



Current overview of Hass avocado in Colombia. Challenges and opportunities: a review

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ABSTRACT: Colombia is the fourth largest avocado producer globally and the third largest in terms of harvested area, with a 6% share of the world area. The development and promotion of this production line represents an important source of growth in agriculture for Colombia, due to the generation of rural employment, equitable development across the different regions of the country, and due to the diversity of thermal floors and the different varieties planted. Imports of this product have decreased by 96% in the last four years from 3128 tons in 2014 to 133 tons in 2017. In recent years, the projects developed in the Colombian avocado sector have been aimed at the foreign market due to the profitability and demand of the Hass variety of this fruit. In addition, there is a state effort to implement plans for regions free of quarantine pests that allow access to foreign markets. This constitutes a strategic proposal made up of a coherent set of objectives, strategies and programmes which, based on a vision of the future, seek the initial goal of doubling the area of production. That move would ensure the technological and innovative conditions for sustainable and quality production, as well as achieve full links in international markets. This review aimed to know the main developments of avocado production in Colombia, its challenges and opportunities for the next decade.

Key words: fruit growing, production chains, research, technological development.

Visão geral atual do abacate Hass na Colômbia. Desafios e oportunidades: uma revisão

RESUMO: A Colômbia é o quarto produtor e o terceiro em termos de área colhida, com uma participação de 6% da área mundial. O desenvolvimento e a promoção desta linha produtiva representam para a Colômbia uma importante fonte de crescimento na agricultura, para a geração de emprego e desenvolvimento rural com equidade para as diferentes regiões do país, devido à diversidade de pisos térmicos e às diferentes variedades plantadas. As importações deste produto diminuíram 96% nos últimos quatro anos, passando de 3128 toneladas em 2014 para 133 toneladas em 2017. Nos últimos anos, os projetos desenvolvidos no setor de abacate colombiano têm como objetivo o mercado externo devido à lucratividade desta fruta por sua demanda com a variedade Hass. Além disso, há um esforço estatal para implementar planos para regiões livres de pragas de quarentena que permitam o acesso a mercados estrangeiros. Dessa forma, constitui uma proposta estratégica composta por um conjunto coerente de objetivos, estratégias e programas que, com base em uma visão de futuro, buscam o objetivo inicial de duplicar a área de produção, garantindo condições tecnológicas e de inovação com alcance total nos mercados internacionais. Esta revisão tem como objetivo conhecer os principais desenvolvimentos da produção de abacate na Colômbia, seus desafios e oportunidades para a próxima década.

Palavras-chave: fruticultura, cadeias produtivas, pesquisa, desenvolvimento tecnológico.

INTRODUCTION

In recent years in Colombia, the areas where avocado (*Persea americana* Mill) is planted have had a significant increase, not only because through research and the experiences farmers have increased knowledge about the management of the crop which generates confidence, but because the opening to international markets has generated certainty and better expectations for farmers who have chosen this fruit tree in the country. In addition,

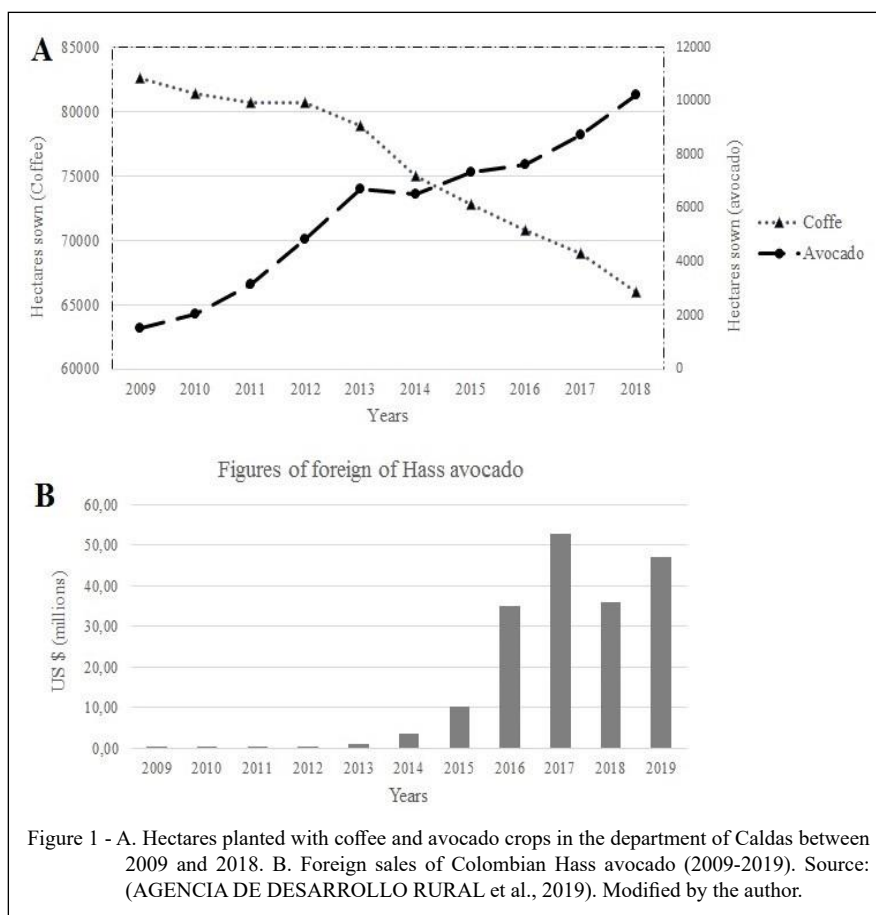
the avocado fruit has increased its demand in the markets for its functional compounds, given its beneficial effects on human health, since they have high amounts of monounsaturated fatty acids and antioxidants (WANG et al., 2019). The growing popularity of avocados has also led to the rise of avocado products, namely avocado oil. Avocado fat consists predominantly of monounsaturated oleic acid, which has been reported to reduce harmful low-density lipoprotein cholesterol, while maintaining beneficial high-density lipoprotein cholesterol, and

outperform typical low-fat diets (FULGONI et al., 2013). Although, avocado is consumed mainly fresh, a substantial increase in the use of avocado-based products (for example, guacamole) and oil for cosmetic and culinary purposes, also suggested further market growth (BOST et al., 2013). The pulp of the fruit is made up of 30% oil. Typical avocado oil has about 75% monounsaturated fats comprising oleic and palmitoleic acids, where 25% are saturated and polyunsaturated fatty acids (FOUDJO et al., 2013). The pulp of the fruit is made up of 30% oil. Typical avocado oil has about 75% monounsaturated fats comprising oleic and palmitoleic acids, where 25% are saturated and polyunsaturated fatty acids (AKTAR & ADAL, 2019).

Additionally, foreign investment has recently become one of the main factors for the vertiginous increase of the planted areas, due to the country's favorable climate that allows having permanent production during the whole year (GONZÁLEZ et al., 2018) a key difference from what happens with other world producers. The

socioeconomic importance of avocado at present contrasts with the reduction in area of one of the most representative crops of the country: coffee. The department of Caldas, considered a traditional coffee region, has seen a decrease of 15000 ha dedicated to coffee production between 2009 and 2018 (GRANADOS & VALENCIA, 2018). In contrast, there have been more than 8000 new ha planted in avocado, which makes this phenomenon one of the most evident impacts in the agricultural economy of the country, considered positive for avocado producers, and an opportunity for coffee growers (Figure 1 A).

Futhermore, it is important to point out that, from the different varieties of avocado present in Colombia, Hass is currently one of the most planted with 20% of the total area (MADR, 2019). Consequently, between 2016 and 2017 there were increases of 49% in the production of this variety in the country (FAO, 2017). Per capita consumption of avocado has been growing globally at a rate of 3.5% per year, in the global context, and it is projected to



continue doing so for several years, reaching values of 0.85 (kilograms/person/year). This data showed a promising scenario for high producing countries, which could see their agricultural sectors profit as demand increases and incomes rise for producers (ARIAS et al., 2018).

However, despite these figures, the country does not have enough information to allow it to apply technological developments to accompany the increase in new areas and safeguard current ones, in order to meet market requirements in fruit quality. The knowledge of the components of the productive function (genotype, environment and the interaction genotype x environment), would allow the country to understand more precisely the response of the species to the tropical conditions in which this fruit tree is currently exploited in the country (BERNAL et al., 2014). Thus this review aimed to know the main developments of avocado production in Colombia, its challenges and opportunities for the next decade.

Avocado cultivation in Colombia Characteristics

In Colombia, the avocado can grow in different thermal floors, from 1000 m above sea level to 2300 m. Currently, more than 10 varieties of avocado are grown throughout the country, being the cv. Hass has seen the largest increase in area in the last 4 years, due to the demand of the product in

international markets (GRANADOS & VALENCIA, 2018). According to this variation of climates, the composition, formation of secondary metabolites and nutritional qualities of fruits are highly variable and are influenced by factors such as climate, soil, temperature, humidity, amount of rain during fruit development and genotypic differences between cultivars (THOMAS et al., 2005). Thus, understanding the physiological behavior of avocado plants from obtaining the rootstock, sowing, flowering, crop management and subsequent harvest, added to the interaction with the soil and the climate environment, is integral to defining the productivity and quality of the fruits.

Therefore, the management currently given to orchards can be potentiated in terms of sustainability and productivity if research is carried out in this line. Currently in Colombia, the demand for research for this production chain is over 158 projects, of which 14.19% are oriented to the harvest and post-harvest areas, and 13.51% to planting material and genetic improvement, being these two areas the most preponderant in number of projects demanded (Table 1) (PORTAL SIEMBRA, 2019).

Furthermore, it is noteworthy that areas such as environmental management and sustainability, as well as the quality and safety of inputs and products, have not yet implemented research projects, especially when these two areas are of particular importance in

Table 1 - Number of research, development and innovation (R+D+i) projects demanded by the avocado agrochain in Colombia and their execution until 2020.

Areas of research, development and innovation (R+D+I)	Number of R+D+i projects (research demand)	Distribution in R+D+I (%)	Number of projects implemented (year 2020)	Projects carried out in the area of research (%)
Harvest and post-harvest handling	21	14.19%	5	23.81%
Environmental management and sustainability	9	6.08%	0	0.00%
Strengthening technical and functional capacities	9	6.08%	0	0.00%
Plant physiology and nutrition	11	7.43%	2	18.18%
quality and safety of inputs and outputs	11	7.43%	0	0.00%
Technology transfer, technical assistance and innovation	12	8.11%	3	25.00%
Partner economy, marketing and business development	12	8.11%	1	8.33%
Information systems, zoning and georeferencing	8	5.41%	1	12.50%
Planting and breeding material	20	13.51%	6	30.00%
Phytosanitary management	11	7.43%	13	118.18%
Management of the production system	13	8.78%	1	7.69%
Soil and water management	11	7.43%	0	0.00%
Total	148	100.00%	32	21.62%

Source: Portal siembra - Modified by the author. (PORTAL SIEMBRA, 2019).

view of the challenges faced by the country in the international market (PORTAL SIEMBRA, 2019).

Economic importance of avocado

Avocado production in the world has been increasing considerably (ARIAS et al., 2018); countries such as Mexico, Dominican Republic, Peru, Indonesia, Colombia, United States, Chile and Brazil are the largest producers (FAO, 2017). In the field of exports, Mexico leads the list with 46% of the total, while in imports, the United States, the Netherlands and France are the most demanding in the avocado market with 64% of total imports (FAO, 2017). Colombia is the fourth largest producer and the third largest in terms of harvested area, with a 6% share of the world's area (GRANADOS & VALENCIA, 2018). As such, there is a promising scenario for the country in economic terms against the cultivation of avocado. However, there is a lack of studies to better understand the ecophysiology of the tree and its influence on the processes of growth, development and production in Colombia (FISCHER & ORDUZ-ROGRÍGUEZ, 2012).

Hass avocado variety

The green-skinned 'Fuerte' avocado was initially one of the varieties preferred by consumers. But, as many of the other new varieties selected, it was plagued by short harvest seasons and erratic yields. The black-skinned Hass variety was selected in the 1920s at Rudolph Hass's farm in La Habra, California (SHEPHERD & BENDER, 2013).

In Colombia, production of the Hass cultivar is constant throughout the 12 months of the year (GONZÁLEZ et al., 2018), and especially during the months of October, January and February,

which are different from other producing countries and make Colombia an alternative for times of low supply (Table 2).

This variety is, along with strong, Reed and Collinred, one of the best for planting in cold moderate climate conditions in Colombia (1800 to 2600 m). Hass seems to present good organoleptic characteristics and has shown in Colombian soils higher yields per hectare than those presented by the main exporting countries, ranging from 12.4 to 18.8 t ha⁻¹ in trees of 8 and 9 years old (BERNAL et al., 2014).

Hass avocado in Colombia. promotion and development of the crop

The area of avocado cultivation in Colombia began to expand in the sixties, replacing the native avocado by the 'hass', because this crop had greater acceptance in international markets, excellent organoleptic characteristics and greater resistance to the post-harvest process (CARVALHO et al., 2015). A little more than 17 years ago, the cultivation of hass avocados started in three scenarios: the East of Antioquia, the North of Tolima and the Department of Cauca. Another small nucleus was located in the departments of Eje Cafetero: Caldas, Risaralda and Quindío. In May 2010 the first export to Europe was made. Colombia had 5880 ha of 'Hass', highlighting the leadership of Antioquia as a producer, with more than 40% of the cultivated area (GRANADOS & VALENCIA, 2018).

In 2013 the main producing departments of avocado 'hass' are Antioquia, Tolima, Caldas, Risaralda, Quindío, Cauca, Valle del Cauca, Santander and Nariño, for 2018, Tolima, Caldas and Antioquia are the departments that continue leading

Table 2 - Harvest schedule of avocado cv. Hass in different producing regions of Colombia.

-----Calendar Avocado Harvest hass-----												
Departament	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Antioquia	x	x		x	x	x	x		x	x	x	X
Caldas	x	x				x	x		x	x	x	X
Cauca									x	x	x	X
Risaralda	x	x				x	x		x	x	x	X
Quindio	x	x				x	x		x	x	x	X
Tolima	x				x	x				x	x	X
Valle del Cauca									x	x	x	X

Source: (HERNANDEZ, 2015).

the area planted with avocado 'hass' in the country (GRANADOS & VALENCIA, 2018).

According to the Horticultural Association of Colombia (ASOHOFrucOL), it is estimated that by the year 2022, the departments with the greatest potential for development in the avocado production chain would be Antioquia, Tolima, Caldas, Risaralda, Quindío and Valle del Cauca, and that with the help of the Program of Productive Transformation of the National Government of Colombia for the year 2030 a production of more than 404.700 t of avocado will be reached. From that crop, 165820 will be of the variety 'Hass'. In addition, they project a planted area of 31134 ha throughout Colombia, with more than 53% planted with var. Hass. According to the Ministry of Agriculture, the Hass variety currently corresponds to 21% of the total avocado planted area in the country and it is estimated that about 68% of the planted area is in productive age, and the rest is in development stage, therefore it is expected that the annual production of the fruit will gradually increase (GRANADOS & VALENCIA, 2018).

At this point, it is important to highlight that in the National Fruit Plan (NFP) it was elaborated 2006, projected an increase of 11750 new hectares of avocado planted by 2026 (ASOHOFrucOL, 2006). Likewise, it was estimated that the socioeconomic impacts of avocado for that same year would be GDP increases, greater numbers of direct and indirect jobs and increases in investment demand that led to a 67% increase in the socioeconomic impact of this crop compared to what was achieved in 2004. Likewise, it estimated the socio-economic impact of avocado for the same year represented by increases in GDP, a greater number of direct and indirect jobs and increases in investment demand that led to a 67% increase in the socio-economic impact of this crop compared to what was achieved in 2004. The current figures indicated that all forecasts are being surpassed and that the bet made by the national government and private entities in the cultivation of avocado has been a success for the country's economy and ratify the coming commitment with the challenges that are foreseen in this productive system.

International market of avocado Hass

During the last 15 years, the avocado has been consolidated as one of the fruits of greater demand in the world (CAVALETO, 2015). In Colombia, the avocado has traditionally been a high consumption food. However, the Hass variety only appeared on the national market since the year 2000. Ten years later, in May 2010, the first export of the

fruit in a 20 t container to France took place. At that time the country had only 5500 ha of Hass; today Colombia is positioned as the fifth largest producer of this variety with 5.7% of world production, from more than 24000 ha cultivated (CCCA, 2015). The value of exports has been increasing over time; while in 2017 sales were USD 52.94 million, in 2018 it increased by 18% to USD 62.73 million (ANALDEX, 2019).

Currently there are several destinations for Colombian avocado, the Netherlands being the main destination for exports of this product. According to AnalDEX statistics, it is estimated that from the avocado exports made in 2018, around 57% of the sales are directed to this European country. According to data from ProColombia, in the first half of 2019, exports of this product have increased by 37.6% (Figure 1B) and new destinations have been opened in countries in Europe and Asia. In Colombia there are currently 1710 producers who have cultivated more than 15000 ha, and ProColombia estimates that the country has the potential for 20000 ha.

Given the organoleptic characteristics and production throughout the year, it has allowed the opening of foreign markets and in order to consolidate export markets between 2010 and 2014, the national government, through the Colombian Agricultural Institute (ICA), signed 53 export protocols that allowed the entry of Colombian products to 18 countries. As of 2014, the health eligibility approach defined a target of 48 new products (two to the United States and 51 to the other countries), until 53 agricultural products became eligible in 2017 (DNP, 2018). Although, these figures are interesting and generate optimism, it should be clarified that the goal of products with sanitary admissibility to the United States was not met, since only two products obtained access (Cape gooseberry without quarantine cold treatment and hass avocado). This is due to the fact that Colombia lags behind in its ability to demonstrate the effectiveness of sanitary measures in terms of the appropriate degree of protection, in line with the principle of equivalence, according to the World Trade Organization Agreement (DNP, 2018).

In this sense, the sanitary measures are precisely those that had limited for years the access of avocado to the U.S. market since, under the climatic conditions of the Colombian territory, it was considered that there was a greater risk of propagation of pests typical of this fruit (VASQUEZ et al., 2019). For avocado cultivation, the species *Heilipus Lauri Boheman*, *Heilipus Trifasciatus Fabricius* (Coleoptera: Curculionidae) and *Stenoma catenifer Walsingham* (Lepidoptera: Elachistidae),

better known as fruit borers, were defined as quarantine pests restricting the trade of this product towards international markets (ICA, 2015). Against this background, In recent years, strategies and programs have been advanced that have improved the production process and increased the possibility of accessing new markets, being competitive, sustainable and preserving the current ones. An example of this is resolution No. 448 of 2016 of the Colombian Agricultural Institute (ICA), by which “the requirements for the registration of the production of vegetables for fresh export, the registration of exporters and the registration of the packing plants of vegetables for fresh export are established” (ICA, Colombian Agricultural Institute-Resolution No 448, 2016), this resolution leads to the use of protocols established by the ICA for the management of pests of official control, in which the procedures of surveillance and control for the registered agricultural species are established. Demands such as these have generated greater control and have allowed the responsible accompaniment of new areas planted with avocado; by 2013, for example, Colombia had just over 80 avocado farms registered with the ICA, in 2017, only in Caldas, there were 152 registered farms (ICA, 2017).

The above-mentioned indicated that the growth in area, production and participation in the international market of the Hass avocado in Colombia, has had the intervention and support of governmental and private entities that today support this productive chain, and make it promising for the Colombian agricultural sector.

Social and economic limitations in the production of Hass avocado in Colombia

Despite the increase in the area planted with ‘Hass’ avocado in Colombia in recent years, the production system has many limitations, due to rapid growth not always with adequate technological support, and planting in areas not suitable for this species (RAMÍREZ-GIL et al., 2018). Technological limitations in avocado cultivation are related to the scarce knowledge in aspects such as growth and development, phenology, rootstocks, ecophysiological studies, nutrition, use of growth regulators, water requirements and use of efficient native and introduced pollinators, among other aspects. This situation has prevented the country’s scientific community from understanding and potentializing the production process under conditions of the Colombian tropics (BERNAL et al., 2017).

Ecophysiology of avocado

In Colombia, there are many environments where this fruit tree is currently cultivated; however, the response of the ‘Hass’ variety to this diversity of climates has not yet been sufficiently studied to guarantee its adaptability and, above all, its productive potential. According to a study conducted in 2018 on the geographical potential of the ‘Hass’ avocado in Colombia, it was determined that the areas with greater potential for this crop are the northern altiplano and the eastern slopes of the western Andes, the southwestern region of the department of Antioquia, as well as the altiplano region called Valle de Los Santos (department of Santander), and in the inter-Andean valleys of the department of Cauca. The region with the least suitable areas was the region of Sumapaz in the department of Cundinamarca, the eastern slope of the central Andes in the department of Huila and the Andean region of the department of Nariño (RAMÍREZ-GIL et al., 2018).

Rootstocks

Furthermore, despite the sustained increase in production and exports, there is currently a systematic lack of knowledge about the genetic identity and suitability of the rootstocks planted and those offered by nurseries. This increases the risk that the use of rootstocks poorly adapted to Andean conditions will decrease productivity in the long term (BERNAL et al., 2017). In most of the Colombian planting areas of cv. Hass, there is incompatibility between the pattern and the crown, showing a lower growth in the patterns than in the cups; however, there is no information on the effect that this condition has on production or on the useful life of the orchard (BERNAL et al., 2014).

In countries such as the United States of America, Israel, South Africa and Australia, the use of clonal rootstocks is increasing every day, while in Latin America these have yet to be adopted to boost the productivity of orchards.

Pollinating insects

In Colombia, the increase in the area planted with avocado implies greater participation of pollinating insects such as bees (*Aphis mellifera* L.), the yields of most insects-mediated crops still depend largely on wild pollinators (GARIBALDI, et al., 2013). Avocado pollination cannot depend only on bees (GRASS, et al., 2018), but also on the diversity and abundance of insects naturally attracted by its flowers (CARABALÍ et al., 2017). Assessments in Pakistan and Kenya showed that among the visiting

insects of avocado flowers, such as Lepidoptera, Diptera (MEHMOOD et al., 2015), Coleoptera and Hemiptera (ODANGA et al., 2017) were present, thus demonstrating that there are other insects different than bees with potential for avocado pollination.

Pollinating insects are increasingly threatened and there are evident reductions in abundance and diversity. Such trend can be reversed through a combination of practices that include weeding before fruit harvest (VILLAMIL et al., 2018), conservation of wild flora and management of biological corridors, providing resources and nesting sites, making a targeted use of agrochemicals, and restoring forests and natural areas close to crops (CARABALÍ et al., 2017).

Other production constraints

The sanitary problems of the avocado in Colombia are headed by root rot due to the fungus *Phytophthora cinnamomi* Rands and the drying of trees due to *Verticillium* sp. (BERNAL et al., 2014). Many insects are associated with avocado in Colombia, but most of them are beneficial or harmless. Among the main pests are those with sucking habits, such as Monalonia, thrips, scale insects and mites. Also those with chewing habits, among which are the fruit and seed drillers and the Marceños (BERNAL et al., 2014).

Furthermore, the 'Hass' avocado in Colombia is produced mainly without irrigation, depending on rainfall to ensure production (DORADO et al. 2017), this means that at certain times of the year when there is not enough rainfall, the behavior of the tree may be affected, especially in its flowering phase and filling with fruit (ANGUIANO et al., 2007).

In this sense, research should be carried out in the country to promote the implementation and adequate use of irrigation systems, since as it is stated (DORADO et al., 2017), technifying the Hass avocado crop with a drip irrigation system, increases production by at least 23%, applying the adequate layer, which would allow recovering the investment in at least two production cycles.

Challenges and opportunities for the avocado production chain in Colombia

The differential that has the production of Colombian avocado, is its supply of production throughout the year. This advantage could be a bet to reach high quality standards and become one of the markets that bets on the internationalization of this product, mainly in the United States which is one of the largest consumers of Hass avocado in the world.

According to the Ministry of Agriculture and Rural Development (MADR, 2019), some of the challenges for the activity of planting, production and marketing of Hass avocado are: 1) to consolidate the organization of the chain; 2) to design a strategy to strengthen the follow-up, monitoring and control of free zones for sanitary admissibility; 3) to generate added value leading to market diversification; 4) to encourage technical assistance for the implementation of technological packages; and 5) to promote certification under traceability, quality and safety protocols.

It is important to consider at this point the need the country has to socialize with all the entities involved, which are the suitable areas for the establishment of the crop; at present, significant numbers of Hass avocado trees are constantly being planted without always taking into account the soil and climate characteristics of the area. It is very likely that, regardless of the soil and environmental offer where the trees are located, there will be fruits to be harvested. But the challenge for the country is to be productive and competitive, that is, to increase current yields and improve quality. Colombia has the potential to remain at the top of the list of countries with best yields and largest planted area, but as the number of trees planted grows, research and technical assistance must increase to accompany, for example, the 20182 ha of Hass avocado that were planted in the country in 2019.

CONCLUSION

Continue and strengthen the phytosanitary programs of quarantine pests and policies of the national government through its institutions and in alliance with private entities in order to ensure sustained growth of Colombia as an important player in international markets. The prospects for growth of the avocado market in the international context remain high, as a result of the strong demand in the United States and Europe; while countries like China, which are not yet big buyers, show promise for increasing demand, which would further boost the existing market.

Colombia presents optimal conditions for the development of cultivation and obtaining crops at times different from the main producing countries. It is evident the need to deepen in the investigation of the avocado crop in areas such as harvest, post-harvest and transformation management, planting material and genetic improvement, and management of the productive system to have a sustainable and lasting growth in time.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final.

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