

Solanum quitoense Lam.



Agricultural Science Monograph

Daniel Gómez

Wojciech Simon Waliszewski

Colegio Bolívar

2021-2022

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Chapter 1: Importance

Solanum quitoense is a fruit native to the south american Andes region. Firstly called “lulum” by natives, meaning “small orange” it is now a typical fruit grown in Ecuador’s eastern area, mostly between the Andean foothills and the amazonian plains. It is grown in Ecuador, Peru, Colombia, Bolivia, Venezuela, Panama, El Salvador, Costa Rica and Honduras; as well as in other regions far from South America like New Zealand (Pastrana, 1998; Ochse et al., 1972). With this said, being a culturally and economically important plant for Colombia, and given that it is an under-researched plant, in this monograph I shall investigate various aspects of the crop.

In chapter 2, I write about the ecology of *S. quitoense*, its affinity, other species of the *Solanaceae* family, its fossil records, its origin, distribution and environmental factors that affect its cultivation. In chapter 3, I look into the biology of the plant. This entails its chromosome complement, chemical composition, life cycles, phenology, flower production, fruit development, reproductive biology, pollination and sexuality and reproduction. Then, in chapter 4 I discuss the propagation, management, planting and lulo’s pest disease and how it is controlled. Finally, to close the monograph, in chapter 5 I talk about the fruit’s markets and uses.

Chapter 2: Ecology

2. Ecology

Solanum quitoense, commonly known as “lulo” belongs to the *Solanaceae* family (also known as the nightshade or potato family), containing more than 90 genera and approximately 3000 species. The *Solanaceae* are characterized by having flowers of five petals each, sepals and stamens. (Petruzzello, 2017) Below, we can see the distinctive flowers of the *Solanaceae* and all the parts described above. Later on, the complete taxonomy specific to *Solanum quitoense* will be explained.

Figure 1

Depiction of the flowers of the Solanaceae family.

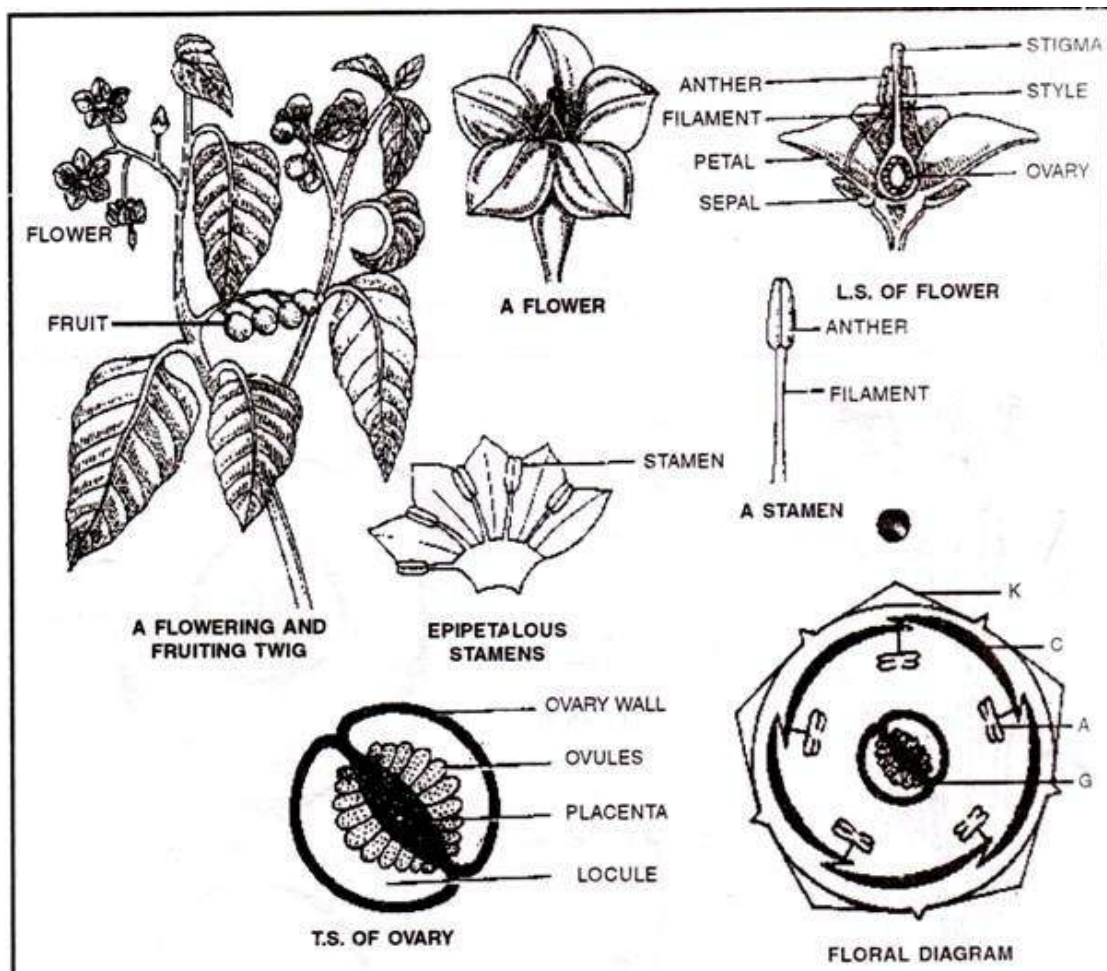


Figure 1 displays the structure of the flowers of the *Solanaceae* family.

Figure 2

Picture of *Solanum quitoense*.



Figure 3

Picture of the shrub of *Solanum quitoense*.



2.1. Affinity

Table 1

Taxonomy of the *Solanum quitoense*.

Kingdom	<i>Plantae</i> - Plants
Subkingdom	<i>Tracheobionta</i> - Vascular plants
Superdivision	<i>Spermatophyta</i> - Seed plants
Division	<i>Magnoliophyta</i> - Flowering plants
Class	<i>Magnoliopsida</i> - Dicotyledons
Subclass	<i>Asteridae</i>
Order	<i>Solanales</i>
Family	<i>Solanaceae</i> - Potato family
Genus	<i>Solanum</i> - nightshade
Species	<i>Solanum quitoense</i> Lam. - naranjilla

Table 1: the table above displays the taxonomy of the *Solanum quitoense*, from its kingdom (*Plantae*) to its species (*Solanum quitoense*).

As the table shows, *Solanum quitoense* belongs to the *Solanum* genus (known as the nightshade genus), which covers approximately 2300 species from the *Solanaceae* family. (Petruzzello, 2021) The *Solanaceae* family itself makes part of the *Solanales* order, which includes five families, about 165 genera and 4080 species, the two main families being *Solanaceae* and *Convolvulaceae*. (D'Arcy et al., 2018)

2.2 Common species related to lulo (*Solanaceae* family)

Figure 4

Species of the Solanaceae family.



Figure 4: The diverse variations of fruit morphology in the *Solanaceae* family. (1–3), *Solanum melongena*; (4), *Solanum pimpinellifolium*; (5–8), *Solanum lycopersicum*; (9–14), Variants of *Capsicum annuum*; (15), *Physalis alkekengi*; (16), *Physalis floridana*; (17–19), *Physalis philadelphica*. (Chaoying, 2015)

Other species different than *S. quitoense* we can find among the *Solanaceae* family include *S. tuberosum* (potatoes), *Solanum lycopersicum* (tomato), *C. pubescens* (tree peppers, other species of peppers also belong to *Solanaceae*), *Solanum melongena* (aubergine, or eggplant), *Nicotiana tabacum* and *Nicotiana rustica* (tobacco), etc. (D’Arcy et al., 2018) Members of the *Solanaceae* family can most abundantly be found in South America, to where, about 40 endemic species within the *Solanaceae*, are native. (Hosch, 2008) The phylogeny below explains the way in which the species within the *Solanaceae* family are related.

Figure 5

Phylogeny of the *Solanaceae* family.

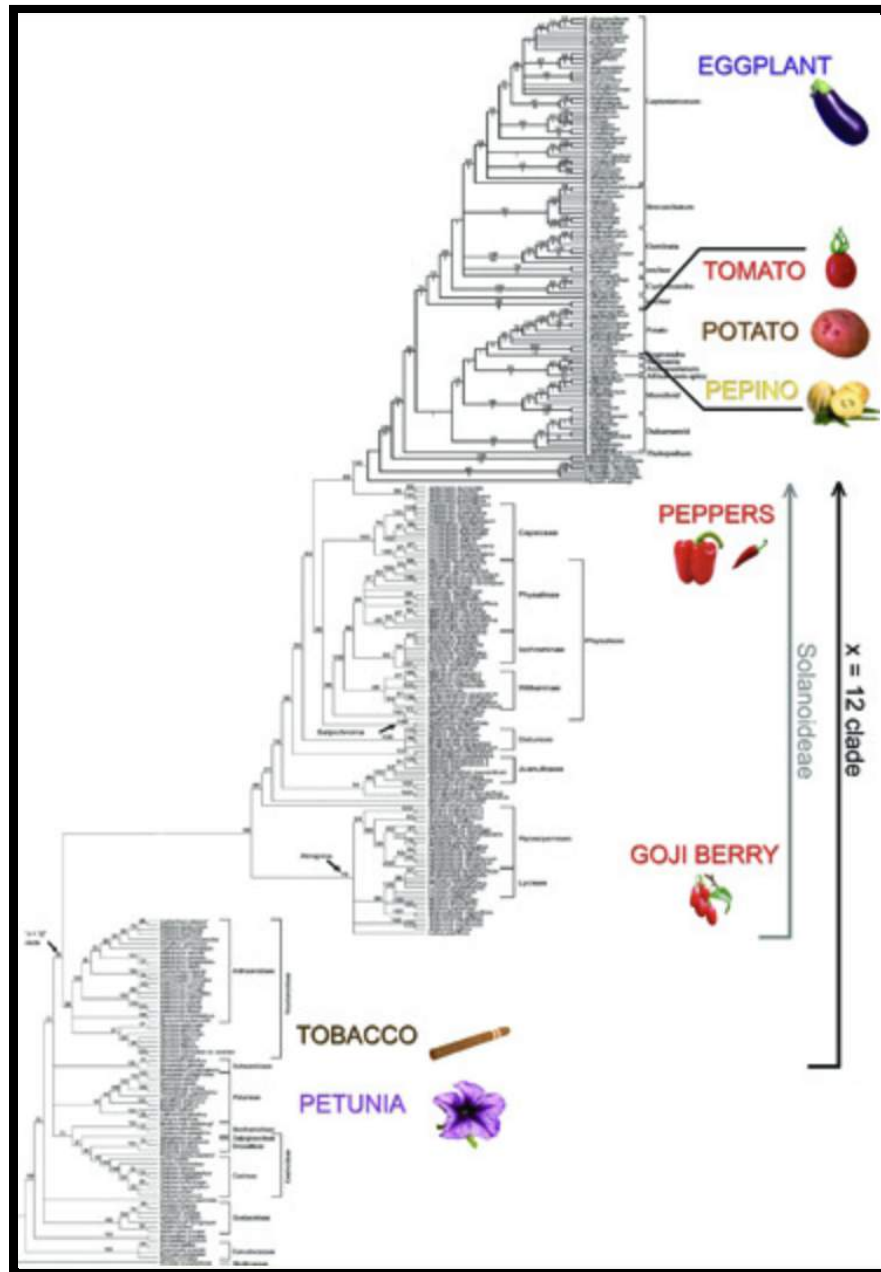


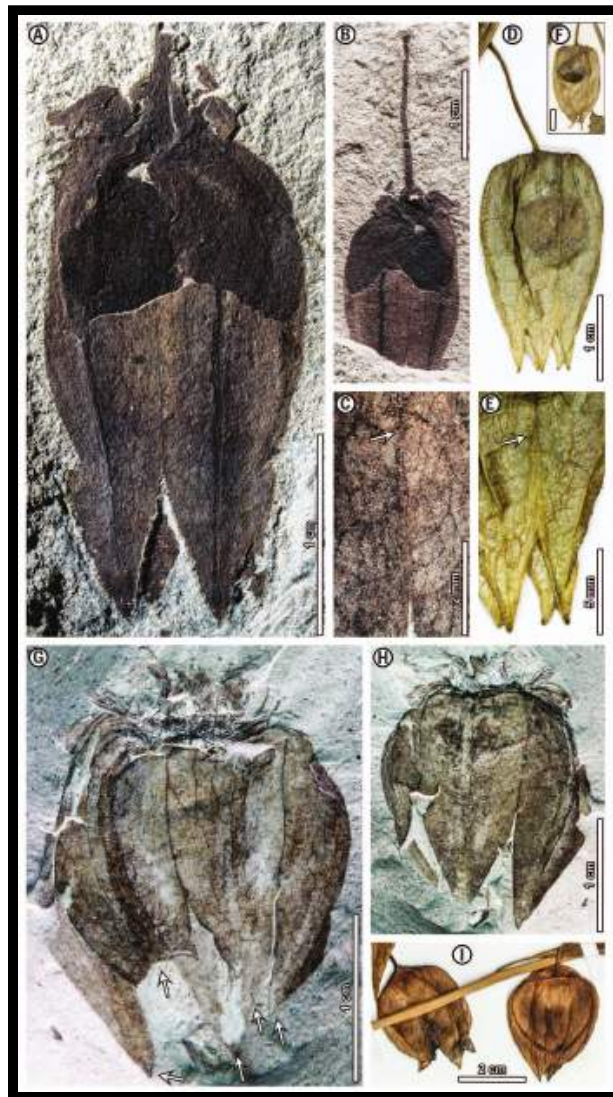
Figure 2: The figure above displays the common species related to lulo, among which we can find eggplant, the tomato, the potato, the pepino, the pepper, the goji berry, the tobacco and the petunia. These all make part of the *Solanaceae* family.

This scheme shows us roughly 30% of the species in the *Solanaceae* family associated with Lulo. As stated earlier we can see some common species, such as eggplants, tomatoes, peppers, goji berries, tobacco and flowers like petunias. (*NaturePlus: Seeking Nightshades in South America: Setting the Scene...*, 2012) Although these are distinct species, they all make part of the *Solanaceae*, meaning they keep family relationship with *S. quitoense*.

2.3 Fossil Record

Figure 6

Fossils of ancestors of modern-day Solanaceae plants.



Fossils of the modern-day *Solanaceae* have been found, but help us little in understanding their origin (Wilf et al.) Fossilized lantern fruits have been found in *Patagonia* in Argentina, suggesting they're at least 52.2 million years old, and that all have developed in completely distinct environments regarding their molecular dates, and thus suggesting the importance of herbivores in the development and evolution of the *Solanaceae*.

The distinct characteristics and diversity of the species of the *Solanaceae* makes it difficult to find morphological similarities and trace a clear line of fossil records. The most reliable indicator for the recognition of the family are its flowers, due to its distinctive morphology. Otherwise, fossil history can result in elusive and confusing findings. A well-known case of this is the long-believed *Solanaceae* fossil from the Tertiary of North America, being mistaken with a (now clear) member of the family *Rhamnaceae*, consistent with said fossil leaf record. (Millán, n.d.)

2.4 Origin

The lulo (*Solanum quitoense*) is native to the *NAPO* paleoclimatic refuge (region covering southern Colombia to northern Bolivia (covering the , from which also originated exotic fruits, roots, tubers, etc. (Fontagro, n.d.)

Figure 7

Representation of the territory where the Solanaceae family originated (Southern Colombia to northern Bolivia).



As said before, the Solanaceae family is originary from South America, with surviving 40 species endemic to this continent. *Solanaceae quitoense* is also found in other parts of the world, such as follows.

2.5 Distribution

Solanum quitoense can be found in western South America, predominantly in Colombia and Ecuador. It's also cultivated along Central America, in countries like Costa Rica, Guatemala and Panama. The figure below shows the distribution of *Solanum quitoense* in South America, where it's believed to be originary from.

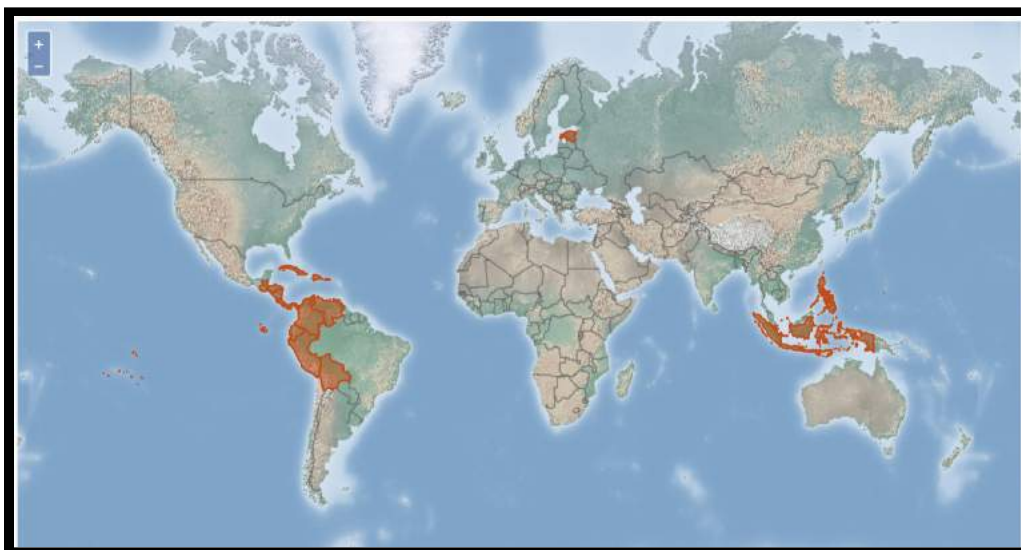
Figure 8

Distribution of the *Solanum quitoense* in South America.



Figure 9

Current distributional context of *S. quitoense*.



S. quitoense can be currently found beyond the Andean region in South America.

2.5 Climate, soil and geology: cultivation

Naranjilla is tolerant to some shade. In many situations, particularly under Amazonia, it is grown in the partial shade provided by trees that remain after the forest has been cleared. Under full light, the plant may also develop and yield properly. There is no particular information on photoperiodic needs, although it does not appear to have any because it blossoms virtually continuously.

There isn't much information about naranjilla's wind tolerance. Because it is a little plant with a well-anchored root structure, it should be resistant to wind uprooting. Its huge, delicate leaves, on the other hand, are likely to be seriously injured.

S. quitoense requires an annual precipitation of 1000 to 2800 mm (optimally 2500 mm), which explains successful growth in the Andean humid tropics. (Fischer et al., 2021) Temperature-wise, research concluded that a range from 16°C to 24°C was recommended, with a desirable temperature of 17°C to 18°C. As for altitude, depending on the variety of lulo in question, it can vary between 1600m to 2400 m. The optimal altitude for its development is found between 2000m and 2200m though (Bonnet et al., n.d.). The figure below displays the “ideal” environment for the development of *S. quitoense*.

Figure 10

Andean undergrowth: optimal environment for the development of S. quitense.



Bibliography Chapter 2

USDA, Agricultural Research Service, National Plant Germplasm System. 2021. Germplasm Resources Information Network (GRIN Taxonomy). National Germplasm Resources Laboratory, Beltsville, Maryland.

Petruzzello, M. (2017, June 29). *List of plants in the family Solanaceae | Genera & Species |*

Britannica. <https://www.britannica.com/topic/list-of-plants-in-the-family-Solanaceae-2026039>

Petruzzello, M. (2021). *Nightshade | plant genus | Britannica*.

<https://www.britannica.com/plant/nightshade>

D'Arcy, W. G. and Berry, . Paul E. (2018, April 5). Solanales. Encyclopedia Britannica.

<https://www.britannica.com/plant/Solanales>

Chaoying, H. (2015). *Figure 1: The diverse variations of fruit morphology in the Solanaceae...*

ResearchGate.

https://www.researchgate.net/figure/The-diverse-variations-of-fruit-morphology-in-the-Solanaceae-family-1-3-Solanum_fig1_275248001

Hosch. (2008). *Solanaceae | plant family | Britannica*. <https://www.britannica.com/plant/Solanaceae>

AGROSAVIA. (n.d.). *Lulo La Selva*. Retrieved February 1, 2022, from

<https://www.agrosavia.co/productos-y-servicios/oferta-tecnológica/0378-lulo-la-selva-primer-lulo-mejorado-para-colombia/>

Fischer, G., Balaguera-López, H. E., & Magnitskiy, S. (2021). Review on the ecophysiology of important Andean fruits: Solanaceae. *Revista U.D.C.A Actualidad & Divulgación Científica*,

24(1), Article 1. <https://doi.org/10.31910/rudca.v24.n1.2021.1701>

Frutas Tropicales—Producción Agrícola. (n.d.). Retrieved February 1, 2022, from

<http://huitoto.udea.edu.co/FrutasTropicales/lulo.html>

Generalidades-sobre-el-Cultivo-de-Lulo.pdf. (n.d.). Retrieved February 1, 2022, from

<https://www.fontagro.org/wp-content/uploads/2017/02/Generalidades-sobre-el-Cultivo-de-Lulo.pdf>

Naranjilla. (n.d.). Retrieved February 1, 2022, from

https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html

Ra, J. H. (n.d.). *El lulo y sus potencialidades en el desarrollo agrícola regional*. 182.

Ra—El lulo y sus potencialidades en el desarrollo agr.pdf. (n.d.). Retrieved February 1, 2022, from

<https://red.uao.edu.co/bitstream/handle/10614/2401/T0000689.pdf?sequence=1&isAllowed=y>

Särkinen, T., Bohs, L., Olmstead, R. G., & Knapp, S. (2013). A phylogenetic framework for evolutionary study of the nightshades (Solanaceae): A dated 1000-tip tree. *BMC Evolutionary Biology*, 13(1), 214. <https://doi.org/10.1186/1471-2148-13-214>

Solanum quitoense Lam. *GRIN-Global*. (n.d.). Retrieved February 1, 2022, from

<https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomydetail?id=101253>

USDA Plants Database. (n.d.). Retrieved February 1, 2022, from

<https://plants.usda.gov/home/plantProfile?symbol=SOQU>

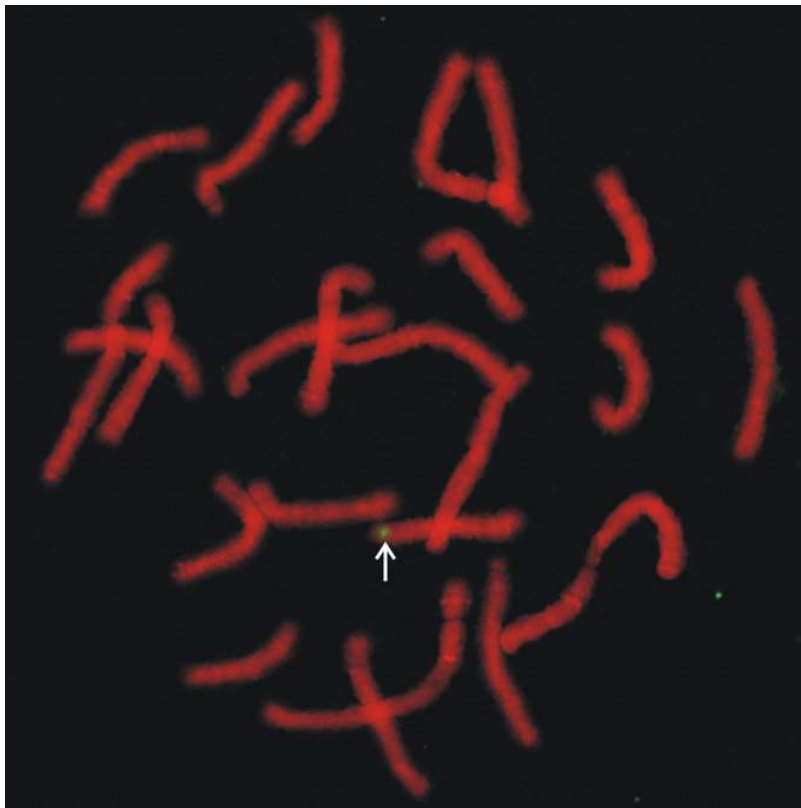
3. Biology

3.1. Chromosome complement

S. quitoense has $2n = 24$ chromosomes (Bernardello et al., 1994). *S. quitoense* hybrids with *S. hirtum*, *S. tequilense*, and *S. vestissimum* have been established (Heiser, 1972), and the majority of 'granadilla fruit' farmed and marketed in Ecuador now derives from hybridization between *S. quitoense* and *S. sessiliflorum* (Heiser et al., 2005). The color of the fruit pulp distinguishes hybrids from the wild type of *S. quitoense*. The fruit pulp of *S. quitoense* is vivid green, whereas hybrids typically have yellow or pale green fruit pulp (Heiser et al., 2005). The figure below displays what a chromosome complement like *S. quitoense*'s.

Figure 11

Chromosome complement of $2n=2x=24$ (Gonzalez et al., n.d.)



3.1.1. Chemical composition

The table below displays the chemical composition of two variations of *S. quitoense*.

Table 2

Chemical composition of S. quitoense

Composición química	lulo la selva	lulo de castilla
% H ₂ O	89.15	87.45
% Ceniza	0.59	0.67
% Grasa	0.11	0.11
% Fibra	0.16	0.17
% Proteína	0.65	0.70
% (CHO)	9.35	10.90
Grados Brix	10.26	7.60
%Azúcares reductores	5.22	2.06
% Azúcares totales	6.95	4.30
pH	3.09	2.98
% Acidez	2.19	2.81
Vitamina C (mg/100 ml)	36.86	33.20
Calcio (mg/100 ml)	15.72	16.54
Fósforo (mg/100 ml)	9.47	8.72
Hierro (mg/100 ml)	1.01	1.81
Potasio (mg/100 ml)	1.70	2.25

Fuente: Universidad La Gran Colombia, Sede Armenia, 1996.

3.2. Life cycles and phenology

3.2.1. Flower production

Flower production of *S. quitoense* was analyzed in a study directed by Ramírez et al. in 2020. The flower production of lulo was measured by the landmark and the Biologische Bundesantalt, Bundessortenamt und Chemische Industrie (BBCH) scales, which are good for phenological descriptions of lulo plants. The landmark scale comprises six main stages:

1. Seed germination
2. Seedling growth
3. Early vegetative growth
4. Leaf development
5. Floral germination
6. Fruit development

Seed germination stages describe seed sowing, imbibition, and subsequent germination. Seedling growth stages include the emergence of hypocotyl hook, seedling growth, the development of cotyledons, and true leaves. During the early vegetative shoot stages, plants increase in height, pubescence turns dark, cotyledons abscise, and thorns become visible at the base of the leaf. Leaf development stages comprise the emergence of young, true leaves, and leaf expansion. During this period, leaf color changes from light green to mature dark green and ends with leaf senescence. Floral development stages include the emergence of the swollen generative buds, early floral-bud development, inflorescence enlargement, anthesis in hermaphrodite or male flowers, and floral parts decay and abscission. Fruit development stages include fruit developing below the petals, the light green tiny fruit enlarges forming the small, enlarged, intermediate, and light green fruit. Fruit turns dark green until reaching the mature dark orange color. The BBCH scale depicts eight principal stages such as seed germination, leaf development, formation of side shoots, inflorescence emergence, flowering, fruit development, fruit maturation, and

senescence. The BBCH mesostages and secondary growth stages were described and coded according to the two- and three-digit-code system. The secondary stages were used as precise steps during development of the plants. Flower and fruit production occurred throughout the year. This research can be used to better understand the flowering and fruiting process and it can be applied to breeding and production programs. (Ramírez & Davenport, 2020)

Figure 12

Development of a S. quitoense plant and leaves from a to y.

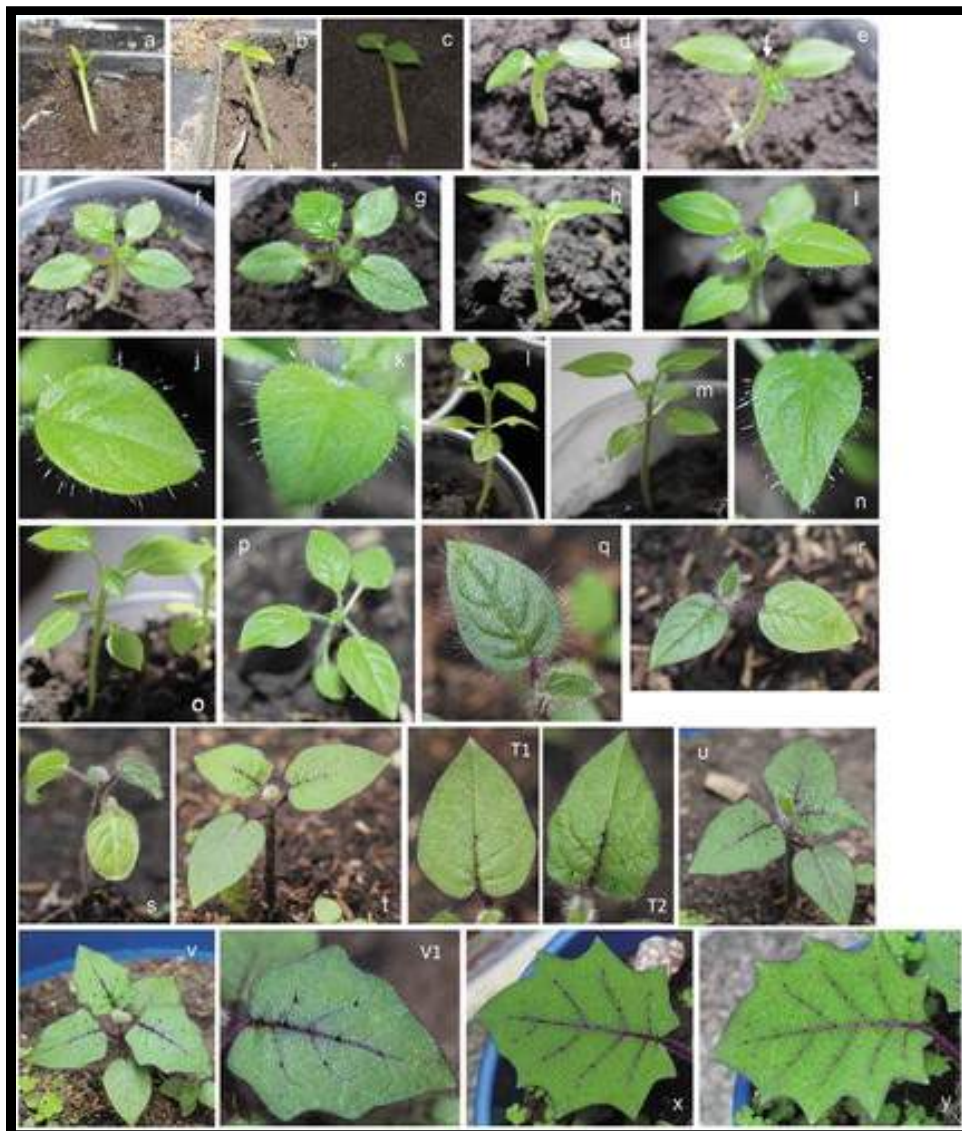


Figure 14
Stages of development of lulo plant leaves from a to j.

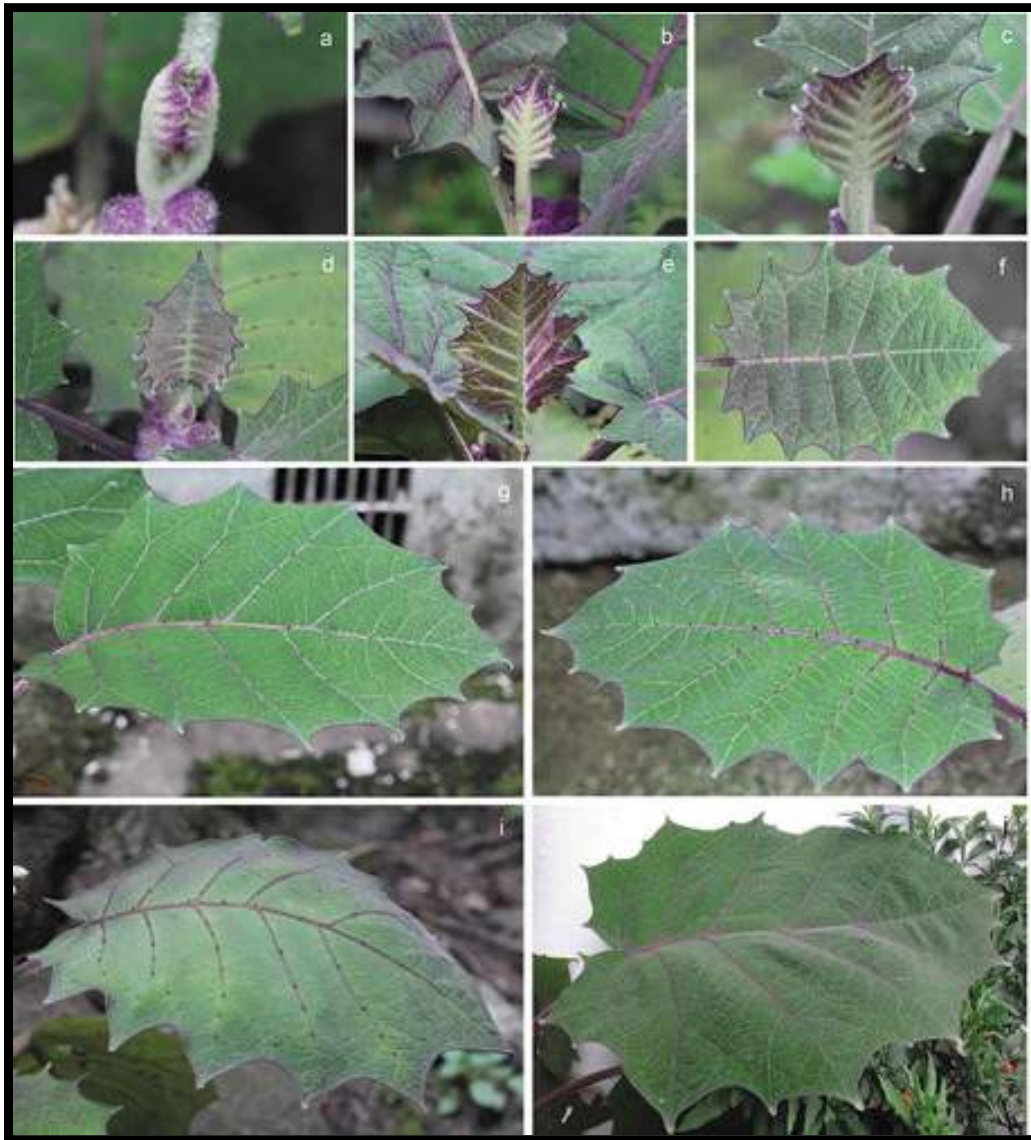


Figure 15

Stages of development of lulo flower from a to o.



Figure 16

Stages of life of lulo plant flower from a to f.



Figure 17



“Hermaphrodite flower (top) and functional male flower (bottom). (1) purple hairy underside of sepal, (2) green upper surface of sepal, (3) pink to purple hairy underside of petal, (4) white hairless upper surface of petal, (5) yellow anthers, (6) long style flower (LSF) with white style and green stigma, (7) short style flower (SSF) with white style and green stigma, and (8) early floral bud with purple hairs. Photos by Fernando Ramírez. “

3.2.2. Fruit development

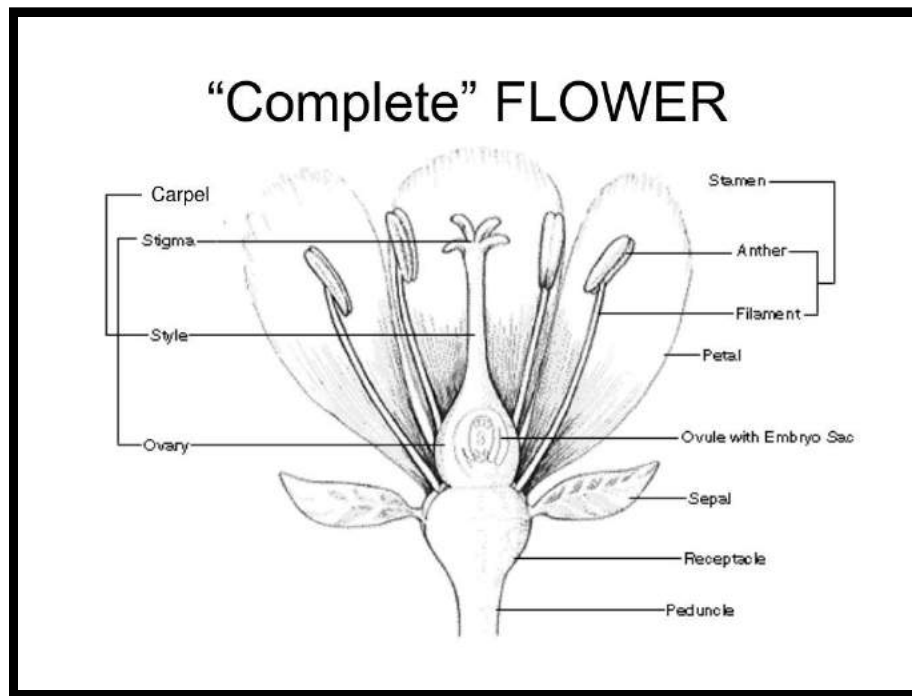
Lulo exhibits vigorous vegetative growth, with the display of flowers 3–4 months after planting, followed in 6 months by fruit maturity in the low-elevation tropics. Growth from seed to harvestable fruit production takes about 8–9 months in warm tropical environments such as in Fusagasugá, Colombia (Ramírez Pers. Obs.). On the other hand, fruits take 12–13 months to reach maturity in the cooler, high-altitude conditions of Bogotá, Colombia (Ramírez Pers. Obs.). It also takes about 12 months to develop harvestable fruit in greenhouse plantings in the United Kingdom (Samuels, 2013).

3.3. Reproductive biology

Buzz pollination syndrome occurs when pollen can only be discharged by specific bee species since all *Solanum* species have poricidally dehiscent anthers. Around 200 genera of flowering plants have this pollination condition (Buchmann, 1983). “Naranjilla flowers are hermaphrodite and can be self-fertile or show allogamy, relying on insects for pollination” (Martin et al., 1987). Flowers can have short, medium, or long styles, with the latter two allowing cross-pollination. Insects such as honeybees and bumblebees pollinate flowers (Paull and Duarte, 2012).

Figure 18

Diagram of a hermaphrodite plant



3.3.1. Pollination

The principal pollinators of lulo are bumblebees and other insects originary from the Andes (such as *Bombus atratus* Franklin) (Messinger et al., 2015). There's also a hypothesis that self-pollination appears in lulo, but this needs further studies. *S. quitoense* has a sigmoid growth pattern. Hybridization is essential for lulo breeding in order to make disease-resistant plants. (Ramírez et al., 2018)

Figure 19

“Bumblebee, pollinator of lulo”



South American lulo (*Solanum quitoense* Lam.) is a plant native to Ecuador and Colombia, which is pollinated by South American bumblebees such as *Bombus atratus* Franklin. To produce optimal fruit set and yield when cultivating lulo outside of its natural region, such as in European glasshouses, effective pollinators are required.

Pollination is essential for *S. quitoense* fruit sets. Lulo flowers may also be effectively self-pollinated, however this results in 25% fewer fruit sets than pollination by repeated bumblebee visits or cross-pollination by hand. Pollination by *B. terrestris* resulted in the same fruit set, seed set, and fruit size as cross-pollination by hand, demonstrating that this bumblebee is a suitable pollinator for lulo. When a bloom was only visited once, however, *B. terrestris* was noticeably less effective. Multiple bumblebee

visits should be encouraged while cultivating lulos economically, but the behavior of *B. terrestris* is likely to ensure this anyhow. *B. terrestris* is an appropriate and effective pollinator for the development of lulo fruits, according to our findings. (Messinger, M., 2015)

3.3.2. Sexuality and reproduction

(Almanza Fandino, 2007; Barboza et al., 2016; Miller and Diggle, 2003; Ramirez et al., 2018; Whalen and Costich, 1986). Lulo is an andromonoecious plant with two floral kinds: hermaphroditic long-style flowers (LSF) and staminate (female-sterile) short-style flowers (SSF) (Figure 1). (Almanza Fandino, 2007; Ramirez et al., 2018; Whalen and Costich, 1986) The LSF flowers are functionally female flowers that produce fruit, whilst the SSF flowers are functionally male flowers that bear fruit. The stamens are yellow, while the carpel is white or cream in hue (Morton, 1987).

Figure 1. Hermaphrodite flower (top) and functional male flower (bottom). (1) purple hairy underside of sepal, (2) green upper surface of sepal, (3) pink to purple hairy underside of petal, (4) white hairless upper surface of petal, (5) yellow anthers, (6) long style flower (LSF) with white style and green stigma, (7) short style flower (SSF) with white style and green stigma, and (8) early floral bud with purple hairs. Photos by Fernando Ramírez. Reproduced with permission.

Bibliography Chapter 3

- Fandiño, M. T. A. (2007). Management of *Bombus atratus* bumblebees to pollinate lulo (*Solanum quitoense* L), a native fruit from the Andes of Colombia (Vol. 50). Cuvillier Verlag.
- Deanna, R., Acosta, M. C., Scaldaferrò, M., & Chiarini, F. (2022). Chromosome Evolution in the Family Solanaceae. *Frontiers in Plant Science*, 12.
<https://www.frontiersin.org/article/10.3389/fpls.2021.787590>
- Messinger, J., Martini, M., Rossi, G., Samuels, J., & Lauerer, M. (2015). Successful pollination of the Neotropical crop *Solanum quitoense* by *Bombus terrestris*: Behaviour, efficiency and yield. *Journal of Applied Entomology*, 140. <https://doi.org/10.1111/jen.12237>
- Ramírez, F., & Davenport, T. L. (2020). The Development of Lulo Plants (*Solanum quitoense* Lam. Var. Septentrionale) Characterized by BBCH and Landmark Phenological Scales. *International Journal of Fruit Science*, 20(3), 562–585. <https://doi.org/10.1080/15538362.2019.1613470>
- Ramírez, F., Kallarackal, J., & Davenport, T. L. (2018). Lulo (*Solanum quitoense* Lam.) reproductive physiology: A review. *Scientia Horticulturae*, 238, 163–176.
<https://doi.org/10.1016/j.scienta.2018.04.046>

Chapter 4: propagation and management

4.1. Propagation and management

Air-layering or cuttings of mature wood can be used to grow the naranjilla. In Latin America, it is frequently cultivated from seedlings that must first be spread out in the shade to ferment slightly to remove the mucilage, then cleaned, air-dried, and dusted with fungicide. There are around 140,000 seeds per pound (.5 kg) and 9,000 seeds every ounce (28 g). Seedlings are cultivated in greenhouses using the same methods as tomato seedlings and are ready to transplant in 2 to 3 months. (Morton, J., 1987)

Figure 21: real life example of air layering propagation



In Florida, the naranjilla can be easily grafted onto *S. macranthum* seedlings that have grown to a height of 2 feet (60 cm) and been cut back to 1 foot (30 cm) from the ground, then split down the center for a distance of 1 to 2 inches (2.5-5 cm). Selected scions around 2 to 3 in (5-7.5 cm) in length are inserted and firmly bound in the slit. The scion requires 2 to 3 weeks to fully merge with the stock. The plants are not put until the scion has grown to a size of around 2 feet (30 cm). “Other grafting methods—saddle, side, and whip—have also been successful.” (Morton, 1987)

4.2 Planting

4.2.1. Soil

Naranjilla grows best in bright, rich, well-drained soils with high organic matter (ideally >10 %) (Martin et al., 1987). It thrives in sandy or clay loams, as well as loamy soils. (Rojas-Sandoval, J., 2017)

4.2.2. Planting *S. quitoense*

1. Finding the right soil

We need to find a lot with access to water, ease of transportation, not too inclined, not too exposed to constant wind, it shouldn't be too deep and it shouldn't have many stones. Ideally, the darker soil should work better for *S. quitoense*, since it's more fertile. (Morelia & de Saladoblanco, n.d.)

Figure 22

Ideal terrain to plant lulo.



2. Prepare the ground

After selected, the ground is first disinfected with formalin and boiled water. Then, the soil is covered for 5 days and the process is repeated. Then, the soil is put into a black bag, of about a pound each. Then the soil is ready to plant in. (Morelia & de Saladoblanco, n.d.)

Figure 23

Example of a plastic bag with black soil inside.



3. Finding the right seeds

Before choosing the right seed, we need to ensure that they come from a good, big and healthy fruit and plant. First we need to ferment the fruit, squeeze. Take the seeds out and wash them. There are four varieties of lulo seeds: “liso” seeds, “espinoso” seeds, “la Selva” seeds and the “chonto morado” seeds. After we’ve chosen the seeds, they’re air dried and planted. (Morelia & de Saladoblanco, n.d.)

Figure 24

Picking the right seeds for lulo.



4. Planting

Lulo seeds are planted in pairs per bag. They should be germinating in about two weeks from that day, and two months later, they can be transplanted into the actual field from the black bag. According to Colombians, lulo should not be planted during “luna viche” or “new moon”. (Morelia & de Salado blanco, n.d.)

5. Grazing

The seedbed is grazed and the lot is “chopped”. (Morelia & de Salado blanco, n.d.)

6. Layout

Preferably the lot should be laid out at 3x3 meters. It must be traced on the same side.
(Morelia & de Saladoblanco, n.d.)

7. Hollow out

When hollowing out, we should dig at about 30x30 cm. It shouldn't be sown too deep, since the dimensions seen here are where the most fertile soil can be found. In very acidic soils, quicklime is applied. An alternative to this is to apply phosphorite, from 70 to 100 grams per hole (about a handful). (Morelia & de Saladoblanco, n.d.)

8. Transplant

After a few days have passed, the plant can be put into the actual soil. The bag is opened carefully, trying our best not to damage or spoil the plant. Then, we plant it and pressure is put into the soil to set it. Then, we would have to wait about 2 to 3 weeks to check on the plant again.
(Morelia & de Saladoblanco, n.d.)

9. Fertilization

At around 15 days, the first fertilization is made. We can do this by mixing 10 kilos of urea, 10 kilos of 10-30-10 and 10 kilos of DAP, 30 grams of this mixture per part are applied. After 60 days, the second fertilization is made, but it is increased to 70 grams per plant. After this, each plant should be fertilized every two months. The fertilizer should not be irrigated near the stem, but near the roots. (Morelia & de Saladoblanco, n.d.)

4.3 Pest disease and control

The root knot nematodes (*Meloidogyne* sp.) are the naranjilla's main predators, hence grafting on nematode-resistant rootstock is critical for fruit production in southern Florida. Nematicide treatment of the soil each time it is invaded is deemed too expensive in the Chinchiná coffee-growing region of Caldas, Colombia, and the plants can only be kept in production for one year before succumbing to nematode damage. Nematodes are causing a decline in naranjilla output across the country, and Indiana University's Dr. Charles Heiser is researching the possibility of hybridizing with nematode-resistant wild relatives to salvage the business. During hot, dry times in Guatemala, nematode populations are controlled by rejecting nursery seedlings and adult plants that display characteristic signs (chlorosis, dwarfing, rachitic look), mulching, or repeated plowing. The cochinita blanca attacks the main stem and branches, as well as the fruits, of mature plants in Panama (white, or West Indian, peach scale, *Pseudaulacaspis pentagona*). In Colombia, naranjilla plants are plagued by a variety of pests and illnesses. In Puerto Rico, bacterial rot is a serious problem. (Morton, 1987)

Bibliography Chapter 4

Morelia, V., & de Salado blanco, M. (n.d.). *El CULTIVO DEL LULO BIEN MANEJADO NOS SACA ADELANTE*. 21.

Morton, J. (1987) *Fruits of Warm Climates*. J.F. Morton, Miami, Chapter Naranjilla. p. 425–428.

Retrieved April 20, 2022, from

https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html#Food%20Uses

Paull, R. E., & Duarte, O. (Eds.). (2012). *Tropical fruits, Volume 2* (2nd ed.). CABI.

<https://doi.org/10.1079/9781845937898.0000>

Rojas-Sandoval, J. (2020). *Solanum quitoense (naranjilla)*. [Preprint]. Invasive Species

Compendium. <https://doi.org/10.1079/ISC.50543.20203482861>

Vargas, A. M., Ocampo, L. M. Q., Céspedes, M. C., Carreño, N., González, A., Rojas, A., Zuluaga, A. P., Myers, K., Fry, W. E., Jiménez, P., Bernal, A. J., & Restrepo, S. (2009). Characterization of *Phytophthora infestans* Populations in Colombia: First Report of the A2 Mating Type.

Phytopathology®, 99(1), 82–88. <https://doi.org/10.1094/PHYTO-99-1-0082>

Chapter 5: Market and uses

5.1. Markets

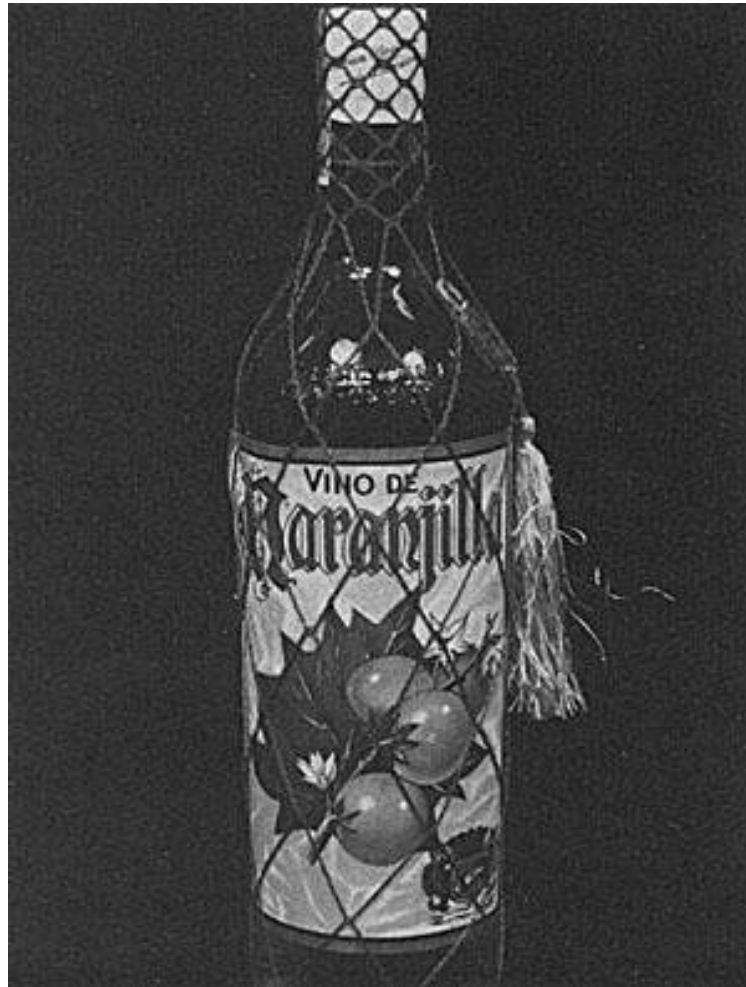
World production of lulo is reduced to Colombia (44,400 tons) and Ecuador (15,500 tons). Colombian imports from Ecuador to meet the local market gap and supply raw material for Colombia's export of frozen lulo pulp and other processed forms of lulo to the US and Europe. However, because this commodity does not have its own 10-digit customs number, Colombia's (limited) export volumes remain unknown. 10 Exporters of processed lulo to the United States, Spain, Belgium, England, Aruba, Haiti, and Jamaica were contacted for this study, and they stated that worldwide demand is significantly greater than what they can offer. The fruit's flavor, scent, and color of lulo's pulp, as well as its nutritional value, which is high in vitamins A and C and iron, are its distinguishing features. It has become a fruit with enormous potential in both domestic and international markets as a result of these qualities and its various uses in processing industries. Farmers sell lulo to a variety of buyers, with roughly 47% selling to wholesalers in the county seat, 30% to other wholesalers, 18% to collection sites, 3% to processors directly, 2% to supermarkets, and 1% to exporters.

In response to rising demand for processed lulo, mostly as a juice, production has increased. Its cultivation is widespread across Colombia's 19 departments. Lulo crop management strategies and competitiveness differ significantly among areas. Risaralda, Cesar, and Cundinamarca are the most competitive departments, however Huila is the greatest producer, followed by Valle del Cauca, Boyacá, and Nario. There are several types cultivated. Researchers have produced a new variety (La Selva) that is favored by processing enterprises, but it has yet to achieve widespread support among farmers since it is more suited for the processing sector than for fresh consumption. (*Solanum Quitoense - an Overview* | *ScienceDirect Topics*, n.d.)

5.2. Uses

Figure

“Colombian lulo wine.”



Free of hairs, ripe naranjillas can be eaten out of hand by cutting them in half and pressing the contents of each half into the mouth. The empty shells are thrown away. The flesh, complete with seeds, can be crushed and used to make desserts, sauce for native foods, or pie and other prepared delicacies. The shells can be packed with a banana mixture and other ingredients before being cooked. The naranjilla is most commonly consumed as fresh fruit juice. The fruits are cleaned, the hairs are scraped off, the fruits are split in half, the pulp is squeezed into an electric blender and processed briefly; the green juice is then

filtered, sweetened, and served as a refreshing, frothy drink with ice cubes. 8 oz (227 g) of juice may be obtained from twelve fruits. In the commercial world, the juice is mechanically obtained from cleaned and diced fruits, filtered, concentrated, and canned, or frozen in plastic bags. (*Naranjilla*, n.d.)

Sherbet is created at home by partly freezing naranjilla juice with corn syrup, sugar, water, and a pinch of lime juice, then whipping to a froth and freezing. In Cali, Colombia, Naranjilla jelly and marmalade are manufactured on a low scale.

Food Value Per 100 g of Edible Portion*	
Calories	23
Moisture	85.8-92.5 g
Protein	0.107-0.6 g
Carbohydrates	5.7 g
Fat	0.1-0.24g
Fiber	0.3-4.6 g
Ash	0.61-0.8g
Calcium	5.9-12.4 mg
Phosphorus	12.0-43.7 mg
Iron	0.34-0.64 mg
Carotene	0.071-0.232 mg (600 I.U.)
Thiamine	0.04-0.094 mg
Riboflavin	0.03-0.047 mg
Niacin	1.19-1.76 mg
Ascorbic Acid	31.2-83.7 mg

*According to analyses of fresh fruits in Colombia and Ecuador.

52.2. Other uses

Among other uses of lulo we can find the following:

- Anti-fungal cream for adults (*Order Lulo 1% Tube Of 20gm Cream Online at Discount Rate*, n.d.)
- Food additives
- Yogurt
- Ice cream
- Frozen pulp for other purposes

Bibliography Chapter 5

Naranjilla. (n.d.). Retrieved May 2, 2022, from

https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html#Food%20Uses

Order Lulo 1% Tube Of 20gm Cream Online at discount rate. (n.d.). Retrieved May 7, 2022, from

<https://pharomeasy.in/online-medicine-order/lulo-1-tube-of-20gm-cream-237451>

Solanum Quitoense—An overview | ScienceDirect Topics. (n.d.). Retrieved May 9, 2022, from

<https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/solanum-quitoense>

Bibliography

Chapter 2

USDA, Agricultural Research Service, National Plant Germplasm System. 2021. Germplasm Resources Information Network (GRIN Taxonomy). National Germplasm Resources Laboratory, Beltsville, Maryland.

Petruzzello, M. (2017, June 29). *List of plants in the family Solanaceae | Genera & Species |*

Britannica. <https://www.britannica.com/topic/list-of-plants-in-the-family-Solanaceae-2026039>

Petruzzello, M. (2021). *Nightshade | plant genus | Britannica*.

<https://www.britannica.com/plant/nightshade>

D'Arcy, W. G. and Berry, . Paul E. (2018, April 5). Solanales. Encyclopedia Britannica.

<https://www.britannica.com/plant/Solanales>

Chaoying, H. (2015). *Figure 1: The diverse variations of fruit morphology in the Solanaceae...*

ResearchGate.

https://www.researchgate.net/figure/The-diverse-variations-of-fruit-morphology-in-the-Solanaceae-family-1-3-Solanum_fig1_275248001

Hosch. (2008). *Solanaceae | plant family | Britannica*. <https://www.britannica.com/plant/Solanaceae>

AGROSAVIA. (n.d.). *Lulo La Selva*. Retrieved February 1, 2022, from

<https://www.agrosavia.co/productos-y-servicios/oferta-tecnologica/0378-lulo-la-selva-primer-lulo-mejorado-para-colombia/>

Fischer, G., Balaguera-López, H. E., & Magnitskiy, S. (2021). Review on the ecophysiology of important Andean fruits: Solanaceae. *Revista U.D.C.A Actualidad & Divulgación Científica*,

24(1), Article 1. <https://doi.org/10.31910/rudca.v24.n1.2021.1701>

Frutas Tropicales—Producción Agrícola. (n.d.). Retrieved February 1, 2022, from

<http://huitoto.udea.edu.co/FrutasTropicales/lulo.html>

- Generalidades-sobre-el-Cultivo-de-Lulo.pdf*. (n.d.). Retrieved February 1, 2022, from <https://www.fontagro.org/wp-content/uploads/2017/02/Generalidades-sobre-el-Cultivo-de-Lulo.pdf>
- Naranjilla*. (n.d.). Retrieved February 1, 2022, from https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html
- Ra, J. H. (n.d.). *El lulo y sus potencialidades en el desarrollo agrícola regional*. 182.
- Ra—El lulo y sus potencialidades en el desarrollo agr.pdf*. (n.d.). Retrieved February 1, 2022, from <https://red.uao.edu.co/bitstream/handle/10614/2401/T0000689.pdf?sequence=1&isAllowed=y>
- Särkinen, T., Bohs, L., Olmstead, R. G., & Knapp, S. (2013). A phylogenetic framework for evolutionary study of the nightshades (Solanaceae): A dated 1000-tip tree. *BMC Evolutionary Biology*, 13(1), 214. <https://doi.org/10.1186/1471-2148-13-214>
- Solanum quitoense Lam. GRIN-Global*. (n.d.). Retrieved February 1, 2022, from <https://npgsweb.ars-grin.gov/gringlobal/taxon/taxonomydetail?id=101253>
- USDA Plants Database*. (n.d.). Retrieved February 1, 2022, from <https://plants.usda.gov/home/plantProfile?symbol=SOQU>

Chapter 3

- Fandiño, M. T. A. (2007). Management of *Bombus atratus* bumblebees to pollinate lulo (*Solanum quitoense* L), a native fruit from the Andes of Colombia (Vol. 50). Cuvillier Verlag.
- Deanna, R., Acosta, M. C., Scaldaferrro, M., & Chiarini, F. (2022). Chromosome Evolution in the Family Solanaceae. *Frontiers in Plant Science*, 12. <https://www.frontiersin.org/article/10.3389/fpls.2021.787590>
- Messinger, J., Martini, M., Rossi, G., Samuels, J., & Lauerer, M. (2015). Successful pollination of the Neotropical crop *Solanum quitoense* by *Bombus terrestris*: Behaviour, efficiency and yield. *Journal of Applied Entomology*, 140. <https://doi.org/10.1111/jen.12237>

Ramírez, F., & Davenport, T. L. (2020). The Development of Lulo Plants (*Solanum quitoense* Lam. Var. Septentrionale) Characterized by BBCH and Landmark Phenological Scales. *International Journal of Fruit Science*, 20(3), 562–585. <https://doi.org/10.1080/15538362.2019.1613470>

Ramírez, F., Kallarackal, J., & Davenport, T. L. (2018). Lulo (*Solanum quitoense* Lam.) reproductive physiology: A review. *Scientia Horticulturae*, 238, 163–176. <https://doi.org/10.1016/j.scienta.2018.04.046>

Chapter 4

Morelia, V., & de Salado blanco, M. (n.d.). *El CULTIVO DEL LULO BIEN MANEJADO NOS SACA ADELANTE*. 21.

Morton, J. (1987) *Fruits of Warm Climates*. J.F. Morton, Miami, Chapter Naranjilla. p. 425–428.

Retrieved April 20, 2022, from

https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html#Food%20Uses

Paull, R. E., & Duarte, O. (Eds.). (2012). *Tropical fruits, Volume 2* (2nd ed.). CABI.

<https://doi.org/10.1079/9781845937898.0000>

Rojas-Sandoval, J. (2020). *Solanum quitoense (naranjilla)*. [Preprint]. Invasive Species Compendium. <https://doi.org/10.1079/ISC.50543.20203482861>

Vargas, A. M., Ocampo, L. M. Q., Céspedes, M. C., Carreño, N., González, A., Rojas, A., Zuluaga, A. P., Myers, K., Fry, W. E., Jiménez, P., Bernal, A. J., & Restrepo, S. (2009). Characterization of *Phytophthora infestans* Populations in Colombia: First Report of the A2 Mating Type. *Phytopathology*®, 99(1), 82–88. <https://doi.org/10.1094/PHYTO-99-1-0082>

Chapter 5

Naranjilla. (n.d.). Retrieved May 2, 2022, from

https://hort.purdue.edu/newcrop/morton/naranjilla_ars.html#Food%20Uses

Order Lulo 1% Tube Of 20gm Cream Online at discount rate. (n.d.). Retrieved May 7, 2022, from

<https://pharmeasy.in/online-medicine-order/lulo-1-tube-of-20gm-cream-237451>

Solanum Quitoense—An overview | ScienceDirect Topics. (n.d.). Retrieved May 9, 2022, from

<https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/solanum-quitoense>