CROP PRODUCTION AND MANAGEMENT

https://doi.org/10.1590/1678-4499.20220055

Article

Economic and quality study of purple passion fruit grafted on a fusarium wilt tolerant rootstock

Camila Lopez[1], Alejandro Hurtado Salazar[1,*], John Ocampo[2], Danielle Fabiola Pereira da Silva[3], Nelson Aguirre Ceballos[1]

1. Universidad de Caldas – Producción Agropecuaria – Manizales, Caldas, Colombia.
2. Universidad Nacional de Colombia – Ciencias Agropecuarias – Palmira, Valle del Cauca, Colombia.
3. Universidade Federal de Jataí – Jataí (GO), Brazil.

Received: Dec. 10, 2021 | **Accepted:** May 4, 2022

Section Editor: Cláudia Sales Marinho

***Corresponding author:** alhuza@gmail.com

How to cite: Lopes, C., Salazar, A. H., Ocampo, J., Silva, D. F. P. and Ceballos, N. A. (2022). Economic and quality study of purple passion fruit grafted on a fusarium wilt tolerant rootstock. Bragantia, 81, e3522. https://doi.org/10.1590/1678-4499.20220055

ABSTRACT: The aim of this work was to determine the influence of *Passiflora maliformis* as rootstock on the physical characteristics of fruits, productivity, and profitability of the purple passion fruit. The study was carried out from May 2020 to April 2021, under a 3 × 3 factorial design distributed in blocks with three repetitions. The treatments were represented by three scions of elite accessions of purple passion fruit PutEdu01, TesEdu11 and a commercial scion, and three rootstocks, ungrafted, autografted and *P. maliformis*. Conventional cleft grafting was used. The fresh fruit mass, the shell weight, the pulp weight, the fruit diameter, the polar diameter of the fruit, the percentage of pulp and skin were evaluated. As economic variables, production costs, income, and their cost benefit ratio were determined. The quality of the fruits derived from the grafted accessions in *P. maliformis* was within the fresh marketing standards, presenting a pulp yield of more than 50%. The combinations of the purple passion fruit TesEdu11 accessions and the commercial one grafted onto *P. maliformis* as the elite accession PutEdu01 without grafting were financially attractive because they presented a cost-benefit ratio greater than one at two years after starting the crop.

Key words: *Fusarium* sp., *Passiflora edulis* f. *edulis* Sims, *Passiflora maliformis*, bioprospecting.

INTRODUCTION

The cultivation of purple passion fruit (*Passiflora edulis* f. *edulis* Sims) is currently very profitable since there is a great international demand for the fruit, and Colombia stands out for being a great potential producer. In fact, in recent years, purple passion fruit has occupied the second export line within exotic fruits, only after cape gooseberry (Agudelo 2019).

Similarly, purple passion fruit has been one of the Colombian products that performed well in the previous year, when the value of exports increased by 3.8%, from USD FOB 33.25 million in 2019 to USD FOB 34.51 million for 2020. It shows a growth in the intrinsic value of the product in international markets (Ocampo et al. 2021).

Added to the economic importance of the crop, there is the appearance of the fruit, which is the criterion most used by consumers to evaluate the quality of the fruit (Krause et al. 2012). A quality fruit is one that meets the expectations of different consumer segments, both in its internal and external characteristics. The internal characteristics are related to flavor (soluble solids and acidity) and juice content (yield), and the external ones to a good appearance (skin color, size, weight, absence of fruit defects), given certain standards to achieve the desired quality in the markets, allowing the identification of elite accessions with high quality fruits (Ocampo et al. 2013).

On the other hand, the cultivation of purple passion fruit presents phytosanitary problems that have generated discouragement among producers, due to the increase in production costs that implies adopting corrective measures. Facing

CC BY

up these inconveniences, farmers choose to abandon crops affected by diseases, which thus become sources of contamination for other nearby crops. It also happens that producers transfer purple passion fruit material to other regions of the country, thus spreading pathogens that disseminate to new areas previously free of these diseases (Guerrero et al. 2016).

According to Ángel et al. (2018), the economic losses due to fusarium wilt can rise from 90 to 100% in passion fruit, and although reports of economic losses are scarce in passion fruit, different authors affirm that they are considerable. In Australia, for instance, fusarium wilt was one of the main diseases that affected this crop before the use of resistant rootstock. More recently, Rheinlander (2010) mentions that the disease may be present in Brazil, Malaysia, and South Africa, which indicates the need to search for alternatives.

One of the alternatives is the use of rootstocks that are widely adopted in fruit growing and other perennial species to propagate superior genotypes, control the size of the plant, reduce the juvenile period, adapt the plant to adverse soil conditions and offer resistance to pests and diseases (Machado et al. 2013, Atucha et al. 2014, Hurtado-Salazar et al. 2015).

The resistance to fusarium wilt by some wild species, such as *Passiflora suberosa*, *Passiflora alata*, *Passiflora coccinea*, *Passiflora gibertii* and *Passiflora maliformis*, was reported by Silva et al. (2013). Hurtado-Salazar et al. (2016) evaluated the effect of the rootstock and the type of graft on the quality of passion fruit, finding that the rootstocks used (*Passiflora edulis*, *Passiflora mucronata* and *P. gibertii*) did not influence the content of soluble solids (SS), titrable acidity (AT), and its SS/AT ratio. Likewise, the grafting method did not affect diameter, length, fresh fruit mass, shell mass and thickness, juice yield, and total soluble solids (TSS) content. However, there is little information on the effect of wild passionflower species as rootstock and its influence on the physical characteristics of purple passion fruit fruits. Thus, the objective of this work was to determine the influence of the wild species *P. maliformis* as rootstock of the purple passion fruit and its effects on the quality of its fruits.

MATERIALS AND METHODS

Study area

The study was carried out from May 2020 to April 2021 in the municipality of Manizales (5,029552 N; 75 W), Caldas, Colombia, in an area with a history of premature death of plants (100% incidence), located at 2,280 meters above sea level. The experimental field presents an average temperature of 17 °C, relative humidity of 78%, annual average rainfall of 1,800 mm, undulating and sloping topography, soils are volcanic in origin, with a loamy texture, and solar brightness of 2,010 h annually, with a solar radiation of 320-350 calories·cm^{-2}·day^{-1} (Herrera et al. 2016).

Plant materials

The purple passion fruit accession PutEdu01 and TesEdu11, from the Palmira National University of Colombia, the commercial control of purple passion fruit, and the rootstock *P. maliformis* from a fruit exporter were used. The seeds of each material were sown in plastic trays 54 cm long × 28 cm wide.

The commercial purple passion fruit material was delivered to the experimental field by the exporting company with the ideal conditions to take to the field for transplantation. The *P. maliformis* rootstock was donated by this same company.

Grafting

The purple passion fruit seedlings for grafting were selected 120 days after sowing with height between 10-13 cm. The rootstock used was *P. maliformis* with 150-day-old plants, when the diameter was 0.5 cm. The grafting on the rootstock was at the top-wedge, where the main stem is cut from the rootstock and a V-shaped slit is made. The graft, called scion, is a small branch that contains two or three buds.

Establishment in the field

The support system was established in semi-cover with a simple layer at a distance of 4 m between bamboo and 2 m between paths, and the purple passion fruit plants were planted at 2 m between plants and 2 m between paths. One hundred and 30 days after grafting, the plants were transplanted.

Weed control was carried out by manual weeding in the row, and mechanical control with a scythe was maintained between rows, cutting whenever necessary.

The formation and production fertilizations were carried out after the establishment of the seedlings in the field, following the recommendation of Ocampo and Wyckhuys (2012), which corresponded, in the formation phase, to 30 g of ammonium nitrate at 30 days, 45 g of ammonium nitrate at 60 days, 100 g of the 05-20-20 formula at 90 days and 150 g of the 20-05-20 formula at 120 days after sowing.

In the production fertilization, 100 $k \cdot ha^{-1}$ of N, 100 $k \cdot ha^{-1}$ of P_2O_5, and 200 $k \cdot ha^{-1}$ of K_2O were used in eight intervals, from May 2020 to February 2021.

Variables evaluated

For the quality of the fruit, the physical characteristics such as the average shell weight (SW) of each fruit were evaluated with a digital scale expressed in g. For the average pulp weight (PW), a digital scale with a reading expressed in g was used. For this, the fruits corresponding to the sampling unit of each treatment were identified, and each fruit was harvested and weighed. Thirty fruits per plant were evaluated for a total of 450 fruits per treatment.

The pulp percentage was evaluated at 307 days after transplant (DAT); for the fruits of each combination, the relationship between the weight of the pulp and the weight of the fruit was used with Eq. 1:

$$\text{Pulp percentage} = \frac{\text{Pulp weight (g)}}{\text{Fruit weight (g)}} \text{ X } 100 \tag{1}$$

The shell percentage was evaluated at 307 DAT. For the fruits of each combination, the relationship between the weight of the shell and the weight of the fruit was used with Eq. 2:

$$\text{Shell percentage} = \frac{\text{Shell weight (g)}}{\text{Fruit weight (g)}} \text{ X } 100 \tag{2}$$

For the pulp percentage *versus* the shell percentage, the results of the pulp extracted from the fruits of each combination were added, and the same procedure was carried out for the shell at 307 DAT.

The fruit diameter (FD) was calculated by measuring the fruits per plant of each combination in the equatorial region of these with the use of a digital caliper, and its reading was expressed in cm.

The polar diameter (PD) of the fruit was calculated by measuring the longitudinal axis of the fruit per plant of each combination, using a digital caliper, and its reading was expressed in cm.

The estimated production per plant was measured at 307 DAT, and it was carried out by taking the data of the average fruit weight with the number of fruit set per plant, and these data were multiplied, thus obtaining the estimated production per plant in the first productive cycle.

Determination of production costs and profitability of the combinations

For the analysis of production costs, a record was kept of the agronomic tasks, and efficiency was evaluated taking into account the time taken for each task. All the values in the calculation of the production costs were quoted in Manizales, in the fourth quarter of 2020. As a reference for the costing, market prices in Manizales for the fourth quarter of 2021 were used. The reference price for the calculation of the benefit/cost ratio (RB/C) was made with the average price per kg of purple passion fruit handled by one of the country's exporters, together with the averages of the qualities for its farmers in the markets of the region over the past three years (2019, 2020 and 2021).

For the definition of production costs, the concept of operational cost was applied (Hoffmann et al. 1987), which includes all production costs, without taking into account the interests of the invested capital. Thus, it was possible to obtain production costs and cash flows, on the basis of which the profitability of the crop was estimated, directing the product to the local market.

For the characterization of production costs, records were kept in a cost calculation sheet adopted from the Colombia International Corporation model (SIPSA, 2021). All values were calculated in US dollars per hectare ($USD{\cdot}ha^{-1}$) with the exchange rate reported in the fourth quarter of 2021 according to the Bank of the Republic of Colombia.

After the production costs were defined, the cash flow was estimated, considering an investment of 15 months. The values were expressed in US dollars per hectare at the time of the investment.

To analyze the profitability of the crop, the following financial indicators were calculated: income, production costs, and economic indicators for each combination, such as the cost benefit ratio (RB/C).

Experimental design and data analysis

It was established in a randomized complete block design with a 3 × 3 factorial arrangement, in which three rootstocks were evaluated (without grafting, autografting and *P. maliformis*), for three scions (TesEdu11, PutEdu01, and a commercial one as a farmer-type control), with three repetitions and five plants as an experimental unit for a total of 15 plants evaluated per combination. The data obtained were evaluated by analysis of variance using the statistical program SAS, version 9.0 (SAS Institute Inc., Cary, NC, United States of America). Additionally, comparative means tests were performed by means of Tukey's test at a significance level of 5%.

RESULTS AND DISCUSSION

The variables associated with fruit quality such as equatorial diameter and PD did not show significant statistical differences between the combinations, indicating that the rootstock has no effect on the diameters of the fruit. However, it was observed that the rootstock does have a significant effect on the yield components that allow a variation and differential projection for the fruit in production per plant and for the expected yield (Table 1).

In the analysis of the equatorial diameter, no statistical differences were found, being the commercial purple passion fruit the one with the largest equatorial diameter, 5.5 cm, followed by the purple passion fruit accession TesEdu11 autografted, with 5.43 cm. The elite accessions PutEdu01 and TesEdu11 ungrafted were 5.31 and 5.25 cm, respectively. The combination of the accession TesEdu11 with the rootstock did not show any difference with the ungrafted commercial purple passion fruit with 5.21 and 5.20 cm, respectively. The combinations commercial purple passion fruit *P. edulis* f. *edulis*/*P. maliformis*, the elite autografted accession PutEdu01 and PutEdu01 *P. edulis* f. *edulis*/*P. maliformis* were 5.18, 5.08, and 5.08 cm, respectively. These last two combinations were the ones that presented the smallest diameter, as observed in Table 1.

These results indicate that the rootstock has no effect on the equatorial diameters of the purple passion fruit. According to Pachón et al. (2006), the purple passion fruit produces fruits with a diameter between 4 and 8 cm, which agrees with Pinzón et al. (2007), since the evaluated fruits presented equatorial diameters between 5 and 5.6 cm.

Ocampo et al. (2021) describe the main factors that can influence the size of the fruit: the leaf-fruit^{-1} ratio, the number of fruits per tree, the age of the plant, the fertilization scheme and soil management, the phytosanitary status of the plant, pruning and thinning of fruits, climate, period of time of growth and state of maturity at harvest.

For the PD, there were significant differences for the combinations of commercial purple passion fruit *P. edulis* f. *edulis*/*P. maliformis* with 6.09 cm and the elite accession PutEdu01 with 6.08 cm, compared to the commercial autografted purple passion fruit combination with 5.08 cm. With respect to the other combinations, there were no statistical differences (Table 1).

Table 1. Physical characterization of purple passion fruit fruits (*Passiflora edulis* f. *edulis* Sims), grafted on *P. edulis* Sims and *Passiflora maliformis* and without grafting (via seed), in Manizales, Caldas, Colombia. Equatorial diameter (cm), polar diameter (cm), fruit weight (g), pulp weight (g), shell weight (g), pulp, and shell percentage*.

Combination	Equatorial diameter (cm)	Polar diameter (cm)	Fruit weight (g)	Pulp weight (g)	Shell weight (g)	Pulp (%)	Shell (%)
(TesEdu11) *Passiflora edulis* f. *edulis* Sims (via seed)	5.25 ns	6 ab	51.4 bc	25.25 bc	26.15 ab	49.12	50.88
(TesEdu11) *P. edulis* f. *edulis*/ *P. maliformis*	5.21 ns	5.9 ab	51.4 bc	27.29 bc	24.11 cd	53.09	46.91
(TesEdu11) *P. edulis* f. *edulis*/ *P. edulis* f. *edulis* (autograft)	5.43 ns	6 ab	49.1 bc	24.14 c	24.96 cd	49.16	50.84
(PutEdu01) *P. edulis* f. *edulis* (via seed)	5.31 ns	6.1 ab	52 bc	26.15 bc	25.85 ab	50.29	49.71
(PutEdu01) *P. edulis* f. *edulis*/ *P. maliformis*	5.08 ns	5.8 ab	47.8 c	24.17 c	23.63 cd	50.56	49.44
(PutEdu01) *P. edulis* f. *edulis*/ *P. edulis* f. *edulis* (autograft)	5.08 ns	5.8 ab	48 c	24.83 bc	23.17 d	51.73	48.27
(Commercial) *P. edulis* f. *edulis* (via seed)	5.5 ns	6 ab	52.1 bc	26.88 bc	25.22 cd	51.59	48.41
(Commercial) *P. edulis* f. *edulis*/ *P. maliformis*	5.18 ns	6.1 a	59.2 a	31.18 a	28.02 a	52.67	47.33
(Commercial) *P. edulis* f. *edulis*/ *P. edulis* f. *edulis* (autograft)	5.2 ns	5.7 b	54 b	27.8 b	26.2 ab	51.48	48.52

*Averages with different letters indicate a significant difference according to Tukey's test ($P < 0.05$); ns: not significant.

Fruit weight

Regarding fruit weight at 307 DAT, significant differences were found between the commercial purple passion fruit grafted with *P. maliformis* with 59.2 g·plant^{-1} compared to the other combinations, and this grafted material was the one with the best weight. The commercial purple passion fruit autografted, with 54 g·plant^{-1}, also had significant differences with respect to the combinations of the elite accession PutEdu01 autografted with 48 g·plant^{-1} and PutEdu01 *P. edulis* f. *edulis*/ *P. maliformis* with 47.8 g·plant^{-1}. These last two combinations were the ones that yielded the lowest fruit weight. For the other combinations, there were no statistical differences among them (Table 1).

Hernández et al. (2009) affirm that the rootstock has an influence on the weight of the fruit, since the rootstock can have a greater capacity for absorbing water and nutrients, and the compatibility. In this regard, Lee and Oda (2002) mentions that one of the basic purposes for grafting is the use of the vigorous root systems of the rootstocks. Grafted plants tend to show higher water and mineral uptake compared to ungrafted plants.

On the other hand, Ozlem et al. (2007) carried out the experiment in grafted watermelon (*Citrullus lanatus* (Thunb.) Matsum and Nakai), finding a higher weight of the fruit compared to ungrafted watermelon, supporting their results on the advantages of plant grafting, since these can be tolerant to low temperatures and salinity, and they can have a greater absorption of water and nutrients. The greater weight of the fruit could also be related to the fruit load, since a smaller number of fruits can determine a greater individual weight of them, due to a greater availability of water, nutrients and photosynthates (Fischer et al. 2018).

Statistical differences were found in pulp weight and shell weight between the combinations. The combinations that had a pulp percentage higher than 50% stand out, as they are all the accessions grafted onto the rootstock *P. maliformis*. In this way, the rootstock *P. maliformis* presents a good potential for use taking into account that it does not negatively affect the pulp yield, and it is one of the main characteristics for its commercialization. On the other hand, the combinations that presented a percentage higher than 50% in the percentage of shell are the accession TesEdu11 (via seed) and autografted with 50.88 and 50.84%, respectively (Table 1), denoting with this a low pulp yield for the accession TesEdu11, considered unwanted in the fresh industry and market. Meanwhile, Fischer et al. (2018) found a higher percentage of pulp in the fruits obtained by grafting and a lower percentage in the fruits obtained from ungrafted plants.

Regarding the shell weight at 307 DAT, it was observed that the combination of commercial purple passion fruit on *P. maliformis* presented the highest weight with 27.91 g·plant^{-1} and significant differences with respect to the combinations of commercial purple passion fruit autografted with 24.75 g·plant^{-1}, followed by combinations of the accessions TesEdu11 self-grafted, with 24.64 g·plant^{-1}, TesEdu11 *P. edulis* f. *edulis*/*P. maliformis*, with 24.43 g·plant^{-1}, elite accession PutEdu01 autografted, 22.92 g·plant^{-1}, and purple passion fruit PutEdu01 *P. edulis* f. *edulis*/*P. maliformis*, 22.33 g·plant^{-1}. This last combination presented the lowest shell weight of all the evaluated combinations, as can be seen in Table 1.

The commercial purple passion fruit on *P. maliformis* did not present statistical differences compared to the combinations of the commercial accession autografted with 26.2 g·plant^{-1}, followed by the accessions purple passion fruit TesEdu11 and PutEdu01 without grafting with 26 and 25.39 g·plant^{-1}, respectively. Fischer et al. (2018) found a higher percentage in skin in grafted tree tomato plants when compared to ungrafted plants.

Costs of purple passion fruit grafted and planted in one hectare with semi-cover

Table 2 describes the cost analysis for the first 24 months of the crop, including the cost of labor, general inputs for the crop, such as the cost of the structure or the semi-cover of the plants, and irrigation for 1 hectare of purple passion fruit. It was observed that the combinations of the accessions of grafted purple passion fruit TesEdu11 *P. edulis* f. *edulis*/*P. maliformis*, the elite accession PutEdu01 and commercial purple passion fruit grafted on *P. maliformis* were the only combinations that generated profits two years after starting cultivation with semi-cover, with a cost benefit ratio (RB/C) of 1.56, 1.03, and 1.29, respectively (Table 2).

Table 2. Structure of production costs, yield, income in USD·ha^{-1} and their cost benefit ratio (RB / C) of nine combinations of grafted purple passion fruit in Manizales, Caldas, Colombia.

Concept per hectare	Combinations								
	(TesEdu11) *P. edulis* f. *edulis* (via seed)	**(TesEdu11) *P. edulis* f. *edulis*/ *P. maliformis***	**(TesEdu11) *P. edulis* f. *edulis*/*P. edulis* f. *edulis* (autograft)**	**(PutEdu01) *P. edulis* f. *edulis* (via seed)**	**(PutEdu01) *P. edulis* f. *edulis*/ *P. maliformis***	**(PutEdu01) *P. edulis* f. *edulis*/*P. edulis* f. *edulis* (autograft)**	**(Comercial) *P. edulis* f. *edulis* (via seed)**	**(Comercial) *P. edulis* f. *edulis*/ *P. maliformis***	**(Comercial) *P. edulis* f. *edulis*/*P. edulis* f. *edulis* (autograft)**
Irrigation (USD$)	$ 3,898	$ 3,898	$ 3,898	$ 3,898	$ 3,898	$ 3,898	$ 3,898	$ 3,898	$ 3,898
Semi-covers (USD$)	$ 6,677	$ 6,677	$ 6,677	$ 6,677	$ 6,677	$ 6,677	$ 6,677	$ 6,677	$ 6,677
Supplies (fertilizers, fungicides, insecticides and biologics) (USD$)	$ 5,414	$ 5,414	$ 5,414	$ 5,414	$ 5,414	$ 5,414	$ 5,414	$ 5,414	$ 5,414
Other (USD$)	$ 3,728	$ 3,728	$ 3,728	$ 3,728	$ 3,728	$ 3,728	$ 3,728	$ 3,728	$ 3,728
Labor (USD$)	$ 19,708	$ 19,708	$ 19,708	$ 19,708	$ 19,708	$ 19,708	$ 19,708	$ 19,708	$ 19,708
Total costs (USD$)	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**	**$ 39,425**
Export quality production (kg·ha^{-1})	25,371	52,494	29,043	39,866	34,433	23,943	35,576	43,258	18,558
National quality production (kg·ha^{-1})	22,326	46,195	25,558	35,082	30,301	21,070	31,307	38,067	16,331
Fruit income Export (USD$)	$ 28,105	$ 58,150	$ 32,172	$ 44,161	$ 38,143	$ 26,523	$ 39,409	$ 47,919	$ 20,557
Fruit income National (USD$)	$ 1,698	$ 3,514	$ 1,944	$ 2,669	$ 2,305	$ 1,603	$ 2,382	$ 2,896	$ 1,242
Income (USD$)	**$ 29,803**	**$ 61,664**	**$ 34,116**	**$ 46,830**	**$ 40,448**	**$ 28,125**	**$ 41,791**	**$ 50,814**	**$ 21,800**
R B/C	**0.76**	**1.56**	**0.87**	**1.19**	**1.03**	**0.71**	**1.06**	**1.29**	**0.55**

On the other hand, the TesEdu11, PutEdu01 and commercial accessions that were not grafted presented low profitability with an RB/C of 0.76, 1.19 and 1.06, respectively (Table 2). This is how the need for this grafting practice is clear, with the increase in the profitability of the crop with a decrease in the impact of soil diseases, complemented with the integrated management of the crop. According to Furlaneto et al. (2011), evaluating the production costs and profitability of the passion fruit crop, they showed that the profitability indicators are unfavorable for the passion fruit production system, due to the high price of inputs and practices for pest control diseases. These same authors highlight the need for technical adjustments related to the phytosanitary management of the crop to reduce the total cost of production in order to make the activity profitable.

The grafted TesEdu11, PutEdu01 and commercial accessions obtained high yields of first quality fruit (export type), with 52.4, 34.4 and 43.2 $t{\cdot}ha^{-1}$, respectively (Table 2). It shows that they were financially attractive for obtaining an RB/C greater than 1, while Lima et al. (2009), in Brazil, analyzed the profitability of passion fruit in six Brazilian production centers and observed that the cultivation of yellow passion fruit is economically viable when productivity is greater than 19 $t{\cdot}ha^{-1}$ year. However, due to the strong increase in the price of inputs and the stability of the price of a kg of fruit in recent years (average of $1.01{\cdot}kg^{-1}$), it is necessary to increase productivity per hectare, as well as minimize inputs to make the activity economically sustainable.

CONCLUSION

The quality of the fruits derived from the accessions grafted onto the rootstock *P. maliformis* was within the fresh marketing standards, presenting a pulp yield of more than 50%.

Combinations of accessions of grafted purple passion fruit TesEdu11 (*P. edulis* f. *edulis*/*P. maliformis*) and the grafted commercial accession (*P. edulis* f. *edulis*/*P. maliformis*), such as the elite accession PutEdu01 ungrafted (*P. edulis* f. *edulis* – via seed), were financially attractive because they presented a cost-benefit ratio greater than one at two years after starting the crop. The other combinations did not show utility.

AUTHORS' CONTRIBUTION

Conceptualization: Hurtado-Salazar, A., Ceballos-Aguirre, N. and Ocampo, J.; **Methodology:** Hurtado-Salazar, A., Ceballos-Aguirre, N., Lopez, C., Silva, D. and Ocampo, J.; **Investigation:** Lopez, C. and Hurtado-Salazar, A.; **Writing – Original Draft:** Hurtado-Salazar, A., Ceballos-Aguirre, N., Lopez, C., Silva, D. and Ocampo, J.; **Writing – Review and Editing:** Hurtado-Salazar, A., Ceballos-Aguirre, N. and Ocampo, J.

DATA AVAILABILITY STATEMENT

All dataset were generated and analyzed in the current study.

FUNDING

Not applicable.

ACKNOWLEDGMENTS

The authors thank the Universidad de Caldas and Universidad de Pamplona for their technical support during the research.

REFERENCES

Agudelo, L. (2019). Fortalecimiento del área técnica y de mercados a unidades productivas de gulupa (*Passiflora edulis* sims) en el municipio de Duitama bajo el enfoque de cadena de valor. Duitama: Universidad Pedagógica y Tecnológica de Colombia.

Ángel, C., Nates, G., Ospina, R., Melo, C. and Amaya, M. (2018). Biología floral y reproductiva de la gulupa *Passiflora edulis* Sims F. *edulis*. Caldasia, 33, 433-451.

Atucha, A., Emmet, B. and Bauerle, T. L. (2014). Growth rate of fine root systems influences rootstock tolerance to replant disease. Plant and Soil, 376, 337-346. https://doi.org/10.1007/s11104-013-1977-5

Fischer, G., Melgarejo, L. M. and Cutler, J. (2018). Pre-harvest factors that influence the quality of passion fruit: A review. Agronomía Colombiana, 36, 217-226. https://doi.org/10.15446/agron.colomb.v36n3.71751

Furlaneto, F., Martins, A., Esperancini, M., Vidal, A. and Okamoto, F. (2011). Custo de produção do maracujá-amarelo (*Passiflora edulis*). Revista Brasileira de Fruticultura, 33, 441-446. https://doi.org/10.1590/S0100-29452011000500058

Guerrero, E., Potosi, C., Melgarejo, L. M. and Hoyos, L. (2016). Manejo agronómico de Gulupa (*Passiflora edulis* Sims) en el marco de las buenas prácticas agrícolas (BPA). In L. M. Melgarejo (Ed.). Ecofisiología del cultivo de la gulupa (*Passiflora edulis Sims*) (p. 123-143). Bogotá: Universidad Nacional de Colombia.

Hernández, H., Castellanos, J. Z., Alcántar, G., Sandoval, M. and Muñoz, J. J. (2009). Efecto del injerto y nutrición de tomate sobre rendimiento, materia seca y extracción de nutrimentos. Terra Latinoamericana, 27, 1-9.

Herrera, H. J., Hurtado-Salazar, A. and Ceballos-Aguirre, N. (2016). Estudio técnico y económico del tomate tipo cereza élite (*Solanum lycopersicum* L. var. *cerasiforme*) bajo condiciones semicontroladas. Revista Colombiana de Ciencias Hortícolas, 9, 290-300. https://doi.org/10.17584/rcch.2015v9i2.4185

Hoffmann, R. O., Serrano, E. M., Neves, A. C., Thame, J. and Engler, J. J. (1987). Administração da empresa agrícola. 5. ed. São Paulo: Pioneira.

Hurtado-Salazar, A. H., Silva D. F. and Bruckner, C. H. (2016). Effect of two wild rootstocks of genus *Passiflora* L. on the content of antioxidants and fruit quality of yellow passion fruit. Bragantia, 75, 164-172. https://doi.org/10.1590/1678-4499.396

Hurtado-Salazar, A. H., Silva, D. F., Sediyama, C. S. and Bruckner, C. H. (2015). Caracterização física e química de frutos de maracujazeiroamarelo enxertado em espécies silvestres do gênero passiflora cultivado em ambiente protegido. Revista Brasileira de Fruticultura, 37, 630-638. https://doi.org/10.1590/0100-2945-101/14

Krause, W., Neves, L. G., Viana, A. P., Araújo, C. A. and Faleiro, F. G. (2012). Produtividade e qualidade de frutos de cultivares de maracujazeiro-amarelo com ou sem polinização artificial. Pesquisa Agropecuária Brasileira, 47, 1737-1742. https://doi.org/10.1590/S0100-204X2012001200009

Lee, J. M. and Oda, M. (2002). Grafting of herbaceous vegetable and ornamental crops. In J. Janick (Ed.). Horticultural reviews (p. 61-124). John Wiley & Sons. https://doi.org/10.1002/9780470650851.ch2

Lima, M., Azevedo, D. and Santos, S. (2009). Comparativo da rentabilidade da produção de maracujá em seis polos no Brasil. Revista Inovação, Gestão e Produção, 1, 54-69.

Machado, B. D., Rufato, L., Bogo, A., Kretzchmarl, A. A. and Mario, A. E. (2013). Cultivares e porta-enxertos sobre o vigor de plantas de pereira europeias. Ciência Rural, 43, 1542-1545. https://doi.org/10.1590/S0103-84782013005000105

Ocampo, J. A. and Wyckhuys, K. (2012). Tecnología para el cultivo de la gulupa (*Passilora edulis* f. edulis Sims) en Colombia. Bogotá: Centro de Bio-Sistemas de Universidad Jorge Tadeo Lozano.

Ocampo, J. A., Hurtado-Salazar, A. and López, W. R. (2021). Genetic resources and breeding prospects in passiflora species. In A. Hurtado-Salazar, J. A. Ocampo, N. Ceballos-Aguirre, W. R. Lopez and D. Garcia (Eds.). Genetic, grafting and biotechnology approaches (p. 1-76). New York: Nova Science Publisher.

Ocampo, J. A., Urrea, R., Wyckhuys, W. and Salazar, M. (2013). Exploración de la variabilidad genética del maracuyá (*Passiflora edulis* f. *flavicarpa* Degener) como base para un programa de fitomejoramiento en Colombia. Acta Agronómica, 62, 352-360.

Ozlem, A., Nilay, O. and Gunen, Y. (2007). Effect of grafting on watermelon plant growth, yield and quality. Journal of Agronomy, 6, 362-365. https://doi.org/10.3923/ja.2007.362.365

Pachón, A., Montaño, E. and Fischer, A. (2006). Efecto del empaque, encerado y temperatura sobre las características fisicoquímicas y organolépticas de la gulupa (*Passiflora edulis*) en poscosecha. Bogotá: Guadalupe.

Pinzón, M. P., Fischer, G. and Corredor, G. (2007). Determinación de los estados de madurez del fruto de la gulupa (*Passiflora edulis* Sims.). Agronomía Colombiana, 25, 83-95.

Rheinlander, P. (2010). Field guide to common diseases and disorders of passion fruit in New Zealand. New Zealand: Plant & Food Research Mt Albert.

Silva, A., Oliveira, E. J., Haddad, F., Laranjeira, F., Jesus, O., Oliveira, S. A., Carvalho, M. A. and Freitas, P. X. (2013). Identification of passion fruit genotypes resistant to *Fusarium oxysporum* f. sp. *passiflorae*. Tropical Plant Pathology, 38, 236-242. https://doi.org/10.1590/S1982-56762013005000008

[SIPSA] Sistema de Información de Precios del Sector Agropecuarios. (2021). Bogotá: Departamento Administrativo Nacional de Estadística – DANE. Available at: https://www.dane.gov.co/index.php/en/servicios-al-ciudadano-2/servicios-de-informacion/sipsa. [Accessed May 10 2021].