DYNAMICS OF LEAF, FLOWER AND FRUIT ABSCISSION IN AVOCADO CV HASS IN ANTIOQUIA

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Abstract

The nutrient content in the leaf litter of avocado trees cv. Hass, constitutes an important source of mineral resources, consequently the quantification of its production and nature are crucial to understand the cycling of nutrients. The main objective of this study was to quantify the production of leaf litter, and fallen of flowers and small fruits in avocado orchards, in eight locations and in three producing areas of the Department of Antioquia (West, Southwest, and North).The highest leaf litter production occurred in the Southwest of Antioquia, being higher in Jardín (7.6 t.ha^{-1} year^{-1}); the locations of the East had similar leaf falling (4.03- 3.4 t ha^{-1} year^{-1}). The dry matter produced in the North was very similar in both locations. The dry matter obtained was 2.8 t ha^{-1} year^{-1} The highest contributions of leaf litter in all the locations were registered during the driest periods. It was found that approximately 80% of the fallen fruits correspond to diameters less than 1 cm. The highest productions and falling of flowers occurred in the locations of Southwest Antioquia, followed by the northern region.

Keywords: leaf litter, nutrient cycling, *Persea americana Mill*

Resumen

El contenido de nutrientes en la hojarasca de árboles de aguacate cv. Hass, constituyen una fuente importante de recursos minerales, por lo que la cuantificación de su producción y naturaleza son cruciales para comprender el ciclaje de nutrientes. El objetivo principal de este estudio fue cuantificar la producción de hojarasca, flores y frutos pequeños caídos, en huertos de aguacate, en ocho localidades y en tres zonas productoras del departamento de Antioquia (Oriente, Suroeste y Norte). La mayor producción de hojarasca se presentó en el Suroeste antioqueño, siendo superior en Jardín (7,6 t ha^{-1} año^{-1}); las localidades del oriente presentaron caída de hojas similares (4,03- 3,4 t ha^{-1} año^{-1}). La materia seca producida en el norte fue muy similar en ambas localidades. La materia seca obtenida fue de 2,8 t ha^{-1} año^{-1} Los mayores aportes de hojarasca en todas las localidades se presentaron durante las épocas más secas. Se encontró que aproximadamente el 80% de los frutos caídos corresponden a diámetros menores a 1 cm. Las mayores producciones y caída de flores se presentaron en las localidades del suroeste Antioqueño, seguido de la región del norte.

Palabras claves: Hojarasca, ciclaje de nutrientes, *Persea americana Mill*

Introduction

Worldwide avocado (*Persea americana Mill*) is grown in a very wide range of climates (Dreher and Davenport 2013). According to FAO (2013), avocado harvest incremented to 3.9 million tons in 2014, and more than 86 % was obtained in developing countries. Latin America and the Caribbean will be the main producing regions of the world, since Mexico and Chile are two of the largest exporters of avocado and currently, Peru and Colombia are rising in this market. The main Departments of avocado cv. Hass are Antioquia with 3,000 ha, Tolima with 2,000 ha, Caldas with 800 ha, *Eje Cafetero* (Coffee Region) (Quindío and Risaralda) with 700 ha, and Cauca and Valle del Cauca with 600 ha (Bernal and Díaz 2014).

The vigor of tree growth and fruit production depend on the timing and extent of phenological events, which are controlled by the availability of carbon and energy and their distribution (Wolstenholme and Whiley 1989) in response to environmental conditions (Scholefield et al., 1985). The leaves require about 40 days from sprouting to the transition from sink to source (Whiley 1990). During this period, they can compete for photoassimilates with the developing fruit (Buchholz 1986, Cutting and Bower 1990). As in most persistent leaf fruit trees, the growth of vegetative shoots in avocado is synchronized in flows that vary in vigor, duration and magnitude (Scora et al., 2002, Rocha-Arroyo et al., 2011), and which usually occur two or three times a year and may or may not include the entire tree (Davenport 1986).

One of the limitations for the production of avocado is that crops in Colombia are planted in soils, mostly strong to extremely acid and poor in nutrients (Tamayo and Osorio 2014). This is usually corrected with high doses of calcium, organic amendments and fertilizers, not only in the establishment, but also in the vegetative and productive period (Vitousek et al 1994, Aerts and Chapin 2000, Castellanos and Léon 2011). The continuous contribution to the soil, of the nutrients contained in the leaf litter through its decomposition, is one of the natural forms of renewal and maintenance of ecosystems (Wang et al., 2008).The e accumulation of plant residues on the surface of the soil has positive effects on their productivity, as it has been demonstrated in several studies on the positive effect of such inputs and on the decomposition processes of this leaf litter, both in natural systems and in those of agricultural or forestry production (Prause 1997, Palma et al 1998, Prause et al 2002, Domisch et al 2008). The hypothesis in our study suggests that the nutrients contained in leaf litter are important, they constitute an important source of resources, and consequently, the quantification of their production and nature are crucial to understand the cycling of nutrients. Therefore, a study was established to quantify the production of leaf litter, and fallen of flowers and small fruits in avocado orchards cv. Hass, in eight locations and three producing areas of the Department of Antioquia (East, Southwest and North)

Materials and methods

Experimental sites

The present study was carried out by the Corporación Colombiana de Investigación Agropecuaria AGROSAVIA, in five years old adult trees of avocado cv. Hass, grafted on Antillean race rootstocks, located in three producing areas of the Department of Antioquia (East, Southwest and North), in soils from acidic to strongly acidic pH, of medium content in organic matter, low in P, Ca, Mg, K and B and in general, of low fertility (Table 1).
Table 1. Chemical characteristics of the soils in the farms of the municipalities evaluated.

Site	pH	MO	Al	Ca	Mg	K	Na	P	S	Fe	Cu	Mn	Zn	B
		%	-----------------cmol$_c$ kg^{-1}----------					-----------------------mg kg^{-1}-------------------						
El Retiro 1	4,8	21	1,1	2,4	0,8	0,3	0,0	2,3	6	131	1,0	2,5	7,3	0,6
El Retiro 2	5,1	14	0,7	1,6	0,7	0,3	0,1	3,4	21	144	2,1	1,3	1,3	0,3
Rionegro	5,3	17,3	0,2	3,1	1,3	0,3	0,1	3,6	8	91	5,7	3,1	3,3	0,2
El Peñol	5,1	17,3	1,1	1,4	0,6	0,4	0,0	2,7	9	70	2,1	3,9	1,8	0,2
Amagá	4,9	4,8	1,7	2,1	0,7	0,4	0,0	2,8	21	285	2,2	3,8	1,8	0,2
Jardín	4,9	13,2	0,9	1,4	0,8	0,6	0,1	10,4	50	136	5,7	13,0	12,6	0,5
S. Pedro 1	5,3	9,5	0,5	2,4	0,8	0,4	0,1	3,7	12	266	6,2	6,3	4,5	0,2
S. Pedro 2	5,2	10,6	0,8	1,1	0,4	0,3	0,1	2,7	7	266	6,2	6,3	4,5	0,2

pH in water (1:1); Organic Matter Walkley and Black; Al KCl 1M; Ca Mg K and Na ammonium acetate 1M; P Bray II; S Calcium Phosphate 0.008 M; Fe Mn Cu and Zn Olsen-EDTA; B Hot water.

Leaf litter production, falling of flowers and fruits

The leaf litter production wasevaluated in 18 trees, in each locality. For this purpose, leaf litter traps were installed made from plastic mesh, with maximum retention of light, in the area projected by the tree canopy to the ground (5 x 4 m). Weekly, the fallen leaf litter was collected for 22 months, which was after dried in an oven at 65ºC, until obtaining a constant weight; then its dry mass was determined per month.

Statistical analysis

A completely random block design with 18 replications (one tree per replication) was used in eight farms (localities) of the Department of Antioquia. The difference in means was analyzed by means of a Tukey's test ($P \leq 0.05$). The variables evaluated were: production per plant of leaf litter, number of fallen flowers and fruits by size (<0.5; 0.5-1; 1-2; 2-3; 3-4; 4-5 and 5-6 cm in diameter)

Results and discussion

The contributions of leaf litter vary considerably according to the ecosystem considered; in this sense, the falling of leaves and flowers of trees in all locations was different, being higher in the Southwest, in Jardín (22.761 kg.plant^{-1}) and Amagá (19.43 kg.plant^{-1}), followed by the Northern sites, in San Pedro 2 (15.756 kg.plant^{-1}); the smallest contributions were from the locations of Eastern Antioquia such as Rionegro and El Retiro 2 (13.73 and 14.10 kg.plant^{-1}, respectively) (Table 2). The falling of flowers was also higher in the location of Jardín (754.974 flowers. plant^{-1}), following in order the locations of San Pedro 2, San Pedro 1, and El Peñol (272.360, 210.950 and 198.733, respectively).

Table 2. Falling of leaf litter and flowers in different locations.

Location	Leaf kg/plant *	Flowers No/plant *
Retiro 1	16,752 b	128,912 e
Retiro 2	14,103 b	75,850 g
Rionegro	13,734 bc	73,447 g
El Peñol	17,858 ab	198,733 d
Amaga	19,430 ab	85,963 f
Jardín	22,761 a	754,974 a
San Pedro 1	15,353 b	210,950 c
San Pedro 2	15,756 b	272,360 b
P	<0.0006	<0.0001

* Means with the same letter do not differ statistically, Tukey's (P≤0.05).

The highest contributions of leaf litter in all the locations occurred during the driest periods (Figure 1). This behavior may be associated with the biomass flows or changes in the physiological phases recently found by Bernal (2015). The leaf litter, in its decomposition process and even with some nutrient content, returns minerals back to the plant from the ground to the aerial part, to contribute with all the metabolic processes of it; in addition, it improves the physical condition of the soil, since it functions as a weed controller, maintains soil'shumidity in dry seasons, regulates the temperature of this in extreme times and protects it from erosion, as reported in several studies (Barlow et al. 2007; Schessl et al. 2008).

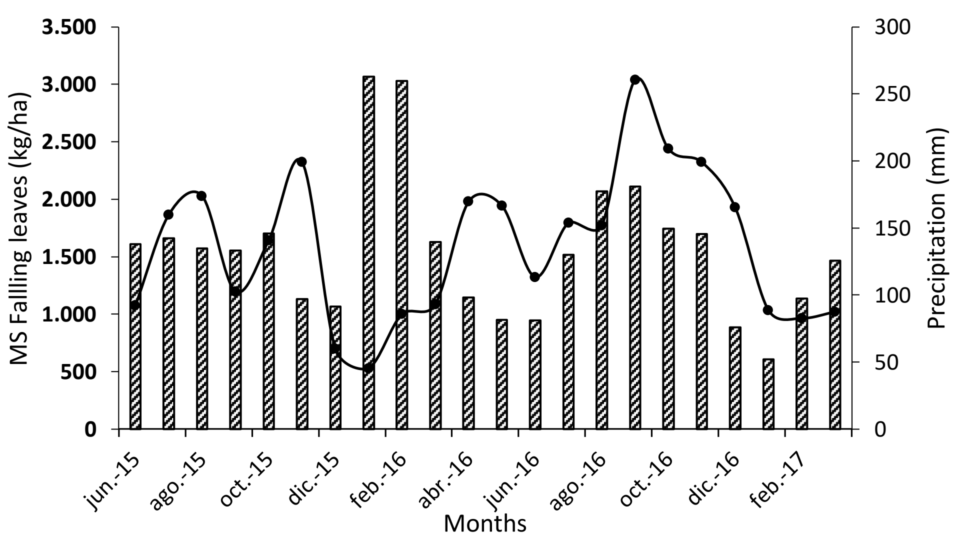

Figure 1. Behavior of the dry matter of the totality of falling leaves, in avocado trees of cv. Hass, planted in 8 farms, according to the rainfall

In a study carried out in avocado cv. Lorena, Romero (2012) found a direct relationship between the dry period and the stages of floral development. The peaks with the highest number of shoots in stages A and B occur during the dry season and the increase in rainfall coincided with a greater number of shoots in the D1 state, defined as the state of cauliflower (Salazar-García et al. 1998). The behavior found for the Colombian tropics coincides with the reports made by Wolstenholme and Whiley (1990) who describe water stress as an inductive of flowering for the tropics.

The location with the highest leaf fall was Jardín (Southwest) with 7.6 $t.ha^{-1}$ $year^{-1}$; followed by Amagá (6.42 $t.ha^{-1}$ $year^{-1}$) in the same area, and El Retiro 1 (East) (4.03 $t.ha^{-1}$ $year^{-1}$); the dry matter produced in the two locations of the North (San Pedro 1 and 2) was very similar, being on average 2.8 $t.ha^{-1}$ $year^{-1}$ (Figure 2). This behavior can be associated to a response of the tree to the lack of water, since by eliminating some leaves, this can reduce the loss by transpiration (Schaffer and Whiley 2007). The leaves that fall are the oldest, with self-shadowing by other leaves that, before falling, translocate good part of their mobile nutrients (N, P, K, Mg) to new leaves, flowers or fruits in formation. In this process of senescence, the leaves become chlorotic. It is worth noting that a non-mobile element such as Ca tends to remain in the leaves that fall and its potential contribution tends to be greater; hence, the falling of leaf litter constitutes a potential contribution of that element to the soil.

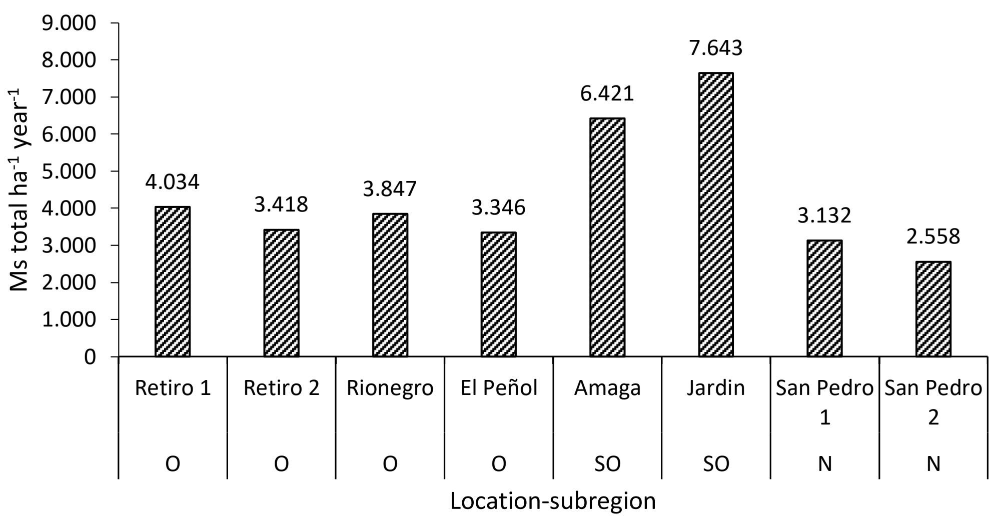

Figure 2. Dry matter behavior of the total fallen leaves in each location, in avocado cv. Hass in Antioquia.

In a study conducted by Tamayo (2016) on falling and decomposition of the leaf in avocado cv. Hass in several locations of Antioquia, it was found that the general pattern of nutrient release was: K>Ca>Mg>N>P. In addition, the soil fertility parameters evaluated changed according to the application of leaf litter inoculated with a saprophyte fungus (*Mortierella* sp.); on the other hand, the pH and the contents of K, Ca, Mg and P increased.

Fruit dropping

Avocado trees produce an excessive number of flowers, between 1 and 2 million per tree. However, only one or two fruits of each inflorescence reach maturity, this is how avocado fruit production could represent only 0.002 to 0.02% of the quantity of flowers produced initially. In this study, significant differences were found in the number of falling fruits by location; in the municipality of Jardín 52,926 fallen fruits of less than 0.5 cm were recorded, followed by El Peñol with 26,744 fallen fruits (Table 3); likewise, it was observed that 57% of the falling fruits correspond to those with diameters less than 0.5 cm, 24% with diameters between 0.5 and 1 cm; meaning, approximately 80% of the fallen fruits correspond to those with diameters less than 1 cm; when the fruit starts to develop, this falling percentage decreases considerably (Table 4).

Table 3. Number of fallen fruits, according to size and location.

Location	**<0.5 cm**	**0.5-1 cm**	**1-2 cm**	**2-3 cm**	**3-4 cm**	**4-5 cm**	**5-6 cm**
Retiro 1	10,522 d	5,463 c	1,719 b	1,062 b	766 b	28 c	1 c
Retiro 2	4,796 e	1,724 d	704 c	506 c	174 f	15 c	1 c
Rionegro	905 f	1,257 d	385 c	166 de	141 g	29 c	2 c
El peñol	26,744 b	2,114 d	1,462 b	273 cde	374 d	93 b	15 b
Amagá	19,457 c	7,614 b	1,656 b	304 cd	348 e	37 c	18 b
Jardín	52,926 a	17,509 a	4,256 a	506 c	449 c	240 a	45 a
San Pedro 1	2,504 ef	548 d	407 c	2,704 a	1,152 a	75 b	21 b
San Pedro 2	8,642 d	5,019 c	1,755 b	33 e	17 h	7 c	1 c
P	<0.0001	<0.0001	<0.0001	<0.0000	<0.0001	<0.0001	<0.0001

* Means with the same letter do not differ statistically, Tukey's ($P \leq 0.05$).

Table 4. Percentage of fallen fruits according to their size and location.

Location	**<0.5 cm**	**0.5-1 cm**	**1-2 cm**	**2-3 cm**	**3-4 cm**	**4-5 cm**	**5-6 cm**
Retiro 1	53.79	27.93	8.79	5.43	3.92	0.14	0.01
Retiro 2	60.56	21.77	8.89	6.39	2.20	0.19	0.01
Rionegro	31.37	43.57	13.34	5.75	4.89	1.01	0.07
El Peñol	86.06	6.80	4.70	0.88	1.20	0.30	0.05
Amagá	66.10	25.87	5.63	1.03	1.18	0.13	0.06
Jardín	69.70	23.06	5.61	0.67	0.59	0.32	0.06
San Pedro 1	33.79	7.39	5.49	36.49	15.54	1.01	0.28
San Pedro 2	55.85	32.44	11.34	0.21	0.11	0.05	0.01
%	57.15	23.60	7.97	7.11	3.70	0.39	0.07

In general terms, the Southwest region (Amagá and Jardín) has the highest average of fruit falling (51,878), followed by the Northern locations (San Pedro 1 and 2) with 13,099 fruits and finally the Eastern region (El Retiro 1 and 2, Rionegro and El Peñol) with 8,844 fruits (Figure 3). This first fall of fruit coincides with that reported by Wolstenholme and Whiley (1995), Rosales et al. (2003) and Cossio-Vargas et al. (2007), who assure that in avocado, there is an important fruit falling due to the competition between vegetative growth, root growth and fruit development, directly affecting productivity. Whiley et al. (1988) and Wolstenholme et al. (1990), indicate that in avocado, the plant adjusts its capacity to nourish the fruits by modifying its number, by means of the massive fall of freshly set fruits during the first three to four weeks and again, when the fruit has already reached a 10% and 40% of its size. It should be noted that fruit falling in avocado, when it has reached 2/3 or more of its size, can be accentuated by the single or excessive application of nitrogen fertilizers. Excess nitrogen stimulates a vigorous vegetative flow that increases this problem (Salazar 2002).

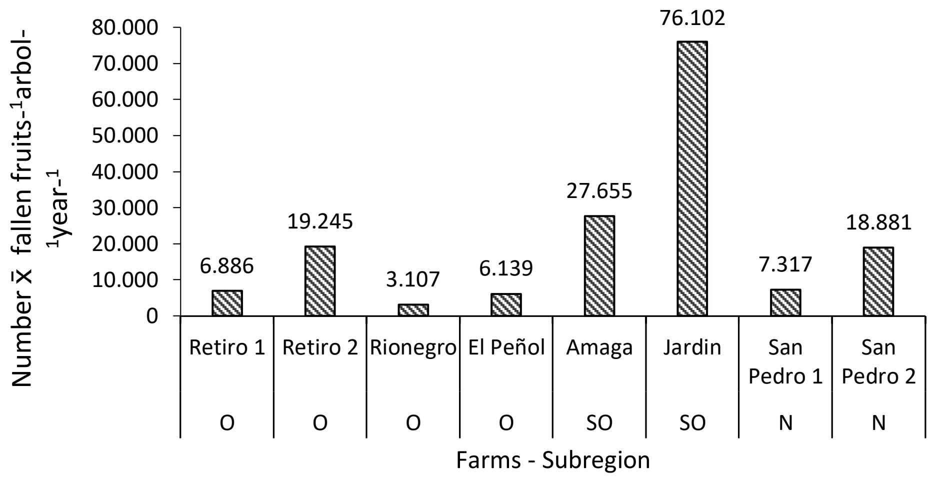

Figure 3. Fruit falling by subregion in avocado cv. Hass in Antioquia.

Several authors suggest that the reduced fruit set in avocado is explained by the competition between setting and vegetative growth, which occurs in indeterminate inflorescences. Studies carried out by Cutting and Bower (1990) reinforce this hypothesis, which increased the initial fruit set in indeterminate inflorescences by removing the vegetative bud; this can be explained by competition for carbohydrates, water or growth regulators, among others (Teliz 2002; Salazar 2007).

An idea about the potential avocado production can be obtained by comparing the energy cost of the fructification with the photosynthetic capacity of the tree (Wolstenholme 1986). The avocado fruit is rich in mono and polyunsaturated fats (oils). Thus, avocado has an "energy cost" higher than the cost of the fruits accumulating sugar with similar weight, as apples or citrus fruits (Teliz and Mora 2007). The consequence is a lower production per hectare (Wolstenholme, 1986, 1987). If the average potential production of an apple orchard of high density and intensive management on dwarf rootstocks was 100 t ha^{-1}, the equivalent energy cost for the avocado would be 32.5 t.ha-1 (Teliz 2000). One of the possible causes of the low yields of the avocado in Colombia and in several producing areas of the world is that the majority of the production is based on common cultivars, which have a low level of domestication (Wolstenholme and Whiley 1992; Mora 2007).

Falling of flowers

Figure 4 shows a high falling of flowers, with differences between loctions, the largest amounts being found in the Southwestern loctions, followed by those of the North of Antioquia. In avocado, for the Hass variety, it has been found that a tree can produce up to 2 million flowers, more than a thousand times the amount of fruit it can bear, but it has been estimated that it only reaches fruit set between 0.001% and 0.01 % (Whiley et al., 1988; Dixon and Sher 2002; Can-Alonzo et al., 2005; Cossio-Vargas et al., 2007a, Scora et al., 2007).

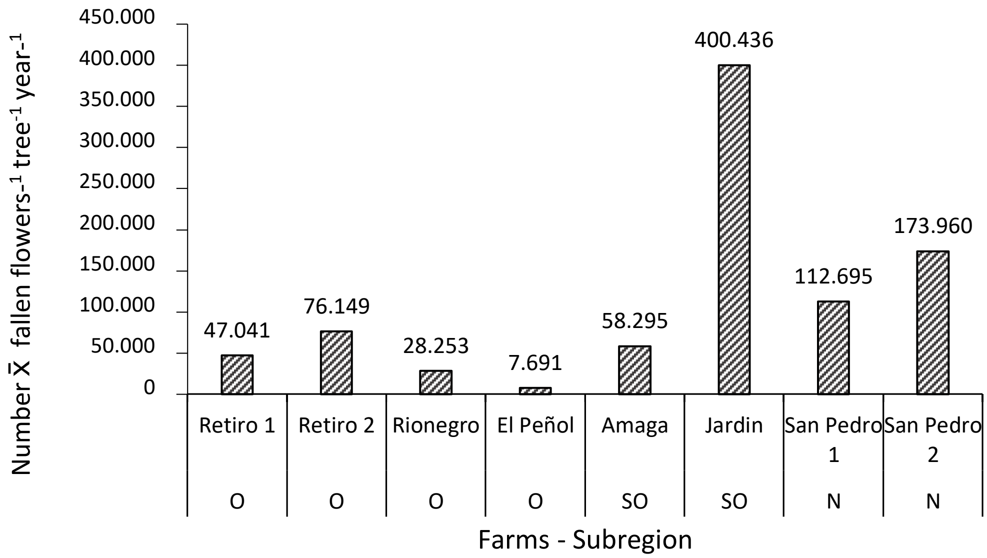

Figure 4. Falling of flowers by subregion in avocado cv. Hass in Antioquia.

Conclusions

The greatest contributions of leaf litter in all the locations occurred during the driest periods.

The locations that showed the highest leaf fall were the locations of Southwest Antioquia

In Antioquia it was found that 57% of the fruits that fall correspond to diameters smaller than 0.5 cm, likewise 24% fruits with diameters in 0.5 and 1, meaning that approximately 80% of the fallen fruits correspond to diameters less than 1 cm.

The highest amounts of fallen flowers were found in the locations of Southwest Antioquia, followed by the Northern region.

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