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Composition and removal of nutrients by the harvested fruit of avocado cv. Hass in Antioquia

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Composición y remoción de nutrientes por la cosecha de aguacate cv. Hass en Antioquia

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Álvaro Tamayo V[1]*, Jorge A. Bernal E.[1] and Cipriano A. Díaz D.[1]

ABSTRACT

Keywords:
Persea americana Miller
Seed
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In three Antioquia producing areas (El Retiro, El Peñol and Amagá), three orchards of cv. Hass avocado were selected, in order to quantify the amount of nutrients removed by the fruit. A completely randomized design with 12 replications (trees) was used, for which 25 fruits/tree were collected, from which the fresh and dry weight of the epidermis, pulp, testa and seed were obtained. In each fruit structure, the concentration of N, P, K, Ca, Mg, Fe, Cu, Mn, Zn and B was determined and the removal of each was calculated. The tissue with the highest concentration of nutrients was the testa. The nutrient with the highest concentration in the four tissues was K followed by N. The total removal by the fresh fruit, in kg t^{-1}, for K was 4; N, 3.3; S 0.56; Mg 0.51; Ca 0.31; 0.48 P and in g t^{-1} for Fe was 0.45; B 0.2; Zn 0.11; Mn 0.01 and Cu 0.03.

RESUMEN

Palabras clave:
Persea americana Miller
Semilla
Testa
Pulpa
Epidermis
Nutrición mineral

En tres zonas productoras de Antioquia (El Retiro, El Peñol y Amagá), se seleccionaron tres huertos de aguacate cv Hass, con el fin de cuantificar la cantidad de nutrientes removidos por el fruto. Se usó un diseño completamente al azar con 12 repeticiones (árboles), para lo cual se colectaron 25 frutos/árbol, de donde se obtuvo el peso fresco y seco de la epidermis, la pulpa, la testa y la semilla. En cada estructura del fruto, se determinó la concentración de N, P, K, Ca, Mg, Fe, Cu, Mn, Zn y B y se calculó la remoción de cada uno de ellos. El tejido con mayor concentración de nutrientes fue la testa. El nutrimento con mayor concentración en los cuatro tejidos fue K seguido de N. La remoción total por el fruto fresco, en kg t^{-1}, para K fue de 4; N 3,3; S 0,56; Mg 0,51; Ca 0,31; 0,48 P y en g t^{-1} para el Fe fue 0,45; B 0,2; Zn 0,11; Mn 0,01 y Cu 0,03.

[1] Corporación Colombiana de Investigación Agropecuaria - Corpoica. C.I. La Selva. Kilómetro 7, vía a Las Palmas, vereda Llano Grande, Rionegro, Colombia.
* Corresponding author: <atamayo@corpoica.org.co>

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In order to have an appropriate management of fertilization and production and maintain adequate levels in both, size and quality of fruits is important to know the amount of nutrients that are extracted from the soil by a harvest. Currently, the nutritional requirements of avocado fluctuate, according to the oil content in the fruits of each variety, which could be between 3-20%. Therefore, factors such as size and quality (external and internal) of the fruit are important in the productivity of commercial crops. This is why the more oil the fruit has, the greater its nutrient extraction will be (Salazar-García *et al.*, 2013).

After the roots absorb nutrients from the soil, these are transformed into organic and inorganic compounds, which are transported to the different organs of the plant. In each crop, a large quantity of nutrients is removed permanently, and another important portion is temporarily removed by flowers, leaves, small aborted fruits and roots, which can be cycled in the crop (Tamayo, 2016).

The decomposition of leaf litter is the set of physical and chemical processes by which its basic chemical constituents are removed (Rincón *et al.,* 2017). It is also the most important process of nutrient cycling in any ecosystem (Wang *et al*., 2008; Castellanos and Léon, 2011), because through the decomposition of leaf litter, nutrients are again available to plants. Processes regulate both amount and biochemical content of organic matter produced in an ecosystem, and they are responsible for the formation of humic substances that contribute to soil quality/fertility (Versini *et al*., 2014; Rashida *et al.,* 2016).

Once the fruit has reached physiological maturity, it can be harvested and removed from the tree, taking with it important quantities of various nutrients that, if not reintegrated into the soil, through fertilization, could decrease the fertility of the soil and cause its depletion. Therefore, it is necessary to know the amount of nutrients that were removed by the fruits, since these nutrients were definitely removed from the soil.

The postharvest quality of the avocado fruit is influenced by the concentration of its nutrients at the time of harvest (Arpaia *et al*., 2015); increasing in the N concentration in the leaf, increase the N content in the pulp, as it been reported in avocado cv. Hass (Pérez de los Cobos, 2012). Similarly, applications of Ca to the soil increased the concentration of Ca in the pulp and delayed the ripening of the fruits in the postharvest in avocado (Barrientos-Priego *et al.,* 2016).

Currently in Antioquia, there are no documented works on the nutritional requirements in the avocado cv. Hass. Therefore, it is essential to know the removal of nutrients by the harvest, which allows an adequate management of fertilization that helps to obtain quality fruits. The objectives of this work were to know the nutritional composition of the different tissues of the fruit (epidermis, pulp, testa and seed) and to determine the amount of removed nutrients by the Hass cv avocado, in different localities of the department of Antioquia.

MATERIALS AND METHODS

Soil sampling

In each selected tree, four equidistant sampling sites were chosen, which are located under the tree, in the area between the middle of the crown and the perimeter of it. Then, the sub samples were mixed to obtain a composite sample that was taken to the soil laboratory of Corpoica for its respective chemical analysis.

The contents of the macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Cu, Mn, Zn, B) were determined pH in water (1:2); soil organic matter (SOM), Walkley and Black; Al, 1 *M* KCl; Ca, Mg, K and Na, 1 M ammonium acetate; P, Bray II; S, 0.008 M calcium phosphate; Fe, Mn, Cu and Zn, Olsen-EDTA; B, hot water.

Fruit analysis

In each orchard, 12 trees of 7 years of age were selected and planted at a distance of 7 x 6 m, in each of which 25 fruits were harvested at physiological maturity, with a dry matter content ≥ 23%.

Each fruit was separated into epidermis, pulp, testa and seed and recorded its fresh weight was recorded. Each tissue was cut into thin slices, which were dehydrated in an oven with forced air at 60 °C until constant weight was obtained. The dried samples were sprayed on a Thomas Scientific stainless steel mill (Wiley Mini Mill 3383-L10) with sieve 40 (0.425 mm mesh light). The nutritional composition was determined in three composite samples, each conforming to the tissues of the 25 fruits of each tree, of 12 trees (replications). The dried samples were sent to the soil and plant tissue chemistry laboratory of Corpoica-Tibaitatá (Mosquera, Cundinamarca, Colombia). There the contents of total N (Kjedhdhal) and the extractable fractions of P (Bray II) were established; Ca, Mg and K (1N ammonium acetate, pH 7.0), Fe, Mn, Zn, Cu (modified Olsen) and B (monobasic calcium phosphate). The protocols are described in Westerman (1990).

Statistical analysis

For the analysis of the information, we used an experimental design with 12 replications (trees), where each repetition consisted of 25 fruits of the same tree. The removal of nutrients per ton of fresh fruit (Rt) was calculated according to the formula described by Mellado-Vázquez *et al.* (2017):

$$Rt = ((CNe \times DWe) + (CNp \times DWp) + (CNt \times DWt) + (CNseed \times DWseed)) / 100 \times Ft$$

Where:

CNe = Concentration of the nutrient in the epidermis; DWe = Dry weight of the epidermis; CNp = Concentration of the nutrient in the pulp; DWp = Dry weight of the pulp; CNt = Concentration of the nutrient in the testa; DWt = Dry weight of the testa; CNseed = Concentration of the nutrient in the seed; DWseed = Seed dry weight; Ft = Number of fruits in one ton (obtained from the quotient 1000 kg between the fresh weight of the whole fruit).

For each element, a variance analysis was performed, with the statistical package SAS for Windows V 9.3. The comparison of means was done with the Tukey test ($P\leq0.05$).

RESULTS AND DISCUSSION

Soil analysis

According to Table 1, the soils of the three locations had an extremely acidic pH, with little saturation of aluminum (20-26%), with high contents in organic matter for El Retiro and El Peñol, and low in the location of Amagá; they also have low Ca and Mg contents and medium in K. Minor elements are low and with exception of Fe, which is high in all locations, a situation that is common in moderate climate soils. Generally speaking they are soils with low natural fertility.

Soil chemical characteristics were very similar in all three regions. The pH fluctuated between acids and strongly acid, with low saturation of interchangeable bases and with contents of medium to low in minor elements, with the exception of the Fe that are high. In general, they are soils of low fertility.

Table 1. Chemical characteristics of soils in the municipalities of El Retiro, El Peñol and Amagá (Antioquia).

Locality	pH	MO (%)	Al	Ca	Mg	K	Na	P	S	Fe	Cu	Mn	Zn	B
			cmol$_c$ kg^{-1}					mg kg^{-1}						
El Retiro	4.8	20.4	1.1	2.3	0.8	0.34	0.05	2.3	5.4	122	1	2.3	7.4	0.55
El Peñol	5.1	17.3	1.1	1.4	0.6	0.40	0.08	2.7	8.6	69	2.1	3.9	1.8	0.19
Amagá	4.9	4.80	1.2	2.1	0.8	0.40	0.04	2.8	21.2	284	2.2	3.8	1.8	0.24

Concentration of nutrients in tissues

The concentration of the different nutrients showed significant differences between the tissues of the fruit (Table 2). The testa was the tissue that presented a greater number of nutrients with higher concentration (%). The highest concentrations of P and K were present in the pulp (0.29 and 1.21%, respectively). The concentrations of N, Fe and B were high in the epidermis, this agrees with that found by Salazar *et al.* (2011) in Michoacán México. The epidermis presented the lower values of Ca, Mg and S (0.033, 0.049 and 0.13%, respectively); A similar situation was observed for the minor elements Cu, Mn, Zn and B with 4.9, 8, 12 and 23 mg kg^{-1}, respectively.

Removal of nutrients by fruit

Fruit tissues showed differences in the quantity of removed nutrients (Table 3). The most removed

Table 2. Concentration of nutrients in tissues of avocado fruit cv. Hass in Antioquia.

Tissue	N	P	K	Ca	Mg	S	Fe	Cu	Mn	Zn	B
	%						mg kg^{-1}				
Epidermis	0.893 a	0.105 b	0.943 ab	0.081 b	0.133 b	0.133 c	116.4 a	8.57 ab	20.1 b	38.2 b	64.7 a
Pulp	0.892 a	0.291 a	1.211 a	0.048 b	0.120 c	0.153 a	89.9 a	6.55 ab	16.3 bc	22.5 c	34.7 b
Seed	0.594 b	0.107 b	0.777 b	0.033 c	0.049 d	0.128 d	117.7 a	4.92 b	7.98 c	12.3 d	23.8 b
Testa	0.918 a	0.092 b	1.074 a	0.140 a	0.212 a	0.148 b	131.9 a	10.9 a	64.3 a	46.6 a	78.2 a
P***	<0.00001	<0.0095	<0.0028	<0.00001	<0.00001	<0.00001	<0.024	<0.0194	<0.001	<0.00001	<0.00001

Means with different letters in the same column are statistically different, according to Tukey's ($P\leq0.05$).

elements in all tissues were K, N and S. The pulp showed the greatest removal of all nutrients analyzed both major and minor. Removal by the epidermis and seed was intermediate, although it was higher in the seed. The total removal of macronutrients by avocado cv. Hass was higher for K (4 kg t^{-1}), N (3.3 kg t^{-1}), P (0.48 kg t^{-1}). For the minor elements, Fe and B (0.45 and 0.2 g t^{-1}, respectively) were the most removed (Figure 1).

These results are similar to those reported by Salazar-García *et al.* (2011), in avocado cv. Hass in Michoacán

Table 3. Amount of removed nutrients by the tissues of the avocado fresh fruit cv. Hass in Antioquia.

Tissue	N	P	K	Ca	Mg	S	Fe	Cu	Mn	Zn	B
	kg t^{-1}					g t^{-1}					
Epidermis	0.280 c	0.032 b	0.310 c	0.025 b	0.039 b	0.043 c	34.8 bc	2.5 b	6.1 b	11.77 b	20.7 b
Pulp	1.296 a	0.266 a	1.758 a	0.090 a	0.174 a	0.222 a	126.7 a	9.4 a	23.6 a	32.71 a	50.7 a
Seed	0.465 b	0.083 b	0.611 b	0.027 b	0.037 b	0.099 b	88.7 b	3.8 b	1.7 b	9.56 c	18.7 b
Testa	0.025 d	0.002 c	0.031 d	0.004 b	0.006 b	0.004 d	3.67 c	0.3 d	6.09 b	1.3 c	2.22 c
P***	<0.00001	<0.0015	< 0.00001	< 0.00001	< 0.00001	< 0.00001	<0.0001	<0.00001	<0.00001	<0.00001	<0.00001

Means with different letters in the same column are statistically different, according to Tukey's ($P\leq0.05$).

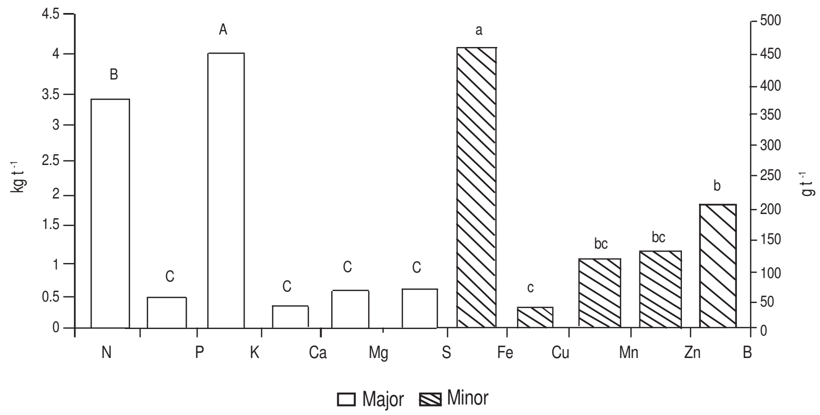

Figure 1. Total removal in kg t^{-1} for fresh avocado fruit cv. Hass in Antioquia. Means with different capital letters (macronutrients) or lowercase (micronutrients) in g t^{-1} are statistically different according to Tukey's test ($P\leq0.05$).

(Mexico); however, they differ slightly from what was obtained by the same authors, with cv. Méndez in Jalisco (Mexico), where N removal was lower (2.7 kg t^{-1}) but higher in Cu, Mn, Zn and B (3.23, 2.05, 4.08 and 7.35 g t^{-1}, respectively). Research carried out by Rebolledo and Dorado (2017) in the municipalities of Rionegro, Herveo and Morales found, in relation to the content of N in fruits, values of extraction of 62 kg of N for the location of Rionegro, 96 kg for Morales and 74 kg for Herveo.

Some authors (Salazar-García and González-Duran, (2005), Tapia-Vargas *et al.* (2007), Tapia-Vargas *et al.*, (2008) affirm that there is a wide variation for nutrients extracted by the fruit in avocado; however, all agree in a noteworthy way, that K is the element of greatest demand, even more than N in proportions ranging from 1:1.5-2. This is consistent with studies done by Montgomery-Taboada *et al.* (2017) in the northern Peruvian coast, where the K extraction was between 3-5 kg t^{-1} of harvested fruit, depending on the rootstock, being the Antillean-type the most extracted. In the present study, greater amounts of B, Fe and Mn were removed than those reported in Mexico and the North Coast of Peru.

The removal of B that is greater than the other micronutrients, close to that of P and other macronutrients Ca, Mg and S.

The high contents in Fe are explained because in these soils it is common to find high concentrations of this element; however, the opposite happens with B, since despite having low available contents of this element in the soil, it is fixed, and the Hass cultivar has the capacity to remove it, a situation most commonly observed in andisols (Osorio, 2014). This assessment is worthy of consideration in fertilization programs.

The extraction of elements such as N and K with the crops exhausts the natural reserve of the soil, therefore fertilization should be done not only with a view to nourishing the tree, but also to maintain the fertility levels of the root zone, necessary for the balance and sustainability of the soil resource. The crop nutritional requirements must be based on what happens under the management conditions where it is cultivated (Salazar-García *et al.*, 2013).

The differences in the amount of removed nutrients by the tissues are due to the proportion of each structure in the fruit. The pulp presented the highest amount of removed nutrients and the epidermis presented intermediate values. The highest pulp removal was due to the fact that the highest percentage of fruit biomass corresponded to this tissue (Salazar-García *et al.*, 2015). The testa was the tissue with less removed nutrients, which coincided with the reports of Mellado-Vásquez *et al.* (2015), in fruits of avocado cv. Méndez in the south of Jalisco (Mexico).

CONCLUSIONS

The tissue with the highest concentration of nutrients was the testa. The nutrient with the highest concentration in the four tissues was K, followed by N. The highest amount of nutrients removed was found in the pulp, followed by the seed, the epidermis and finally the testa. The order of total nutrient removal per ton of fresh fruit was: K> N> S> Mg> P> Ca> Fe> B> Zn> Mn> Cu.

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