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Evaluation of Removed and Recycled Mineral Nutrients in Italian Commercial Persimmon Orchards

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Abstract: Persimmon is a typical fruit crop of the Mediterranean region and, since it is considered a minor species, little information is available on its nutrients need. In the present experiment, it was estimated the quantity of removed and recycled nutrients by Kaki Tipo and Rojo Brillante, the two main varieties of persimmon grown in Emilia-Romagna region (Po Valley, Italy). Plants from ten mature orchards were selected and harvested; organs (leaves in summer, fruits at harvest, abscissed leaves, roots and skeleton) biomass and mineral composition were determined. The yearly uptake of macronutrients was similar for the 2 varieties, accounting for (kg ha^{-1}): N 89-91, P 10-11, K 79-91, Ca 132-162, Mg 22-26 and S 9. While K was mostly found in fruits, Ca and Mg were mainly partitioned to leaves. Among micronutrients, Mn and Fe showed the highest values (1.1–1.3 and 1.2–2.1 kg ha^{-1}, respectively), followed by B (370 g ha^{-1}), while Cu and Zn showed the smallest amounts (less 100 g ha^{-1}). Nitrogen, Ca, Mg and S were those more recycled than removed, while K showed an opposite trend; among the microelements, the annual recycled fractions of B and Mn were higher than that removed.

Keywords: *Diospyros kaki*; fertilization; Kaki Tipo; macronutrients; nutrient remobilization; potassium; Rojo Brillante

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1. Introduction

Persimmon (*Diospyros kaki* Thunb.) is a typical fruit crop of the Mediterranean region, but in Italy it is considered a minor species, being cultivated on an area of less than 2900 ha [1]. The intensive and specialized persimmon cultivation is located mainly in Emilia-Romagna region, where this species finds optimal environmental conditions. Persimmon fertilization management is often based on the knowledge acquired from other major fruit crops such as peach [2], apple [3] and pear [4], while little is known on its nutrient needs. The widespread use of vigorous rootstocks requires careful management of water and nutrients in order to control tree vegetative growth and fruiting. If nutrients supply exceed plants needs it results in an excessive vigour that is known to delay the end of the unproductive juvenile period in young orchards and increases fruit drop in mature ones [5,6]. Furthermore, the improper use of fertilizers increases the risk of water pollution [7,8] with negative impact on surface and ground water quality. An adequate management of fertilization requires the knowledge of soil fertility as well as tree needs in each specific phenological phases, in order to synchronise nutrient supply with plant demand [9]. During the vegetative season part of the nutrients up-taken by roots is allocated to fruits and removed from the orchard at harvest; on the other hand, nutrients partitioned to vegetative organs (shoots and leaves) can be translocated within the tree or return back to the ground through abscissed leaves and pruned wood. The development of a correct fertilization plan should, thus, take into consideration the distribution of nutrients within plant organ, their mobility and availability during the vegetative season. Fertilization should aim at maintaining inputs (fertilizers, crop residues, irrigation water and rain falls) equal to outputs, that include quantities removed with fruits and stored in the perennial organs (skeleton and roots), and lost through erosion, runoff, immobilization and volatilisation.

An effective way to evaluate tree nutritional status is leaf analysis, particularly if done in the summer, that is able to evidence lack or excess of nutrients by comparing results of analysis with appropriate indices obtained in the same area of cultivation. However, currently, there are not leaf indexes for Italian persimmon and usually those from Australia [10,11], Spain [12] and Turkey [13] are used.

The aim of the present investigation was to (1) define summer leaf indexes for Italian cultivation and (2) assess the nutrient requirements of the two main varieties of persimmon grown in Emilia-Romagna Region by estimating the quantities of nutrients removed and recycled.

2. Materials and Methods

2.1. Characteristics of the Orchards Investigated

The study was carried out in 2018–2019 and involved seven farms specialized in persimmon (*Diospyros kaki* Thunb.) cultivation, located in the provinces of Modena, Ravenna and Forlì-Cesena (between 44°, 38′ and 44°, 08′ N and between 10°, 55′ and 12°, 14′ E), in the Central and South-Eastern part of Emilia-Romagna region (Po valley, Italy). Ten mature orchards located in the seven farms were selected for similar features, including: (1) cultivars: Kaki Tipo, a local cultivar, and Rojo Brillante, a Spanish variety [14] introduced in Italy about 20 years ago, that are the two most used varieties in Emilia-Romagna region; (2) rootstock: both varieties were grafted on seedlings; (3) tree spacings: 4.3–4.5 m between rows and 3.5–4.5 m between trees along the row (average planting density of 614 and 616 trees ha^{-1} for Kaki Tipo and Rojo Brillante, respectively); (4) soil type: mainly loam and silt-loam; (5) soil management: use of herbicide on tree row, and alleys covered with spontaneous grass mowed regularly during the season; (6) pest control, irrigation and fertilization managed according to the Integrated Crop Management guideline of the Emilia-Romagna region [15]. In detail, Kaki Tipo orchards were fertilized, yearly, with an average of 53 kg ha^{-1}, 20 kg ha^{-1} and 63 kg ha^{-1} of nitrogen (N), phosphorus (P) and potassium (K), respectively; while Rojo Brillante received 71 kg N ha^{-1}, 17 kg P ha^{-1} and 63 kg K ha^{-1} of N, P and K.

2.2. Plant Organ Sampling and Analysis

In each of five orchards per cultivar, four plots of five trees each were selected and used for sample collection. At the beginning of August, leaf samples were taken from the middle part of shoots. Leaf chlorophyll was measured by SPAD 502 (Minolta Co., Ramsey, NJ, USA) and leaf area was measured by a portable area meter (Li-3000, LiCor Inc., Lincoln, NE, USA). Leaves were then washed, oven-dried and milled, and analysed for the concentration of N, P, K, calcium (Ca), magnesium (Mg), sulphur (S), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). Nitrogen was determined by the Kjeldahl method, while other macro and micronutrients were determined by spectrometry emission (ICP-OES, Ametek Spectro, Arcos, Kleve, Germany), after mineralization in an Ethos TC microwave lab station (Milestone, Bergamo, Italy). At fruit harvest, plant yield was recorded and a representative sample of fruits was collected to measure dry matter and fruit mineral composition as previously described. In autumn, the naturally abscised leaves and the wood removed with pruning in one tree per plot were collected, weighed, oven-dried, milled and analysed for mineral composition as described above; in addition, leaf area was measured as described for summer leaves. To collect senescent leaves, the area below trees was delimited and the fallen leaves were collected several times until complete defoliation. The biomass and mineral composition of perennial organs (roots and skeleton) were recorded in winter on four trees from one orchard of both Rojo Brillante (12 years old) and Kaki Tipo (19 years old). Each tree was harvested and divided in roots, trunk and branches; a sub-sample of this organs was oven-dried, milled and analysed for macro and microelement concentration as previously described.

The mineral content of each organ was calculated by multiplying its nutrient concentration by its dry weight (DW). Leaf nutrient content was also referred to leaf specific weight calculated by dividing DW for leaf area. The knowledge of the nutrient content in tree organs allowed us to calculate the recycled and removed fractions. In detail, recycled nutrients are those that at the end of the vegetative season return to the soil and were calculated as the sum of nutrients content in abscised leaves and pruning wood. Removed nutrients were calculated as the sum content in root, skeleton and fruits at harvest. Total orchard demand was calculated as the sum the recycled and removed fraction multiplied by the number of trees per hectare. Finally, to estimate the annual contribution in terms of biomass and of removed nutrients by perennial organs, all the data were divided by the age of plants.

2.3. Statistical Analysis

Data of biomass, nutrients concentration and nutrients content for each cultivar are reported as means ± standard deviation (SD) of 20 samples for leaves (summer and abscised, fruits at harvest and pruned wood) and of 4 samples for skeleton and roots. Leaf nutrients content was analysed with the software R according to a discriminant canonical analysis (DCA). Pearson correlation coefficient was employed to estimate the linear relationship between leaf nutrient concentration and SPAD measurements.

3. Results

3.1. Tree Biomass

Fruits DW (11–12 kg tree^{-1}) was higher than the rest of plant organs and accounted for half of the total tree DW (22–24 kg tree^{-1}; Figure 1). Abscised leaves biomass was around 5.5 kg tree^{-1} in both cultivar while wood removed with winter pruning showed higher values in Kaki Tipo (4.8 kg tree^{-1}) than in Rojo Brillante (2.9 kg tree^{-1}; Figure 1). Annual increase of skeleton biomass was higher in Rojo Brillante than Kaki Tipo (2.0 and 1.2 kg tree^{-1}, respectively) and it was three times higher than roots, that showed the lowest DW (0.5–0.7 kg tree^{-1}; Figure 1).

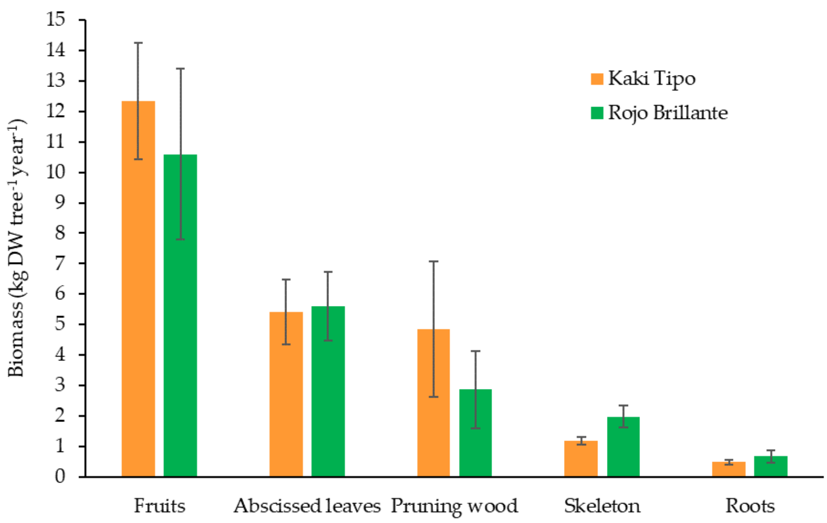

Figure 1. Annual production of biomass (DW) of mature persimmon tree of cultivar Kaki Tipo and Rojo Brillante. Bars are standard deviation (*n* = 20 for new growth organs and 4 for perennial organs).

Considering the planting density (614 and 616 trees ha^{-1} for Kaki Tipo and Rojo Brillante, respectively), the total plant biomass produced annually ranged between 14.9 and 13.4 t ha^{-1} for Kaki Tipo and Rojo Brillante, respectively.

3.2. Leaf Chlorophyll and Mineral Concentration

Leaf chlorophyll (expressed as SPAD values) was positively correlated (r = 0.83, ***) to leaves N concentration (Figure 2); in addition, SPAD was also statistically positively correlated with S (r = 0.35; *), B (r = 0.42, **), Cu (r = 0.48, **) and Mn (r = 0.53, ***). No significant correlation was found for other nutrients.

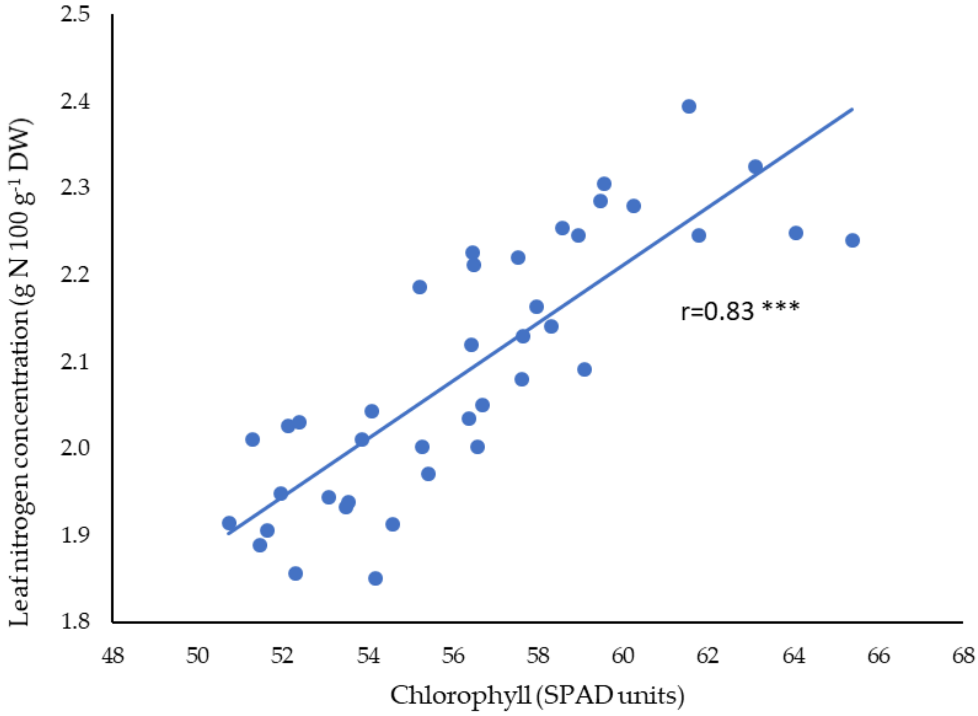

Figure 2. Correlation between SPAD readings and nitrogen concentrations of the leaves collected in summer from mature Kaki Tipo and Rojo Brillante persimmon orchards. For each cultivar, each point represents the mean of 4 trees selected in 5 different farms; r = Pearson correlation coefficient. ***: significant for $p \leq 0.001$.

Summer leaves macronutrient concentration averaged 2, 0.12, 1.8, 2.5, 0.5 and 0.2 g 100 g^{-1} DW for N, P, K, Ca, M and S, respectively (Table 1).

Table 1. Chlorophyll (SPAD unit) and macronutrients (g 100g^{-1} DW) concentration of persimmon leaves sampled in summer (means ± SD, *n* = 20).

Cultivar	Chlorophyll	N	P	K	Ca	Mg	S
Kaki Tipo	59.1 ± 2.84	2.21 ± 0.10	0.12 ± 0.01	1.76 ± 0.35	2.52 ± 0.43	0.59 ± 0.11	0.20 ± 0.03
Rojo Brillante	53.7 ± 2.19	1.97 ± 0.07	0.12 ± 0.01	1.86 ± 0.36	2.59 ± 0.51	0.54 ± 0.07	0.17 ± 0.02

Average micronutrients concentration was, in g kg^{-1} DW, 65 for B, 4.5 for Cu, 58 for Fe, 144 for Mn and 12 for Zn (Table 2).

Table 2. Micronutrients concentration (mg kg^{-1} DW) of persimmon Kaki Tipo and Rojo Brillante leaves sampled in summer (mean ± SD, *n* = 20).

Cultivar	B	Cu	Fe	Mn	Zn
Kaki Tipo	65.9 ± 7.78	4.86 ± 7.78	61.8 ± 6.42	153 ± 67.1	11.9 ± 1.98
Rojo Brillante	64.0 ± 8.32	3.86 ± 0.57	53.4 ± 5.56	134 ± 44.9	11.3 ± 1.56

The canonical discriminant analysis performed on leaf macro and micronutrient content showed that all the gradient of variability of these data sets was represented by the first canonical variable (Can1); consequently, the distribution of objects was represented only for this axis (Figures 3 and 4). The box plot separated abscised leaves from those sampled in summer both for macro and micronutrient content. When taking into consideration the structure of data, it was observed that N, K, P, Mg and S were higher in summer than in autumn; the opposite was observed for Ca (Figure 3).

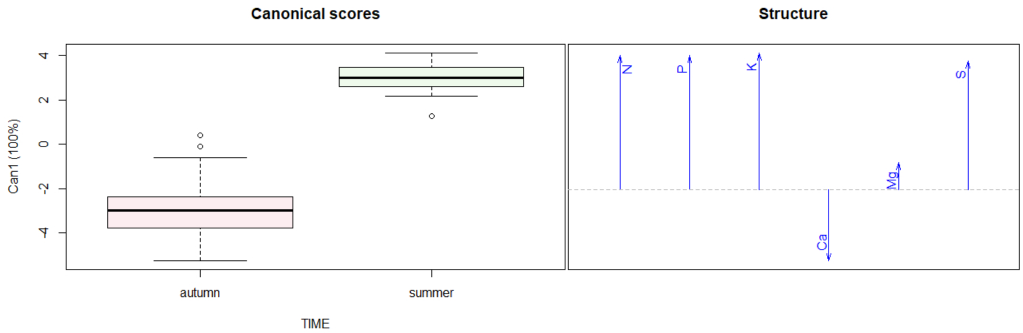

Figure 3. Discriminant canonical analysis on macronutrient content (mg cm^{-2}) in summer and autumn leaves. Data from both cultivars were included. Bar charts (**left**) of discriminant functions and arrows (**right**) represent the direction of each parameter analysed.

The structure of micronutrient data showed higher content of all nutrients analyzed in leaves sampled in autumn than those in summer (Figure 4).

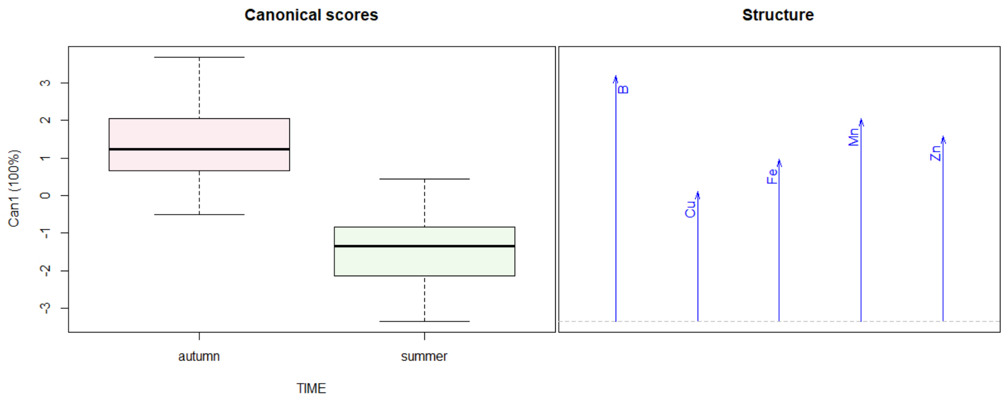

Figure 4. Discriminant canonical analysis on micronutrient content (µg cm^{-2}) in summer and autumn leaves. Data from both cultivars were included. Bar charts (**left**) of discriminant functions and arrows (**right**) represent the direction of each parameter analysed.

3.3. Tree Nutrients Content

Fruits and abscissed leaves accounted for the highest N content within plants of both cultivars, followed by pruning wood, skeleton and roots (Table 3). The amount of P was higher in fruits in both cultivars, followed by pruning wood and abscised leaves (Table 3). In both cultivars, K was mainly concentrated in fruits, with values at least twice those found in autumn leaves and pruned wood. Calcium was the highest nutrient in the tree of both genotypes and was mainly accumulated in abscissed leaves, followed by pruning wood; like Ca, also Mg was found mainly in autumn leaves (Table 3). Finally, S content was similar in fruits, leaves and wood of Kaki Tipo, while in the same organs of Rojo Brillante the amounts ranged between 3 and 6 g $tree^{-1}$ (Table 3). The content of all macronutrients in the skeleton was always higher than in roots (Table 3); Ca was the nutrient than mainly allocated in the skeleton and roots, followed by N and K (Table 3). Total tree macronutrient content (g $tree^{-1}$) accounted, on average, for 155 N, 18.5 P, 151 K, 247 Ca, 41 Mg and 16 S (Table 3).

Table 3. Annual macronutrient content (g tree^{-1} year^{-1}) in tree organs of mature persimmon of cultivar Kaki Tipo and Rojo Brillante (means ± SD; *n* = 20 for new growth and 4 for perennial organs).

Tree Organs	N	P	K	Ca	Mg	S
			Kaki Tipo			
Fruits	53.9 ± 7.95	9.44 ± 0.86	103 ± 19.4	5.33 ± 1.31	4.16 ± 0.56	5.52 ± 0.84
Abscissed leaves	54.9 ± 15.8	3.31 ± 0.98	30.6 ± 15.3	151 ± 58.7	25.1 ± 13.2	5.64 ± 1.67
Pruning wood	45.6 ± 21.8	6.12 ± 3.05	24.5 ± 12.3	53.7 ± 25.5	7.74 ± 3.74	4.88 ± 2.48
Skeleton	5.18 ± 0.43	0.26 ± 0.06	1.56 ± 0.51	13.3 ± 2.04	1.31 ± 0.32	0.51 ± 0.07
Roots	1.30 ± 0.52	0.13 ± 0.04	0.74 ± 0.46	3.75 ± 1.21	0.58 ± 0.35	0.14 ± 0.03
TOTAL	*161 ± 37.7*	*19.3 ± 4.04*	*160 ± 37.3*	*227 ± 74.4*	*38.8 ± 15.7*	*16.7 ± 3.91*
			Rojo Brillante			
Fruits	46.8 ± 12.1	8.99 ± 2.45	85.6 ± 29.1	5.38 ± 1.87	3.71 ± 1.25	4.56 ± 1.33
Abscissed leaves	55.7 ± 20.9	3.38 ± 0.91	36.1 ± 16.4	201 ± 29.8	29.4 ± 6.64	6.05 ± 1.45
Pruning wood	25.9 ± 11.2	3.41 ± 1.85	13.8 ± 6.01	32.5 ± 11.1	4.61 ± 2.01	3.01 ± 1.15
Skeleton	12.4 ± 5.01	1.54 ± 0.24	5.23 ± 0.99	22.6 ± 10.2	3.62 ± 0.85	1.28 ± 0.46
Roots	7.76 ± 4.41	0.37 ± 0.23	1.36 ± 0.45	4.28 ± 1.57	0.71 ± 0.26	0.37 ± 0.14
TOTAL	*149 ± 31.6*	*17.7 ± 3.23*	*142 ± 30.1*	*266 ± 30.6*	*42.1 ± 7.81*	*15.3 ± 2.39*

Boron content was higher in abscised leaves of both cultivars, than in fruits; perennial and new growth woody organs (pruned wood) showed less than 25 mg of B tree^{-1} in both genotypes; roots accounted for the lowest B content (Table 4). Copper mainly accumulated in pruning wood and leaves in kaki Tipo, and in skeleton, abscised leaves and pruned wood in Rojo Brillante (Table 4). In both cultivars, fruit Cu content was around 15 mg tree^{-1} and roots showed the lowest Cu content (Table 4). In Kaki Tipo roots and abscised leaves accounted for the highest Fe content, followed by pruning wood, skeleton and fruits (Table 4); while in Rojo Brillante Fe mainly accumulated in skeleton and abscised leaves (Table 4). For both cultivars, fallen leaves were the main Mn sink, followed by pruned wood of Kaki Tipo, and pruned wood and skeleton of Rojo Brillante (Table 4). Fruits Mn content was similar in the two genotypes, while roots of Kaki Tipo showed higher content than Rojo Brillante (Table 4). Zinc was mainly found in pruning wood, skeleton and fallen leaves (Table 4). The average total content of micronutrients in plants, reported in mg tree^{-1}, was 624 B, 103 Cu, 2600 Fe, 1790 Mn and 348 Zn (Table 4).

Table 4. Annual micronutrient content (mg tree^{-1} year^{-1}) in tree organs of mature persimmon of cultivar Kaki Tipo and Rojo Brillante (means ± SD; *n* = 20 for new growth and 4 for perennial organs).

Tree Organs	B	Cu	Fe	Mn	Zn
			Kaki Tipo		
Fruits	78.7 ± 9.95	16.6 ± 10.9	71.1 ± 16.5	33.2 ± 14.2	43.7 ± 13.6
Abscissed leaves	493 ± 80.4	29.4 ± 5.70	1116 ± 769	1478 ± 613	77.6 ± 15.1
Pruning wood	23.5 ± 11.7	42.6 ± 17.1	155 ± 76.3	213 ± 84.2	153 ± 71.0
Skeleton	23.1 ± 7.32	15.1 ± 4.15	165 ± 19.2	36.1 ± 8.92	97.6 ± 83.4
Roots	10.7 ± 3.36	8.64 ± 7.10	1811 ± 1464	63.9 ± 51.0	7.46 ± 4.25
TOTAL	*629 ± 86.7*	*112 ± 24.8*	*3318 ± 805*	*1824 ± 611*	*379 ± 83.5*
			Rojo Brillante		
Fruits	88.9 ± 30.0	12.4 ± 5.97	66.7 ± 15.8	31.1 ± 12.1	35.8 ± 15.7
Abscissed leaves	484 ± 77.6	25.3 ± 6.63	626 ± 347	1476 ± 420	82.6 ± 20.8
Pruning wood	13.7 ± 5.94	24.8 ± 12.6	160 ± 168	125 ± 61.4	78.9 ± 26.2
Skeleton	19.9 ± 7.84	29.1 ± 12.7	952 ± 835	112 ± 66.0	113 ± 69.4
Roots	11.6 ± 4.49	3.24 ± 0.69	79.1 ± 33.9	13.5 ± 3.97	5.52 ± 1.94
TOTAL	*618 ± 83.7*	*94.8 ± 14.1*	*1884 ± 394*	*1758 ± 441*	*316 ± 37.9*

3.4. Amounts of Nutrient Removed and Recycled in the Orchard

The annual N, Ca, Mg and S (Figure 5) recycled fraction in Kaki Tipo was higher than the fraction removed, the opposite was observed for K, while P showed similar values between the two fractions (Figure 5). Similarly, in Rojo Brillante the recycled fraction of N, Ca, Mg, S was higher than that removed (Figure 5) while the opposite was observed for P and K (Figure 5).

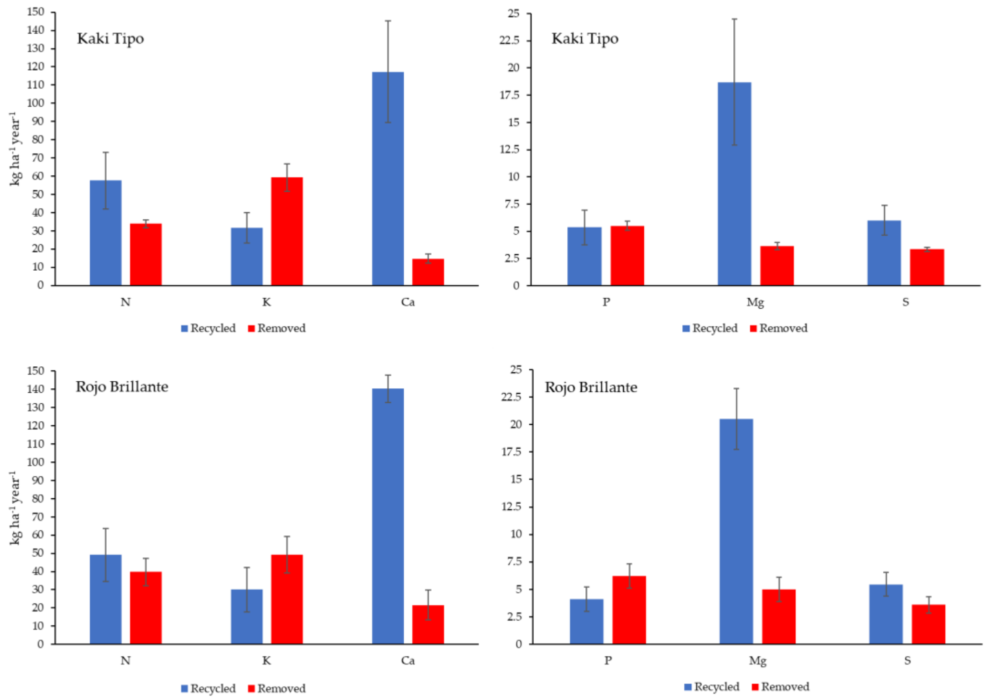

Figure 5. Amounts of macronutrients recycled and removed in mature persimmon orchard. Recycled nutrients: abscised leaves + pruned wood; removed nutrients: fruits + roots and skeleton. Means ± SD (*n* = 20 for leaves, fruits and pruned wood, and 4 for skeleton and roots).

The sum of the two fractions shows the annual requirements of the orchard; that are, on average: 90 kg N ha^{-1}, 10.5 kg P ha^{-1}, 85 kg K ha^{-1}; 147 kg Ca ha^{-1}; 24 kg Mg ha^{-1} and 9 kg S ha^{-1} (Table 5).

Table 5. Total annual demand of macronutrients (kg ha^{-1} year^{-1}) of mature persimmon orchard.

Total Demand	N	P	K	Ca	Mg	S
Kaki Tipo	91.4 ± 3.78	10.9 ± 0.52	90.7 ± 1.61	132 ± 4.26	22.3 ± 1.03	9.4 ± 0.1
Rojo Brillante	88.9 ± 1.42	10.3 ± 0.52	79.2 ± 8.10	162 ± 23.9	25.5 ± 6.23	9.1 ± 1.2

In Kaki Tipo, the amounts of recycled Mn, B, Cu and Zn were higher than those removed; the opposite was observed for Fe (Figure 6). Similarly, in Rojo Brillante the recycled amounts of Mn and B were higher than those removed, while an opposite trend for Fe was observed; similar quantities were measured for Cu and Zn (Figure 6).

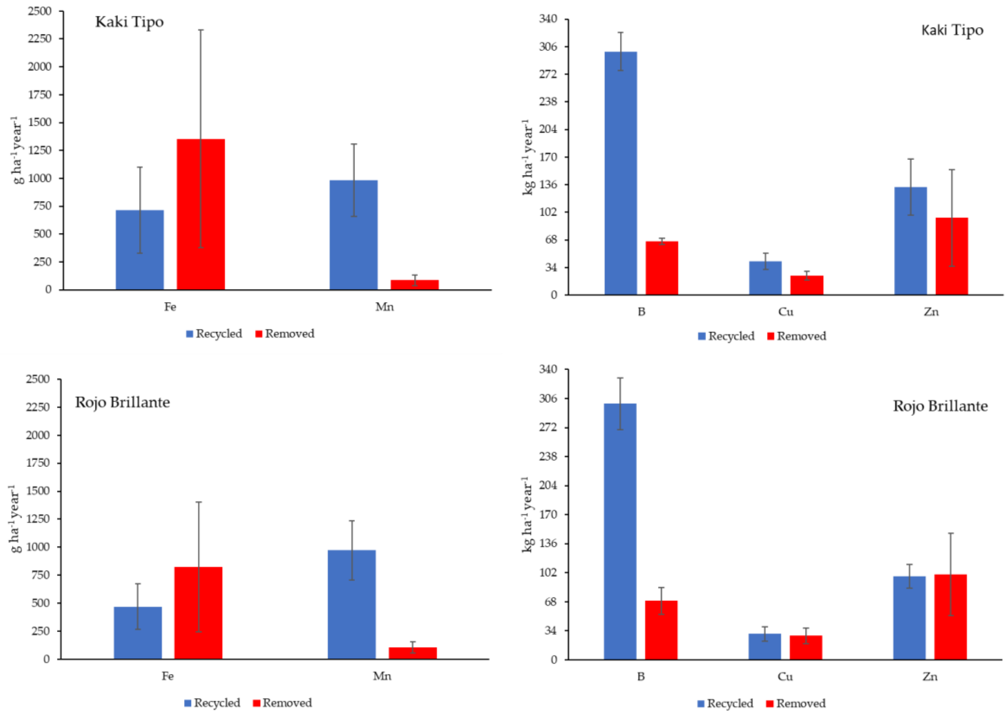

Figure 6. Amounts of micronutrients recycled and removed in mature persimmon orchard. Recycled nutrients: abscised leaves + pruned wood; removed nutrients: fruits + roots and skeleton. Means ± SD (*n* = 20 for leaves, fruits and pruned wood, and 4 for skeleton and roots).

For micronutrients the average orchard yearly demand was 368 g B ha^{-1}, 79 g Cu ha^{-1}, 1700 g Fe ha^{-1}; 1200 g Mg ha^{-1}; and 213 g Zn ha^{-1} (Table 6).

Table 6. Total annual demand of micronutrients (g ha^{-1} $year^{-1}$) of mature persimmon orchard.

Total Demand	B	Cu	Fe	Mn	Zn
Kaki Tipo	366 ± 32	99 ± 3.5	2067 ± 975	1066 ± 276	228 ± 57
Rojo Brillante	369 ± 48	59 ± 8.2	1223 ± 540	1295 ± 106	198 ± 44

4. Discussion

The annual biomass produced by persimmon tree (leaves, fruits and pruning wood) was almost 20 kg per tree, equal to 12 t ha^{-1}, a value similar to that reported for peach trees [2]. Pruned wood and abscised leaves contributed each for 25–30% of the total tree biomass, with values of pruned wood correlated to cultivar vigour that is known to be higher in Kaki Tipo than Rojo Brillante. The contribution of persimmon pruned wood and leaves to total plant biomass was higher than that reported for apple [16] and pear [17] grafted on dwarfing rootstocks, but similar to peach grafted on the vigorous hybrid GF677 [2]. About 50% of the annual biomass was partitioned to fruits, similarly to what previously observed for peach [2]. This result confirms that Emilia-Romagna has the optimal pedo- climate conditions for persimmon intensive cultivation, with yields higher than the Italian average [1].

The intensity of the green color of the leaves depends on several factors such as soil fertility, especially N availability, the age of the leaf and the genotype (cultivar, rootstock and their combination). In our study difference were observed between Kaki Tipo and Rojo Brillante (lower for Rojo Brillante than Kaki Tipo), despite similar orchard management; moreover, for both cultivars, our SPAD values were higher than those reported for Fuyu cultivar (45-50 SPAD unit) [18]. This variability is related to the genotype, as reported for other crops such as apple [19] and grapevine [20]. The relationship between summer values of leaf chlorophyll and N concentration was significant and the coefficient of correlation was similar (r = 0.78–0.91) to that reported in Fuyu cultivar [18,21]. Moreover, we observed a positive correlation between SPAD and leaf S (r = 0.35, *), B (r = 0.42; **), Cu (r = 0.48, **) and Mn (r = 0.53, ***). Consequently, summer leaf chlorophyll could be a useful tool to predict nutrient deficiencies, but without precise information on nutrient concentration [19].

The mineral composition of the leaves in summer showed a nutritional status similar for the two persimmon varieties; Ca, N and K were in line with values reported for several deciduous fruit crops [22]. In Kaki Tipo, summer leaf nutrient concentrations were similar to those reported in Italy [23], Spain [12] and Turkey [13]. In other studies, conducted in Australia [24] and New Zealand [10], K leaf values were significantly higher than those found in the present study. Manganese is the most representative micronutrient in persimmon leaf, as reported in the literature [10,12,23]. For a correct interpretation of the analytical results it is important to compare data with indices available in the same area of diagnosis. This study, therefore, represents a first attempt to define preliminary indices for mineral diagnosis of summer leaves in both Kaki Tipo and Rojo Brillante cultivated in Emilia Romagna region, as already done for other fruit species.

The discriminant canonical analysis of leaf mineral composition in summer and winter, confirm, regardless of genotype, the mobility of N, P, K and S that, at the end of the season translocated to storage organs (roots, stem and branches), as described for deciduous trees [25,26], but also for persimmon [10,27]. Other nutrients such as Ca and microelements are not involved in this process and are accumulated in leaf until abscission [10]. Magnesium was translocated in small quantities and our results contrast with those reported in a study on Rojo Brillante carried out in Spain, which showed an increase of Mg concentration until leaf abscission [27]. In the present study, it was estimated that 50% of N and P, and 67% of K of summer leaves were translocated before leaf abscission, regardless of the cultivar [28], while the residual fractions were potentially recycled in the orchard through the decomposition and mineralization processes [29]. The contribution of recycled fraction through the fallen leaves of persimmon reached 70–80% of the total content in the tree for Ca, Mg, B and Mn, while it was about 36% for N, 20% for P and 20–25% for K.

The mineral content of the one-year-old shoots removed by winter pruning showed values comparable to those reported for persimmon Fuyu [30], except for Ca, that was almost double in our study, while K level was higher than that reported in the literature for the pruned wood of peach [31] and pear [32]. This means that the soils of the investigation are rich in Ca and K. Like abscissed leaves, also pruned wood represents an important source of nutrients that are recycled in the orchard; however, its decomposition process is longer than leaves because the presence of lignin [33]. The return of mineral nutrients to the soil through the pruning wood of persimmon accounts for 45% of the total plant N and K, 65% of the total P, and about the 25% for Ca and Mg, in the case of the Kaki Tipo cultivar.

Fruits at harvest accounted for the highest fraction of nutrients removed from the orchard, representing the major net fraction of the crop. In the present study this fraction was estimated to be about 32%, 50%, 62% and 31% of the total annual requirement of N, P, K and S, respectively; Mg, B, Cu and Zn were removed by fruits for the 10–15%, while the fraction of Ca, Fe and Mn were minimal and therefore their removal by fruits negligible. As for peach [31] and in general for most fruit tree species [34], K was the most important mineral nutrient in persimmon fruit and its amount was about twice that of N and almost twenty times higher than Ca, confirming the results reported in other studies [11,12,30,35]. The remaining nutrients removed annually were stored in the roots and in the skeleton). In our conditions, these reserves, even if represent smaller quantities (4–12, 0.2–1.1, 1.4–4 kg ha^{-1} of N, P and K, respectively), are essential for plant metabolism since they support new tissue development in spring [25].

The sum of the nutrients removed and recycled annually provides the total uptake of minerals during the season and the quantified values are in line with those recommended in Australia [24].

5. Conclusions

In the conditions of our investigation, the two main varieties of persimmon industry cultivated in Emilia Romagna region showed a similar annual nutrients demand, estimated for macronutrients in about 90 kg N ha^{-1}, 10 kg P ha^{-1}, 80–90 kg K ha^{-1}, 130–160 kg Ca ha^{-1}, 25 kg Mg ha^{-1}, while for micronutrients the requirement reaches 1000–2000 g ha^{-1} only for Fe and Mn. Except for K, more than half of yearly plant request of nutrients return to the soil at the end of season and can be reused with positive effect on the nutrient use efficiency. The recycled fraction mentioned above, therefore, must be considered, along with both soil fertility and tree nutritional status, in the definition of the fertilization plan, in order to minimize the external chemical inputs. Finally, this study proposes references indices for summer leaf analysis of Kaki Tipo and Rojo Brillante in Emilia Romagna region, with the aim of proving a correct interpretation of data in the same area of cultivation.

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References

1. Istat. Available online: http://dati.istat.it/viewhtml.aspx?il=blank&vh=0000&vf=0&vcq=1100&graph=0&view-metadata=1&lang=it&QueryId=33654 (accessed on 9 May 2022).
2. Baldi, E.; Quartieri, M.; Sorrenti, G.; Toselli, M. Evaluation of nutrients removed and recycled in a commercial peach orchard over a 14-years-production cycle. *Italus Hortus* **2021**, *28*, 1–12. [CrossRef]
3. Malaguti, D.; Rombola, A.D.; Quartieri, M.; Lucchi, A.; Inderst, C.; Marangoni, B.; Tagliavini, M. Effects of the rate of nutrients by fertigation and broadcast application in 'Gala' and 'Fuji' apple. *Acta Hortic.* **2006**, *721*, 165–172. [CrossRef]
4. Toselli, M.; Mazzanti, F.; Marangoni, B.; Tagliavini, M.; Scudellari, D. Determination of leaf standards for mineral diagnosis in pear orchards in the Po Valley, Italy. *Acta Hortic.* **2002**, *596*, 665–669. [CrossRef]
5. Choi, S.T.; Kim, S.C.; Park, D.S.; Kang, S.M. Tree growth and physiological fruit drop of "Hachiya" persimmon on *D. kaki* and *D. lotus* rootstocks. *Acta Hortic.* **2008**, *772*, 345–349. [CrossRef]
6. Badal, E.; El-Mageed, T.A.; Buesa, I.; Guerra, D.; Bonet, L.; Intrigliolo, D.S. Moderate plant water stress reduces fruit drop of "Rojo Brillante" persimmon (*Dyospiros kaki*) in a Mediterranean climate. *Agric. Water Manag.* **2013**, *119*, 154–160. [CrossRef]
7. Ventura, M.; Scandellari, F.; Ventura, F.; Guzzon, B.; Rossi Pisa, P.; Tagliavini, M. Nitrogen balance and losses through drainage waters in an agricultural watershed of the Po Valley (Italy). *Eur. J. Agron.* **2008**, *29*, 108–115. [CrossRef]
8. Volk, M.; Liersch, S.; Schmidt, G. Towards the implementation of the European Water Framework Directive? Lessons learned from water quality simulations in an agricultural water-shed. *Land Use Policy* **2009**, *26*, 580–588. [CrossRef]
9. Ahmed, Z.F.; Kaur, N.; Hassan, F.E. ornamental date palm and sidr trees: Fruit elements composition and concerns regarding consumption. *Int. J. Fruit Sci.* **2022**, *22*, 17–34. [CrossRef]
10. Clark, C.J.; Smith, G.S. Seasonal changes in the mineral nutrient content of persimmon leaves. *Sci. Hortic.* **1990**, *42*, 85–97. [CrossRef]
11. Clark, C.J.; Smith, G.S. Seasonal changes in the composition, distribution and accumulation of mineral nutrients in persimmon fruit. *Sci. Hortic.* **1990**, *42*, 99–111. [CrossRef]
12. Mir–Marqués, A.; Domingo, A.; Cervera, M.L.; De la Guardia, M. Mineral profile of kaki fruits (*Diospyros kaki* L.). *Food Chem.* **2015**, *172*, 291–297. [CrossRef] [PubMed]
13. Yildiz, E.; Kaplankiran, M. Seasonal Variations in Mineral Nutrients in Leaves and Shoots of Some Persimmons Cultivars grown in Turkey. *Acta Hortic.* **2013**, *996*, 351–357. [CrossRef]
14. Llácer, G.; Martínez-Calvo, J.; Naval, M.; Badenes, M.L. From germplasm to fruit export: The case of 'Rojo Brillante' persimmon. *Adv. Hort. Sci.* **2008**, *22*, 281–285. Available online: https://www.jstor.org/stable/42883470 (accessed on 9 May 2022).
15. Emilia-Romagna. 2022. Available online: https://agricoltura.regione.emilia-romagna.it/produzioniagroalimentari/temi/bio-agro-climambiente/agricoltura-integrata/disciplinari-produzione-integratavegetale# (accessed on 27 January 2023).

16. Scandellari, F.; Ventura, M.; Malaguti, D.; Ceccon, C.; Menarbin, G.; Tagliavini, M. Net primary productivity and partitioning of absorbed nutrients in field-grown apple trees. *Acta Hortic.* **2010**, *868*, 115–122. [CrossRef]
17. Tagliavini, M.; Quartieri, M. I fabbisogni nutrizionali del pero per la definizione del piano di fertilizzazione. *Italus Hortus* **2008**, *15*, 131–137.
18. Choi, S.T.; Park, D.S. Use of a chlorophyll meter to diagnose nitrogen status of 'Fuyu' persimmon leaves. *HortScience* **2011**, *46*, 821–824. [CrossRef]
19. Neilsen, D.; Hogue, E.J.; Neilsen, G.H.; Parchomchuk, P. Using SPAD-502 Values to assess the nitrogen status of apple trees. *HortScience* **1995**, *30*, 508–512. [CrossRef]
20. Porro, D.; Bertoldi, D.; Bottura, M.; Pedò, S. Five-year period of evaluation of leaf mineral concentrations in resistant varieties in Trentino (Northeastern Italy). *BIO Web Conf.* **2022**, *44*, 01002. [CrossRef]
21. Ahmed, Z.F.R.; Alnuaimi, A.K.H.; Askri, A.; Tzortzakis, N. Evaluation of Lettuce (*Lactuca sativa* L.) Production under Hydroponic System: Nutrient Solution Derived from Fish Waste vs. Inorganic Nutrient Solution. *Horticulturae* **2021**, *7*, 292. [CrossRef]
22. Marschner, H. *Mineral Nutrition of Higher Plants*, 3rd ed.; Academic Press: London, UK, 2012. [CrossRef]
23. Natali, S.; Bignami, C. Tecnica colturale del terreno: Lavorazione, concimazione ed irrigazione del kaki. In *Il Kaki, Aggiornamenti Della Coltura*; Ismea: Roma, Italy, 1988; pp. 63–80.
24. George, A.; Nissen, B.; Broadley, R. Persimmon nutrition. In *Sweet Persimmon Grower's Handbook*, 1st ed.; Grower Guide Series QI05102; Belisle, J., George, A., Broadley, R., Nissen, B., Eds.; Department of Primary Industries and Fisheries: Brisbane, Australia, 2005; Chapter 4; pp. 1–64, ISSN 0727-6273.
25. Millard, P. Ecophysiology of the internal cycling of nitrogen for tree growth. *J. Plant Nutr. Soil Sci.* **1996**, *159*, 1–10. [CrossRef]
26. Millard, P.; Grelet, G.A. Nitrogen storage and remobilization by trees: Ecophysiological relevance in a changing world. *Tree Physiol.* **2010**, *30*, 1083–1095. [CrossRef] [PubMed]
27. Vilhena, N.Q.; Quiñones, A.; Rodríguez, I.; Gil, R.; Fernández-Serrano, P.; Salvador, A. Leaf and fruit nutrient concentration in Rojo Brillante persimmon grown under conventional and organic management, and its correlation with fruit quality parameters. *Agronomy* **2022**, *12*, 237. [CrossRef]
28. Quartieri, M.; Toselli, M. Ottimizzare la concimazione del kaki valutando le asportazioni minerali. *Riv. Fruttic.* **2021**, *2*, 52–56.
29. Tagliavini, M.; Tonon, G.; Scandellari, F.; Quinones, A.; Palmieri, S.; Menarbin, G.; Gioacchini, P.; Masia, A. Nutrient recycling during the decomposition of apple leaves (*Malus domestica*) and mowed grasses in an orchard. *Agric. Ecosyst. Environ.* **2007**, *118*, 191–200. [CrossRef]
30. Choi, S.T.; Park, D.S.; Yoon, T.H.; Jae, H.J.; Lee, Y.H. Response of "Fuyu" Persimmon to K Forms and Fertigation Rates on Tree Growth and Fruit Quality. *Acta Hortic.* **2013**, *996*, 293–297. [CrossRef]
31. Baldi, E.; Marcolini, G.; Quartieri, M.; Sorrenti, G.; Toselli, M. Effect of organic fertilization on nutrient concentration and accumulation in nectarine (*Prunus persica* var. *nucipersica*) trees: The effect of rate application. *Sci. Hortic.* **2014**, *179*, 174–179. [CrossRef]
32. Stassen, P.J.C.; North, M.S. Nutrient distribution and requirement of "Forelle" pear trees on two rootstocks. *Acta Hortic.* **2005**, *671*, 493–500. [CrossRef]
33. Marcolini, G.; Toselli, M.; Quartieri, M.; Gioacchini, P.; Baldi, E.; Sorrenti, G.; Mariani, S. Nitrogen and carbon mineralisation of different Meliaceae derivatives. *Plant Soil Environ.* **2016**, *62*, 121–127. [CrossRef]
34. Tagliavini, M.; Zavalloni, C.; Rombolà, A.D.; Quartieri, M.; Malaguti, D.; Mazzanti, F.; Millard, P.; Marangoni, B. Mineral nutrient partitioning to fruits of deciduous trees. *Acta Hortic.* **2000**, *512*, 131–140. [CrossRef]
35. Gorinstein, S.; Zachwieja, Z.; Folta, M.; Barton, H.; Piotrowicz, J.; Zemser, M.; Wisz, M.; Trakhtenberg, S.; Martìn-Belloso, O. Comparative contents of dietary fiber, total phenolics and mineral in persimmons and apples. *J. Agric. Food Chem.* **2001**, *49*, 952–957. [CrossRef]