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Leaf and Fruit Nutrient Concentration in Rojo Brillante Persimmon Grown under Conventional and Organic Management, and Its Correlation with Fruit Quality Parameters

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Abstract: This study aimed to evaluate the concentrations of the main macroelements in leaves and fruit grown following organic and conventional practices, and to relate them to physico-chemical parameters during commercial fruit harvests. Three samplings were carried out during fruit maturation. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were determined in leaves and in two fruit flesh areas: basal and apical. Weight, color, firmness, soluble tannins (ST), and total soluble solids (TSS) were also evaluated in fruit. During the study period, the lowering leaf N concentration was accompanied by its increment in flesh. Leaf P and K lowered but did not imply changes in these concentrations in fruit. N, P, and K concentrations were higher in the apical area than in the basal flesh. No changes in Ca concentration occurred in leaf, but Ca translocation from the basal to the apical area was detected in fruit. Management affected the concentrations of leaf K and Mg and the fruit N, P and Ca. The agronomic efficiency of the macronutrients in the organic crops was superior to that in the conventional crops. The Ca and Mg and the N/Ca and Ca/(K+Mg) ratios were closely related to color, firmness, TSS, and ST content.

Keywords: Diospyros kaki Thunb.; leaf and fruit nutrients; macronutrients; organic farming; fruit quality attributes

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1. Introduction

In Spain, persimmon production has increased exponentially in the last 20 years from 2474 to 17,601 ha [1]. Nowadays with production exceeding 400,000 tons, Spain has become the world's second largest persimmon producer after China [2] and is the largest persimmon supplier worldwide with 46% of global exports. The main persimmon production area lies in eastern Spain, the Valencian Community, where production centers on the Rojo Brillante cultivar.

Persimmon is native to temperate zones and the fruits reach their full color about four months after the end of flowering in June [3]. The commercial maturation period for persimmon is relatively limited, and can vary from September to December, depending on the stage of the fruit, location, and market demands. This variety presents a fall of leaves from the end of November [4]. The fact that the Rojo Brillante persimmon is harvested without having undergone over-ripening, which eliminates its astringency in a natural way, requires it to be subjected to a postharvest deastringency treatment with a high CO_2 concentration, which enables astringency to be eliminated while maintaining fruit firmness. The introduction of this treatment has allowed a quality product to be obtained that is in high demand by national and international markets [5].

The relation between leaf and flesh fruit mineral concentrations and fruit quality has been well documented in some species like apple, orange, and cherry [6–8]. Nevertheless, information about nutritional persimmon requirements and nutritional management to obtain high quality fruit is available, but scarce. Most studies have been carried out about non-astringent Fuyu. Clark and Smith [9] investigated the seasonal changes in the composition and distribution of mineral nutrients in this cultivar. George et al. [10] reported some information about Fuyu growth requirements in Australia. The effect of different nitrogen (N) applications on fruit characteristics and tree production in Fuyu has been studied in Korea [11–14].

Previous reports for persimmon and other fruits indicate that some nutrient concentrations can vary between different areas of the fruit [9,15]. The influence of some macronutrients on the browning of blossom ends that affects Fuyu persimmon has been related to the Ca/(K+Mg) ratio in this flesh fruit area [16]. Ferri et al. [17] found a beneficial effect of applying calcium nitrate and calcium chloride on preventing skin cracks, grooves, and browning of Fuyu persimmon. The "top rot" disease, which affects some cultivars like Gongcheng in China, has been correlated with calcium (Ca) deficiency [18]. In Rojo Brillante, there are no references about the relation between the concentration of the main nutrients and fruit quality parameters. Evaluating nutrition accumulation dynamics in fruit is an interesting strategy for improving nutrient balances and fruit quality [19].

Moreover, it is well-known that applying a different fertilizer type with organic or conventional management will affect plant material composition [20]. Organic agriculture, as an alternative to conventional crop systems, involves the use of mowed or tilled cover crops, animal manures, composts, and the application of organic fertilizers that increase soil-organic matter and provide a steady release of nutrients to the crops as the organic matter breaks down [21]. Conversely, excessive fertilizer rates on conventional crops can led to environmental pollution and biodiversity loss [22].

The effect of these fertilizers on the nutritional composition of several species has been addressed in some studies [20]. Research has compared the nutrient status of fruit and vegetables from organic and conventional production [23–25]. The most widely evaluated produces are carrots, green-leaf vegetables, potatoes, and apples, but the obtained results were not consistent in many cases. In persimmon, no studies have been carried out to compare fruit nutritional concentrations from organic and conventional farms. Nevertheless, in Spain, although most persimmon plots respond to conventional agriculture practices, persimmon production performed by organic farming practices has increased the total organic production in the Valencian Community up to 16% in recent years [26].

In this context, the objective of this study was to analyze the concentrations of the main macroelements in the leaf and flesh of the fruit grown following organic and conventional practices, and to relate them to the physico-chemical parameters associated with fruit quality during commercial fruit harvests. This information could help to carry out adequate nutrition management to achieve better fruit quality.

2. Materials and Methods

2.1. Experimental Conditions and Plant Material

The study was conducted on Rojo Brillante persimmon in six orchards 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. Three plots were organically managed in the last 10 years, and three plots were conventionally managed.

The climate is semi-arid Mediterranean with average rainfall of 499 mm yr^{-1} that concentrates in autumn and spring. The soil characteristics of both growth management systems are shown 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
MO (%)	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] P_{Olsen}: available phosphorus; [2] sse: soils saturation extract.

The plantation was established with spacing of 5 m × 4 m in the conventional and organic orchards. Trees were drip-irrigated with four commercial emitters per tree (4 L h^{-1}) to obtain an approximate 33% wetting area at a depth of 20 cm, according to Keller and Karmelli [27]. The amount of water applied to each tree was equivalent to the total seasonal crop evapotranspiration (ETc) [28]. The volume of water applied weekly to each tree was calculated using the expression:

$$ETc = ETo \times Kc \quad (1)$$

where ETc is crop evapotranspiration, ETo is the reference crop evapotranspiration under standard conditions, and Kc is a crop coefficient. ETo was determined using the Penman–Monteith method, as described by Allen et al. [29]. Kc was based on the information described by Castel and Buj [30], which accounts for crop-specific effects on overall crop water requirements in accordance with canopy size and leaf properties. The fertilization plans of the evaluated orchards are described in Table 2.

Table 2. Nutrient fertilization on the studied crops.

Management	Chemical Compound (kg $year^{-1}$ ha^{-1})					
	N	P_2O_5	K_2O	CaO	MgO	FLUIDOGAMA® [1]
Conventional	170	74	155	0.0	0.0	0.0
Organic	27	1	27	0.5	0.0	840

[1] Organic product with 2.8% organic N, 3.1% K_2O, and 40% organic matter.

2.2. Plant Sampling and Sample Preparation

In each plot, 12 trees, four trees as one replicate, were previously marked to subsequent foliar samplings and fruit collection.

During the 2019 commercial harvest period, three leaf and fruit samples were taken from each replicate on 16 October, 7 November, and 12 December.

Foliar sampling was carried out by taking eight leaves from the summer flush leaves of each tree, with the third or fourth leaf from the axilla of reproductive sprouting, placed in the four orientations. In addition, 36 fruit per repetition were collected by taking nine fruit from each tree from the same reproductive sprouting.

Samples were taken to the Valencian Institute for Agricultural Research (IVIA), where leaves were cleaned with non-surfactant soap to eliminate any possible residue that was still attached. Next, they were rinsed with deionized water, dried, chopped, and placed in an oven for two to three days at 60–65 °C to dry. They were then ground in a water-refrigerated mill (IKA M20, IKA-Werke GmbH & Co. KG, Staufen, German) and stored in falcon tubes (Sarstedt, Numbrecht, Germany) at 4 °C pending further analyses. On fruit, physico-chemical determinations were made, and samples were taken to determine the macro- and microelements in pulp. For this purpose, fruit were cut longitudinally into four parts. Two opposite parts were taken, which were subdivided into two zones: basal and apical half (Figure 1). These fractions were peeled and cut into smaller pieces to facilitate drying. They were placed inside an oven at 60–65 °C for three to four days.

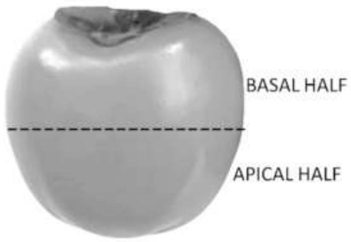

Figure 1. Sketch of the two persimmon fruit parts used for sampling.

2.3. Nutrient Determinations

The total nitrogen (N) concentration of the leaf and fruit flesh fractions was determined by the semi-micro Kjeldahl method [31] with a Tekator still (Tecator Kjeltec 8200, FOSS IBERIA, S.A., Barcelona, Spain). The determination of the phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) concentrations was made in the vegetal material obtained by an open-vessel process. This involved the overnight predigestion of half a gram of dried plant material with 10 mL of concentrated HNO_3, followed by digestion at 120 °C, and then previously cooling to add 2 mL of ultratrace metal-grade 70% $HClO_4$, and a final digestion at 220 °C until white fumes were produced. The thus obtained digest was diluted with 25 mL of ultrapure water prior to nutrient determination by simultaneous inductively coupled plasma-atomic emission spectrometry (ICP-AES 6000, Thermo Scientific, Cambridge, UK). The results were expressed as a percentage of dry weight (DW).

2.4. Determination of Physico-Chemical Parameters

The weight, external color, and firmness of the pulp were individually measured on 20 fruit. Each fruit's individual weight was determined on a digital scale (model PB3002-S/FACT, Mettler 85 Toledo, Switzerland). External color was evaluated with a portable colorimeter (Minolta, mod. CR-400, Ramsey, NY, USA) by taking two measurements per fruit on the opposite sides of the equatorial zone. The results were expressed as Color Index (CI = 1000.a/L.b) [32].

Firmness was evaluated with a texturometer (Instron Corp., mod. 4301, Canton, MA, USA), provided with an 8 mm diameter punch. Two measurements per fruit were taken on the opposite sides of the equatorial zone without skin. The results were expressed as the force in Newtons (N) needed to break pulp.

Soluble tannins (ST) were determined on lots of 15 fruit per treatment, divided into three samples of five fruit. Samples were cut into four longitudinal parts, and two opposite parts were peeled, sliced and frozen at −20 °C to be later evaluated by the Folin–Denis method described by Arnal and Del Río [3]. The results were expressed as a percentage of fresh weight (FW).

The other two opposite fruit parts were used to analyze total soluble solids (TSS). Samples were placed in an electric juice extractor and the filtered juice was used to measure TSS content with a digital refractometer (model PR-1, Atago, Japan). The results were expressed as ^{0}Brix.

2.5. Agronomic Efficiency

To calculate the agronomic efficiency of the main macronutrients, fruit yield per hectare was divided by the amount of each nutrient in kg ha^{-1} applied to each management system. The values were expressed as kg of fruit yield per kg of applied nutrient.

2.6. Statistical Analysis

The statistical analysis was carried out using the Statgraphics Centurion XVII.I software application (Manugistics Inc., Rockville, MD, USA). Data of the macronutrients and fruit quality parameters were subjected to analyses of variance (ANOVA) and multiple comparisons between means at $p \leq 0.05$, as determined by the LSD (Least significant difference) test. A two-way ANOVA was performed by analyzing the effect of the harvesting date and crop management for each leaf nutrient concentration and for each fruit physico-chemical parameter. A three-way ANOVA was performed for the fruit nutrient concentration by analyzing the effect of the three factors (harvesting date, crop management, and fruit part) per nutrient.

A correlation matrix was made to evaluate the strength and direction of the relation between nutrients and fruit quality. The correlation matrix showed the Pearson correlation values, which measured the degree of the linear relation between each pair of elements or variables.

3. Results and Discussion

3.1. Macronutrients in Leaf and Flesh Fruit under Conventional and Organic Management

3.1.1. Macronutrients Concentration in Leaves and Fruit

The leaf nitrogen (N) content obtained values around 1.5% in October (Figure 2A), and this significantly lowered during harvests with values of 1.1% in December (Table 3). Although the N concentration was slightly lower in the leaves from the organic vs. the conventional plots, the differences were not significant. In fruit flesh, the N concentration increased in both measured areas as harvest advanced (Figure 2B). In the apical area, N contents were higher than in the basal area for both management systems. The plot management influence was observed mainly in November and December, with a higher N content in the organic vs. the conventional fruit.

The leaf P concentration significantly lowered and ranged from 0.14% in October to 0.08% in December (Figure 2C). For this element, there were no significant differences between the leaves from the organic and conventional managements during the three sampling events (Table 3). On the three study dates, the P concentration in flesh fruit was significantly lower in the basal area than in the apical area (Figure 2D). In October, average values of 0.06% were detected in the basal flesh, while the concentration in the apical flesh came close to 0.10%, with no differences between the two managements. No major changes were noted during the following harvest. However, in December, the P concentration lowered in the apical area of the conventional cultivation fruit, while it rose in the basal area of the fruit from both management systems.

The K concentration lowered in leaves from October to December, which followed the tendency of the other mobile evaluated macro-elements (Table 3). However, unlike that observed for N and P, the K content in the leaves from the conventional plots was always higher than that from the organic plots (Figure 2E). In conventional crops, the leaf K concentration lowered from 1.3% in October to 0.9% in December, while the values in organic plots went from 1.0% in October to 0.5% in December. In fruit flesh, a higher K concentration in the apical area was found, with values around 0.7% in the basal flesh and 1.0% in the apical flesh in October, which revealed a variation throughout the study period. In both areas, no important differences were observed between managements (Figure 2F).

The Ca concentration in leaves was not affected by management and remained stable during harvests, with average values of 4.45% (Figure 2G) (Table 3). In the fruit harvested in October, a much higher Ca concentration was observed in the basal area (values close to 0.05%) than in the apical area (close to 0.01%) (Figure 2H). In November, the Ca content in the basal flesh significantly lowered, but increased in the apical flesh. Even so, this concentration in the apical area remained lower than in the basal area. In December, the Ca content of the basal flesh dropped to similar values to those for apical flesh, while the apical flesh values were similar to those obtained in November. During harvests, Ca content was higher in the fruit from the conventional plots vs. the organic plots.

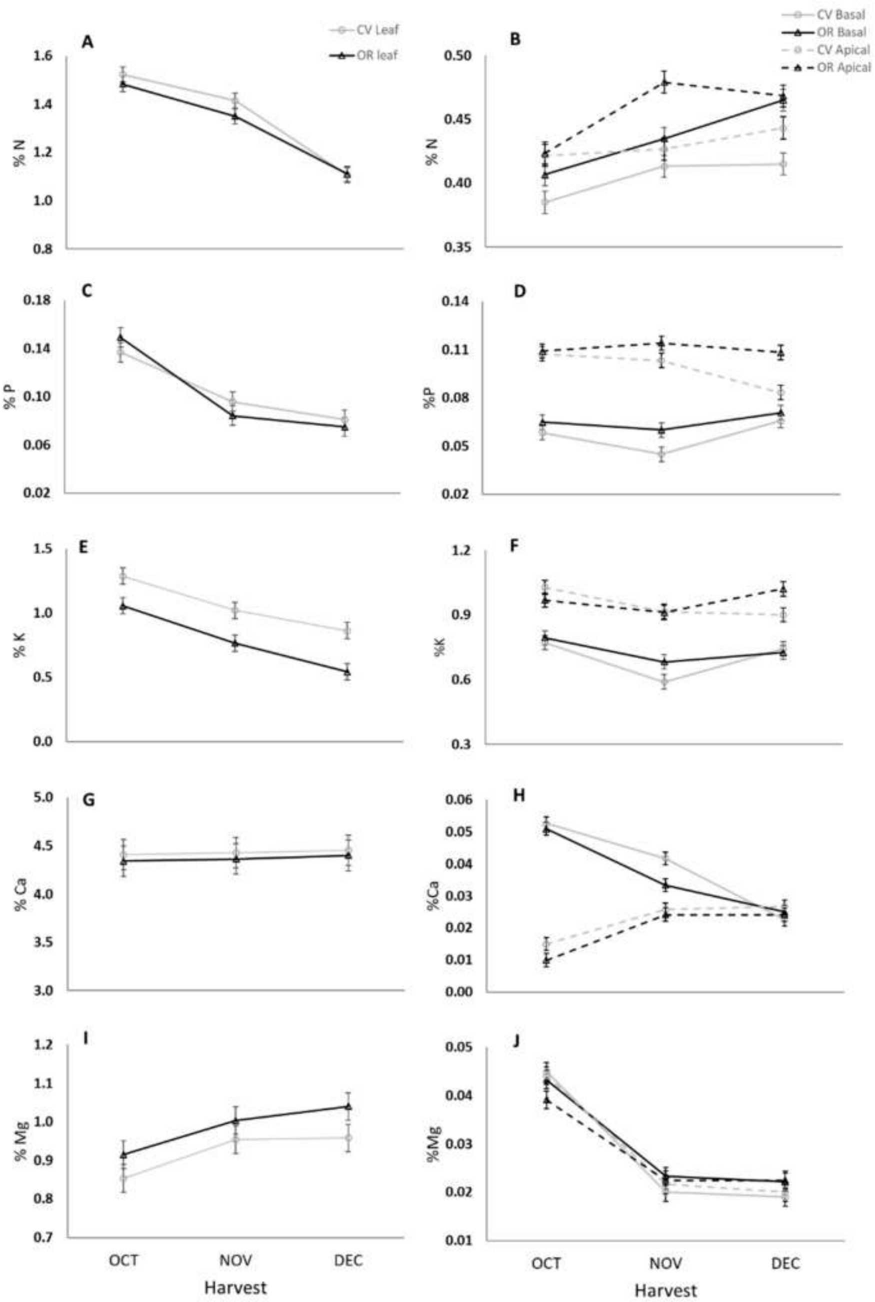

Figure 2. Macronutrient concentration in leaves (**A**,**C**,**E**,**G**,**I**) and in two fruit flesh areas (basal half and apical half) (**B**,**D**,**F**,**H**,**J**) during commercial Rojo Brillante persimmon maturation (October to December) cultivated under conventional (CV) or organic (OR) management. Vertical bars represent the Least Significant Difference (LSD) intervals ($p \leq 0.05$).

The Mg content in leaves gradually increased throughout the study period. The leaves from the organic plots obtained higher values than those from the conventional plots (Figure 2I and Table 3). In October, the Mg concentration values in both fruit flesh parts came close to 0.045%, with no differences between conventional and organic management (Figure 2J). A marked reduction took place in November, but the concentration remained unchanged until December with average values around 0.021%.

The values of the macronutrients found in persimmon leaves and fruit flesh fell within the range of those reported in previous analyses for other varieties, such as Fuyu, Hachiya, and Costata [9,13,33–35]. In the present study, the reduction in the leaf N, P, and K concentrations from October to December would indicate a progressive stop in nutrient uptake from soil, while the remobilization of the nutrients of this organ would continue before leaf senescence [36].

Table 3. Analysis of variance (ANOVA) results for each factor in macronutrient concentration in leaf and fruit.

	Significance					
		N	**P**	**K**	**Ca**	**Mg**
Leaf	A: Harvest	0.000 *	0.000 *	0.000 *	ns	0.004 *
	B: Management	ns	ns	0.000 *	ns	0.030 *
	AB:	ns	ns	ns	ns	ns
Fruit	A: Harvest	0.000 *	ns	0.000 *	0.000 *	0.000 *
	B: Management	0.000 *	0.000 *	ns	0.019 *	ns
	C: Fruit Part	0.000 *	0.000 *	0.000 *	0.000 *	ns
	AB:	ns	ns	ns	ns	0.034 *
	AC:	ns	0.000 *	ns	ns	ns
	BC:	ns	ns	ns	ns	ns
	ABC:	ns	ns	0.018 *	ns	ns

Factor A: Harvest moment (October, November and December); Factor B: Crop Management (Conventional and Organic); Factor C: Fruit Part (basal half and apical half); AB, AC, BC, and ABC represent the interaction of the factors. No significance ("ns") or the actual P-value when significant (*) ($p \leq 0.05$).

In the conventional crops, as many minerals like N, P, and K are widely used in the form of soluble chemical fertilizers, a higher quantity of the available minerals can be expected in conventional products than in organic alternatives [23]. Although the input of these three elements was higher in the conventional plots in the present study (Table 2), in leaves only a higher K concentration was exhibited from the conventional plots compared to the organic ones. Regarding P, organic material application can lower the rhizosphere pH to favor the most available form of P [36,37], which is explained by the similar P concentrations in the leaves from both studied crop systems (Figure 2C) despite the lack of this nutrient's fertilization in organic cultivation.

The influence of crop management on nutrient concentration proved to depend on different factors, such as evaluated species, cultivar, and the nutrient [23,38]. Moreover, the effect of management was studied mainly on the leaf nutrient status, and very few works can corroborate the results obtained in the fruit.

Leaf N, P, and K mobility would not imply increased macronutrient concentration in fruit because these elements possibly move to other reserve organs, such as stems, branches, and roots, before leaves fall [39]. Therefore, in this study, only an increase in the N concentration was observed in fruit, while a decrease occurred in leaves.

The differences found in leaf N, P, and K between the two management systems were not reflected in fruit. Indeed, the fruit N and P concentrations were higher in the organic than in conventional plots, and no differences appeared for the fruit K concentration.

N and K are the two nutrients that fruit accumulate in the largest amounts, which indicates a higher demand for these nutrients, as shown by other research into crops like orange, kiwifruit, and tamarillo [40–42]. According to Tagliavini and Scandellari [43], K is often the most represented mineral nutrient in well-developed flesh fruit, where it acts as osmoticum for the transport and storage of sugars and water in fruit.

Very few studies have investigated nutrient distribution in different persimmon fruit parts, and those that have focused mostly on seeking a relation between nutrient distribution and fruit disorders [9,16,44]. In the present study, significant differences were found in the N, P, K, and Ca concentrations between fruit basal and apical parts (Figure 2B,D,F,H). These differences were also observed for N and K by Clark and Smith [9], who found higher concentrations for these elements in the apical part of persimmon cv. Fuyu. However, they also noted that these differences in the K concentration decreased over time, an effect that was not herein observed.

On average, Ca and Mg presented much higher concentrations in leaves than in fruit parts. The Ca concentration was approximately 130-fold higher, and the Mg concentration was up to 30-fold higher in leaves than in fruit. Both nutrients abound more in leaves in most crops because they are not very mobile elements [43,45]. Ca movement in trees takes place mainly through the xylem, a circumstance for which Ca is not easily mobilized from old leaves during senescence [36]. Although the leaf Ca concentrations remained stable during the sampling period in the present study, a translocation of this element from basal to apical flesh occurred during the study period, which indicates the mobility of this element inside fruit.

The general drop in the Mg concentration in fruit flesh recorded during harvest period has also been reported in some studies for Fuyu persimmon [33] and has been observed in other fruit, such as pomegranate and medlar [46,47].

3.1.2. Correlation between Macroelements

A simple linear correlation among the nutrients measured in both leaves and fruit was performed (Table 4). Leaf N, P, and K concentrations positively correlated with one another, while a negative correlation appeared between K and Mg. In several crops, a positive interaction between N and P has been described [48–51]. The implicated mechanisms are not well understood, although Wilkinson et al. [51] suggest that N can increase P uptake in plants by increasing root growth and their capacity to uptake and translocate P. In a comprehensive review of the effect of antagonisms and synergism between nutrients, Rietra et al. [50] showed a synergism between N and K fertilization that depended on the applied dose of N and K fertilization.

The depressing effect of K on plant Mg uptake has been frequently reported and can be explained as a result of competition for metabolically produced binding compounds [50,52]. The negative correlation herein found between leaf Mg and K concentrations has been previously explained by the antagonism that exists between those cations [53].

For fruit flesh, no correlations were found among N, P, and K measured in the apical or basal flesh areas. However, the fruit Ca concentration appeared to correlate negatively with the N concentration and positively with the Mg concentration in both these parts. The different mobility of these elements in plants from leaves to fruit could lead to an antagonistic effect between Ca translocation in fruit with high N concentrations. However, as Mg and Ca present similar mobilization, the greater absorption of one of them could increase the assimilation of the other in fruit without causing any significant interactions of these nutrients in leaves.

Some significant correlations were found among the nutrients of the flesh basal and apical areas. The Mg of the apical area and the Ca and Mg concentrations of the basal area positively correlated.

While considering the correlations among the nutrient concentrations in leaves and fruit flesh, a negative correlation between K in leaves and N in flesh of both areas was shown, while a positive correlation appeared between Mg in leaves and N in both fruit parts.

Moreover, a positive correlation between Ca in the fruit basal area and N, P, and K in leaves was detected. Mg in leaves was negatively correlated with Ca in the basal flesh area. These same correlations were also observed in the fruit apical area, but inversely so.

Table 4. Simple correlation coefficient between the macronutrients in leaves and fruit parts under conventional and organic management.

Organ	Element	Leaf					Fruit Basal Area					Fruit Apical Area				
		N	**P**	**K**	**Ca**	**Mg**	**N**	**P**	**K**	**Ca**	**Mg**	**N**	**P**	**K**	**Ca**	**Mg**
Leaf	N															
	P	0.701 *														
	K	0.777 **	0.670 *													
	Ca	−0.413	0.202	−0.164												
	Mg	−0.515	−0.432	−0.772 **	0.329											
Fruit basal area	N	−0.458	−0.477	−0.815 **	0.237	0.919 ***										
	P	−0.404	−0.036	−0.439	0.633	0.457	0.554									
	K	0.277	0.203	0.205	0.157	0.308	0.201	−0.198								
	Ca	0.827 ***	0.805 **	0.844 ***	−0.127	−0.749 **	−0.733 *	−0.306	−0.034							
	Mg	0.385	0.706	0.566	0.431	−0.468	−0.455	0.214	−0.066	0.712 ***						
Fruit apical area	N	−0.523	−0.614 *	−0.808 **	−0.116	0.617 **	0.679 *	0.353	−0.448	−0.612 *	−0.454					
	P	0.475	0.29	0.122	−0.292	−0.072	−0.112	−0.287	−0.090	0.509	0.198	0.554				
	K	0.120	0.264	0.168	0.515	-0.038	0.062	0.434	0.088	0.301	0.521	0.201	-0.198			
	Ca	−0.542	−0.812 **	−0.285	−0.346	−0.088	−0.048	−0.152	−0.417	−0.505	−0.568	−0.733 *	−0.306	−0.034		
	Mg	0.599	0.723	0.659	0.247	−0.520	−0.511	−0.005	−0.010	0.878 *	0.894 **	−0.455	0.214	−0.066	0.712 *	

Significant correlation at $p \leq 0.05$ (*), $p \leq 0.01$ (**) and $p \leq 0.001$ (***).

From an agronomic point of view, the relation between elements can provide more information about crop nutritional status than the concentrations of individual nutrients [54]. Moreover, the ratio among Ca, K, and Mg is often analyzed because it has been reported that both K and Mg can impede Ca accumulation in some fruit species [54,55]. Therefore, an imbalance between these elements has been related to some flesh disorders developing in persimmon [16]. The N/Ca ratio is widely used to predict fruit storage quality in apple and pear [56]. The Ca/(K+Mg) and N/Ca ratios were herein evaluated (Table 5). The Ca/(K+Mg) ratio obtained for flesh fruit was higher in the basal area than in the apical area and fell within the range found for persimmon cv. Fuyu [16]. In both management systems, a higher N/Ca rate was observed in the apical area than in the basal area of fruit. This ratio in the basal area increased as harvest advanced, while the N/Ca ratio lowered in the apical area, which reveals low Ca mobility in fruit, as well as the importance of N and Ca fertilization for correct fruit postharvest life.

Table 5. Ratios between elements.

Organ	Harvest	Ca/(K+Mg)		N/Ca	
		Conventional	Organic	Conventional	Organic
Leaf	October	2.06	2.20	0.35	0.34
	November	2.24	2.47	0.32	0.31
	December	2.44	2.78	0.25	0.25
Fruit basal area	October	0.06	0.06	7.33	8.00
	November	0.07	0.05	9.92	13.05
	December	0.03	0.03	18.44	18.60
Fruit apical area	October	0.01	0.01	28.11	42.33
	November	0.03	0.03	16.52	19.83
	December	0.03	0.02	16.52	19.38

3.1.3. Agronomic Efficiency of the Main Macronutrients

Some of the major critiques made of organic management indicate that organic yields are generally lower than conventional yields [57]. However, better productivity in conventional farming is achieved through higher demand for mineral nutrition. Therefore, comparing crop productivity to its fertilization rate can provide a better understanding of the efficient use of key nutrients for plant productivity. The yield obtained for conventional management in the present study was higher than that achieved in organic crops (Table 6).

Table 6. Yields obtained in different orchards.

Management	Orchard (m^2)	Yield (kg)/Orchard	Yield (kg)/ha
Conventional	30	174 [b]	44,452 [b]
Organic	40	97 [a]	33,418 [a]

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

The agronomic efficiency of the main macronutrients in this study varied considerably between managements and was superior in the organic system (Table 7). This indicates that despite lower organic cultivation yields, these crops need less fertilization compared to the conventional system.

Table 7. Agronomy efficiency of the main macronutrients in each management system (kg·kg^{-1}).

Management	N	P	K
Conventional	262 [a]	600	286 [a]
Organic	1243 [b]	∞	1227 [b]

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

The agronomic efficiency of a macronutrient can be defined differently according to its application or the variable to be reflected, which can imply a difficulty in comparing the ranks found by different authors. In general, the values observed in China for major conventionally produced fruit crops, including persimmon, are slightly lower than those found herein, with values of 185, 338, and 208 kg kg^{-1} for N, P, and K, respectively [58]. Lin et al. [59] indicated wide variability for these results depending on site and management conditions. These authors also observed better use efficiency for N in organic crops than conventional crops in different mixed farming systems. Studies into organically managed cropping systems indicate that yields comparable to conventionally managed systems can be achieved, while N losses lower significantly [60]. The high mineral fertilization rates applied in conventional systems can reduce use efficiency. This means that when applied N is not completely taken up by plants, it can contribute to environmental problems like air pollution, global warming, groundwater contamination, and eutrophication [58,59].

3.2. Relation between Macroelements and Fruit Quality

Rojo Brillante persimmon is a variety characterized by being large in size upon commercial maturity. In October, maximum fruit weight is achieved, with an average value of 248 and 270 for conventional and organic orchards, respectively (Table 8). This is due mainly to the higher yields obtained under conventional management, which lead to a larger number of lighter fruit [61]. However, the differences observed in fruit weight were not significant. No increment in size occurred during the following harvests, which agrees with the phenological phases described for this variety in Spain [4].

Table 8. Weight, color index (CI), firmness, soluble tannins (ST), and total soluble solids (TSS) of Rojo Brillante persimmon fruit under conventional and organic managements at different harvest times.

Harvest	Management	Weight	CI	Firmness	ST	TSS
October	Conventional	242.37 ^{a}	−1.26 ^{a}	55.05 ^{a}	0.90 ^{a}	13.84 ^{a}
	Organic	257.73 ^{a}	−1.41 ^{a}	50.17 ^{b}	0.85 ^{a,b}	12.73 ^{b}
November	Conventional	251.90 ^{a}	8.54 ^{b}	42.94 ^{c}	0.79 ^{b}	14.42 ^{a,c}
	Organic	268.88 ^{a}	9.12 ^{b}	42.41 ^{c}	0.69 ^{b,c}	14.90 ^{c,d}
December	Conventional	248.98 ^{a}	14.04 ^{c}	36.07 ^{d}	0.61 ^{c}	16.10 ^{e}
	Organic	283.96 ^{a}	13.26 ^{c}	32.96 ^{e}	0.58 ^{c}	15.33 ^{d}
ANOVA	A: Harvest	ns	0.000 *	0.000 *	0.000 *	0.000 *
	B: Management	ns	ns	0.000 *	0.047 *	0.032 *
	A x B	ns	ns	0.007 *	ns	0.009 *

The mean values followed by the same letter in a column do not significantly differ ($p \leq 0.05$). The table of significance shows the full analysis of variance (ANOVA) results for the evaluated parameters. No significance (ns) or the actual *p*-value when significant (*).

The external color of fruit is one of the most widely used parameters as a nondestructive harvesting index given the close relation between skin color and the physicochemical changes that take place during fruit ripening [62]. Color increased significantly as harvest advanced from values close to −1.3, which correspond to a homogenous yellow tone hue during the first harvest, to values close to 14, denoting deep orange tones, during the third harvest, with no differences between managements (Table 8). In most persimmon varieties, harvest takes place when fruit presents a homogeneous external reddish-orange tone with no green background coloration [63].

Fruit firmness gradually decreased with maturation advance during the three harvests, as shown by Salvador et al. [52] for this variety. The fruit firmness from the organic plots was lower than that from the conventional ones (Table 8). In all cases, however, firmness values were optimal from a commercial point of view. Previous reports indicate a strong negative correlation between skin color and flesh firmness, which allows fruit firmness to be predicted from external color as a nondestructive measurement [64,65].

The soluble tannins (ST) concentration in fruit lowered during all three harvests. In all cases, conventional cultivation obtained higher values than the organic crops (Table 8). This descent was due to ST transformation into the insoluble form [66], although the observed reduction was not enough to detect complete astringency loss, which coincides with other studies [62,65]. Rojo Brillante persimmon is an astringent cultivar that requires deastringency treatment prior to fruit commercialization, which reduces the ST concentration to levels close to 0.01–0.02% [62]. TSS content increased during the three harvests, with higher values for the conventional management.

The correlation matrix between nutrients and quality parameters is shown in Table 9. The leaf N, P, and K concentrations correlated positively with firmness and ST, and negatively with color and TSS content, but did not correlate with fruit weight. However, in the basal and apical areas, no significant correlation was observed between the N, P, and K and concentrations and most of the evaluated quality parameters.

Table 9. Simple correlation coefficient between the macronutrients in leaves and fruit parts and fruit quality parameters under conventional and organic management.

Organ	Nutrient	Weight	CI	Firmness	ST	TSS
Leaf	N	−0.404	−0.836 ***	0.834 ***	0.733 **	−0.781 **
	P	−0.204	−0.897 ***	0.807 **	0.704 *	−0.818 **
	K	−0.634	−0.782 **	0.873 ***	0.859 ***	−0.582
	Ca	0.689	0.001	−0.197	−0.304	0.113
	Mg	0.901 ***	0.563	−0.598	−0.794 **	0.325
	N/Ca	−0.604	−0.747 **	0.751 **	0.708 **	−0.649
	Ca/K+Mg	0.649	0.702 **	−0.776 **	−0.716 **	0.529
Basal area	N	0.823 ***	0.588	−0.683	−0.845 ***	0.346
	P	0.721 **	0.237	−0.400	−0.654	0.151
	K	0.192	−0.161	0.188	−0.027	−0.357
	Ca	−0.454	−0.945	0.943 ***	0.879 ***	−0.837 ***
	Mg	−0.293	−0.934	0.898 ***	0.753 **	−0.805 **
	N/Ca	0.518	0.881 ***	−0.869 ***	−0.876 ***	0.782 **
	Ca/K+Mg	−0.385	−0.769 **	0.801 **	0.795 **	−0.745 **
Apical area	N	0.429	0.601	−0.614	−0.652	0.564
	P	0.011	−0.542	0.491	0.410	−0.595
	K	0.274	−0.307	0.226	0.124	−0.361
	Ca	−0.224	0.722 **	−0.574	−0.352	0.752 **
	Mg	−0.276	−0.888 ***	0.829 ***	0.715 **	−0.761 **
	N/Ca	0.157	−0.716 **	0.537	0.349	−0.705 *
	Ca/K+Mg	−0.193	0.765 **	−0.607	−0.385	0.767 **

Significant correlation at $p \leq 0.05$ (*), $p \leq 0.01$ (**), and $p \leq 0.001$ (***). CI: color index; ST: soluble tannins; TSS: total soluble solids.

Previous studies have also reported a negative correlation between leaf N concentration and fruit color and soluble solids, and a positive correlation with flesh firmness, in persimmon [10,53]. These findings indicate that high N supply could delay fruit maturation. In other fruit like kiwifruit and grape, N and K fertilization influences different fruit quality parameters, such as flesh firmness and TSS [67,68]. In Fuyu persimmon, the negative relation between fruit N and soluble solids and color has been related to carbohydrate use during N assimilation [69]. Hence, fruit would not develop an adequate external color when the carbohydrate supply is limited.

No significant correlation was found between the Ca leaf and fruit quality parameters. Nevertheless, the Mg concentration was positively related to weight fruit and negatively to ST.

For macronutrient concentrations in fruit, the correlations with the quality parameters differed depending on the measured flesh area. In the basal area, Ca and Mg correlated positively with firmness, ST, and TSS. In the apical area, positive correlations between Ca and color and TSS were found, while Mg correlated with color, firmness, ST, and TSS. Ca is most important in physiological functions, such as cell division, senescence, and the formation of cell membranes, and its deficiency can negatively affect fruit quality by generating less firmness and affecting its conservation capacity [36,55]. In persimmon fruit, flesh firmness is an important quality parameter at harvest time because it determines postharvest management. Changes in fruit firmness have been related to microstructural changes in flesh during ripening [65].

In other fruit like papaya and apple, a positive relation between Ca and firmness, and a negative correlation between Ca and TSS and color, have been reported [54,55]. Kim et al. [16] studied the relation between fruit disorders and nutrient concentration and found higher Ca concentrations in the basal area of Fuyu persimmon. These authors reported that the low concentrations of this element in apical flesh, or an imbalance in Ca, K, and Mg distribution, might lead to fruit disorders like blossom-end part browning.

The high correlations between the N/Ca and Ca/(K+Mg) ratios of leaves, or the basal flesh area and color, firmness, and ST, are noteworthy. These results show the importance of a balanced fertilization plan. TSS correlated significantly with N/Ca and Ca/(K+Mg) in fruit. In apples, a high N/Ca is usually linked with high TSS, color, and low flesh firmness values [54].

4. Conclusions

This study provides new information about the macronutrient concentration in leaves and different flesh areas during the maturation period of Rojo Brillante persimmon grown under conventional and organic management.

During the study period, the reduction in the leaf N concentration was accompanied by an increase in this element in fruit flesh. Nevertheless, the descent in P and K observed in leaves did not imply changes in fruit concentration, which indicates that these elements possibly move from leaves to other reserve organs during this period. The flesh apical area accumulates higher N, P, and K concentrations than the basal area.

While no changes were found in the leaf Ca concentration during the maturation period, Ca translocation from the basal to the apical area was evidenced in fruit. No differences in fruit Mg levels were found between the two flesh areas, which lowered during fruit maturation.

Organic management led to a lower K concentration and a higher Mg concentration in leaves compared to conventional production. Nevertheless, management did not affect the concentration of these elements in fruit. Although the management system did not influence leaf N, P, and Ca concentrations, lower Ca and higher N and P were detected in the organic than in the conventional fruit.

An interaction among nutrients was revealed by the correlations performed among them. The correlations between macronutrients and quality parameters highlighted that Ca and Mg, and the N/Ca and Ca/(K+Mg) ratios, were closely related to color, firmness, TSS, and ST content. This result reinforces the relevance of balanced fertilization during the growing season to achieve high fruit quality. Nevertheless, further studies are necessary in subsequent growing seasons to profoundly understand the role of each nutrient in persimmon to improve fruit quality. In addition, the determination of other elements would be important to strengthen the findings of this work.

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