obtained higher ascorbic acid values than the conventional fruit (Table 8). Similarly, strawberry, tomato, and mandarin [46,49,50] grown by organic management exhibited higher vitamin C contents than those grown by conventional practices. Nevertheless, in 'Rama Forte' persimmon, Cardoso et al. [10] found more vitamin C content in conventionally produced fruits than in those organically cultivated.

In the present study, the highest vitamin C values detected in the organic crops could be related to a small amount of N applied with this management. Previous studies have reported that N fertilizers applied at low rates tend to increase the vitamin C content in many fruits and vegetables. This is because low N availability induces the biosynthesis of non-nitrogen-containing compounds, such as ascorbic acid [51,52].

4. Conclusions

This study provides new information about the mineral and nutritional compositions of 'Rojo Brillante' persimmon grown by organic and conventional management systems. The biggest yield was obtained in the conventional crop and was attributed to the higher fertilization rate in this system. Nevertheless, the evaluation of the agronomic efficiencies of the main macronutrients indicated that organic management offered higher use efficiencies of the applied fertilizers than the conventional crop, which is very interesting for the more sustainable use of key nutrients for plant production.

Although a greater N input was supplied in the conventional plots than in the organic plots, the leaf N concentrations fell within the optimal range established for 'Rojo Brillante' persimmon in both crop systems, which corroborate more efficient N use in organic fertilization compared to in conventional fertilization.

The greater macro- and microelements supplied in the conventional system compared to in the organic system did not imply higher concentrations of these elements in leaves and fruit. A similar concentration was observed for P, K, Fe, and B in both management systems, and the highest concentrations for Mn and Zn were found in the organic plots. In addition, the optimum ranges for the leaf concentrations detected in general in both crop systems indicated that adequate fertilization was performed for both managements, as well as the important role of organic matter in favoring nutrient assimilation.

More advanced fruit color and lower firmness values were obtained in the organic fruit compared to those conventionally grown, which is related to the lowest N input in the organic crop. In addition, the higher Ca concentration in the conventional fruit flesh was linked with the highest firmness values for this fruit. The influence of crop management on the fruit biocomponents concentrations was noted only for malic acid, β-cryptoxanthin, and ascorbic acid, which were higher in the organic fruit than in the conventional fruit.

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