AGROMILLORA

# Citrus

# SUPER HIGH DENSITY SYSTEM FOR CITRUS

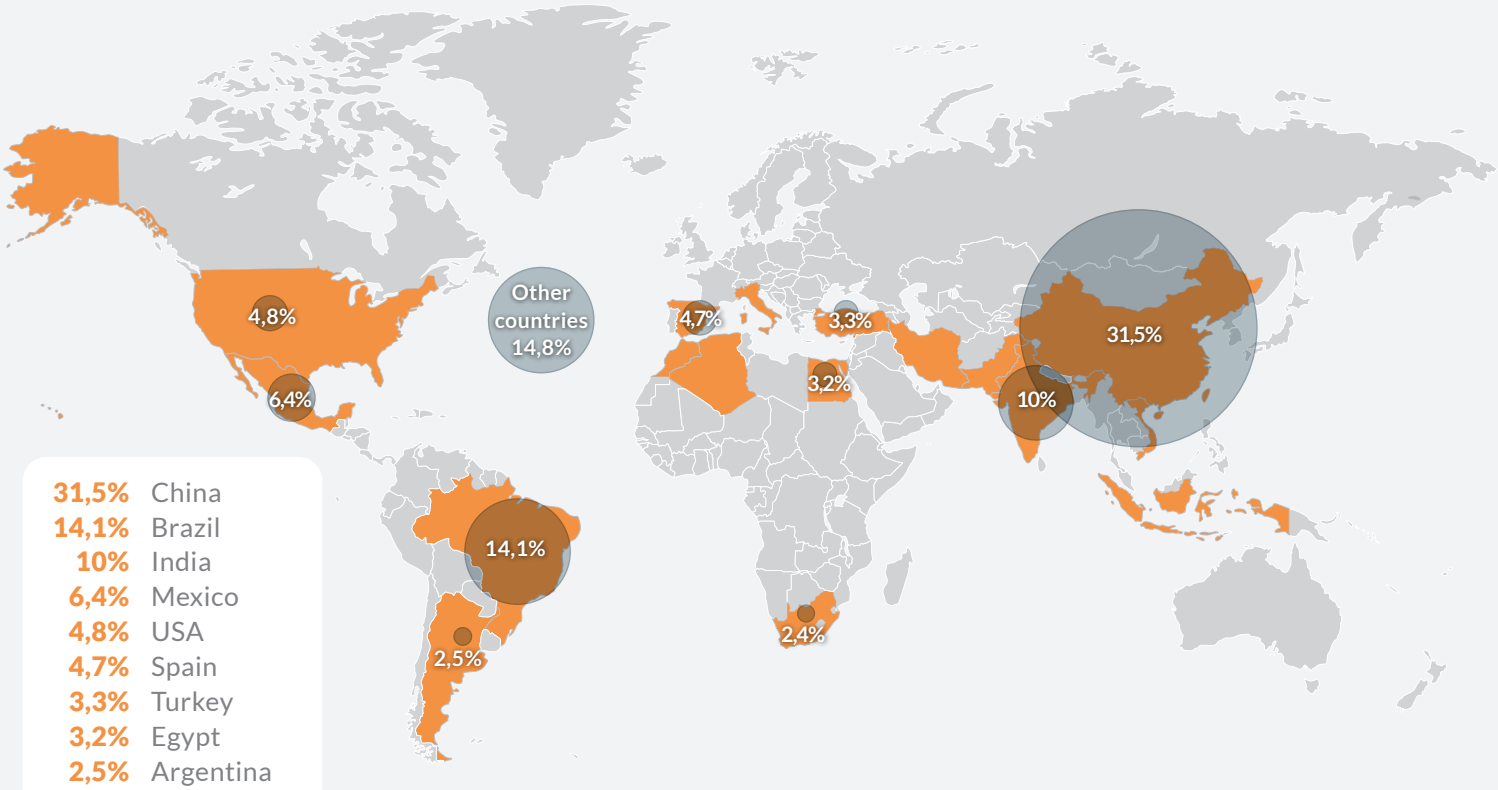
## AN INNOVATIVE, EFFICIENT, AND SUSTAINABLE PROPOSAL

# Citrus species account for 24,2 million acres and an annual world production in 2020 of 158 million tons (FAOSTAT, 2020).

The main producing countries are China, Brazil, India, Mexico and United States. Spain ranks in the sixth position of the world and the first in Europe accounting 765,000 acres of surface and a production of 11,000 million lb per year (6,5 million tons per year).

Main challenges for citrus production are the increase of cost of production, globalization, cross-border pest and diseases, climate change, water availability and sustainability of production.

As in other species in order to overcome the challenges of fruit industry there is an increasing interest for a sustainable intensification aiming for an almost integral mechanization of future orchards and a better efficiency in the use of inputs, in particular labor, water, pesticides and fertilizers.




| | |
|---|---|
| 31,5% | China |
| 14,1% | Brazil |
| 10% | India |
| 6,4% | Mexico |
| 4,8% | USA |
| 4,7% | Spain |
| 3,3% | Turkey |
| 3,2% | Egypt |
| 2,5% | Argentina |
| 2,4% | South Africa |
| 14,8% | Other countries |

Total World Production (Mean 2018 - 2020) = 137,846,239t

# Background

In the last 25 years, specific agronomical models have been developed by Agromillora in Spain and other countries of the world in different woody species.

These models are based in high density orchards, also named Super High Density (SHD), and have been implemented in different species such as olive trees, deciduous fruit species, almond trees, and more recently in prunes, hazelnut and citrus.

Different SHD models. Prunes, almonds, olives and oranges.

## OLIVES

The olive tree is the species in that these models were started 25 years ago. Currently there are more than 1,200 million acres planted in the world, mainly in Spain and Portugal.

## ALMONDS

The first plantations of almonds began in 2010 in Spain, and at present, there are about 15,000 acres planted worldwide

## PRUNES

Regarding prune trees, the first commercial hedge prune plantation was carried out in Chile in 2014 with the French variety D'Agen. The second hedge prune plantation was carried out in California in 2019.

## CITRUS

The first experimental and commercial hedge citrus plantations were stablished 8 years ago in Spain, and they are currently in other countries as Brazil or United States.

Traditionally, the cultivation of citrus (either for industry or fresh market) was growing very large trees with hand-pruning, in a planting distance 20 to 23 ft between lines and 13 to 16 ft between trees. Using the SHD system the spacing is reduced to 11.5 to 13.1 ft between lines and 3.9 to 4.9 ft between trees. The significant reduction of tree volume canopy results in an increased efficiency of labour in particular for harvesting when destination is fresh market, as illustrated in the next figure.

**Traditional orange trees trained in gobelet at 23 x 20 ft**

**Orange trees trained in SHD at 11,5 x 5 ft**

**Traditional orange trees and SHD trees at harvest time**

Differences in the volume and tree architecture of traditional citrus gobelet (left) and hedge-grown trees (right) for orange in Sevilla, South Spain.

The proposal of the citrus hedge or SHD model is based on specific objectives to respond to the requirements of both producers and the environment:

1

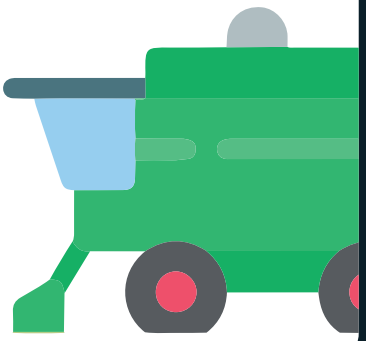
## Reduction of the unproductive period

by intensifying plantation.

2

## Minimal dependence on labor

for pruning and harvesting.



3

## Increase the efficiency

of the use of inputs as pesticides, water and fertilizers.

4

## Adaptation of orchards towards different productive options:

Manual harvesting for fresh consumption of domestic and export markets; mechanically harvesting when the fruit destination is for industry; or combining both options depending on the prices of the growing season.

BASIS OF THE

# Hedge Model and Plantation Management

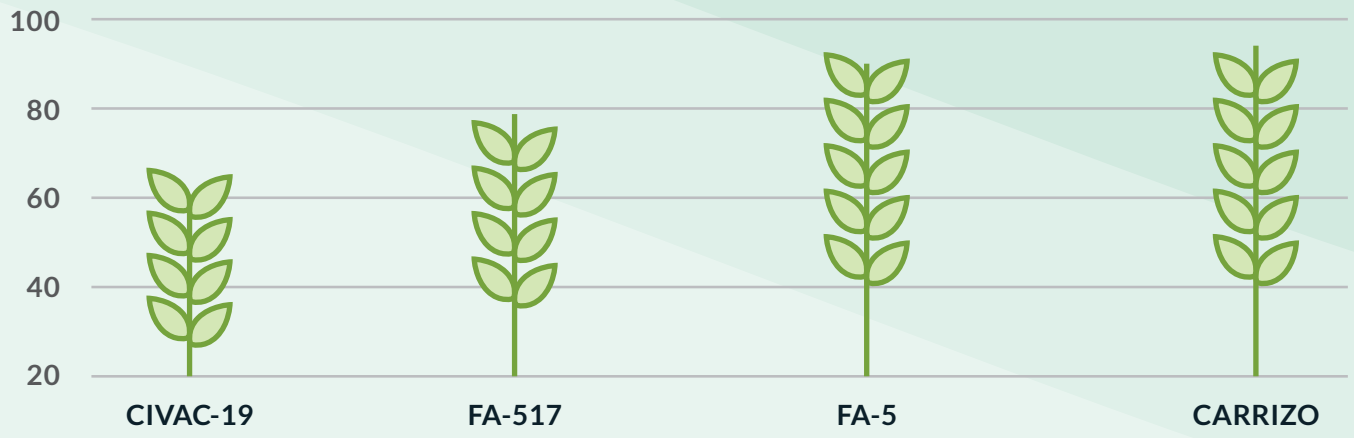
The productive model of the citrus tree in hedges is based on the efficient combination of these factors:

## 1 Right choice of plant material: variety and rootstock

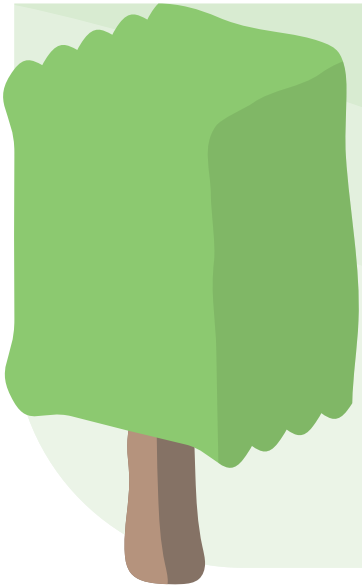
Nowadays, it is the most important factor due to the characteristics of the fruit, the taste quality, and the double suitability for fresh or industry, especially for early harvest varieties. Mechanical harvest for mid and late harvest varieties (May-June) could affect the yields of the next year. The optimum varieties should have a good adaptation to each specific location, providing high and constant yields with optimum fruit quality. Rootstock plays a key role because its adaptation to biotic and abiotic stress, yield, fruit quality, compatibility and size control of the variety.

# 2 Size controlling rootstocks

CIVAC-19 is a citrus rootstock co-obtention of Agromillora and IVIA (Instituto Valenciano de Investigaciones Agrarias, Spain), it gives naturally controlled vigor and good adaptation to a wide range of soils, especially the heaviest ones. Vigor control is key to having small volume canopies that are easily machinable and efficient in light distribution inside the canopy. Also, an efficient use of inputs requires small and bidimensional canopies. Other rootstocks tested in several plots and used as a reference have been Forner-Alcaide nº. 5 (FA-5) and Forner-Alcaide nº. 517 (FA-517), also released by IVIA (Valencia, Spain). Rootstocks as 1600 and 1711 from the Centro de Citricultura de Cordeiropolis in Brazil and UFR-4, UFR-5, UFR-6 and UFR-17 from University of Florida are also showing good results.




These rootstocks were obtained by the Centro de Citricultura Silvio Moreira in Cordeiropolis (Sao Paulo). The potential for both, fresh market and industrial destination was evaluated. In the next figure the yield for fresh consumption corresponding to the 3rd and 4th year of planting are represented and also the cumulative yield. The best performance was obtained with 1600 and 1711 rootstocks.

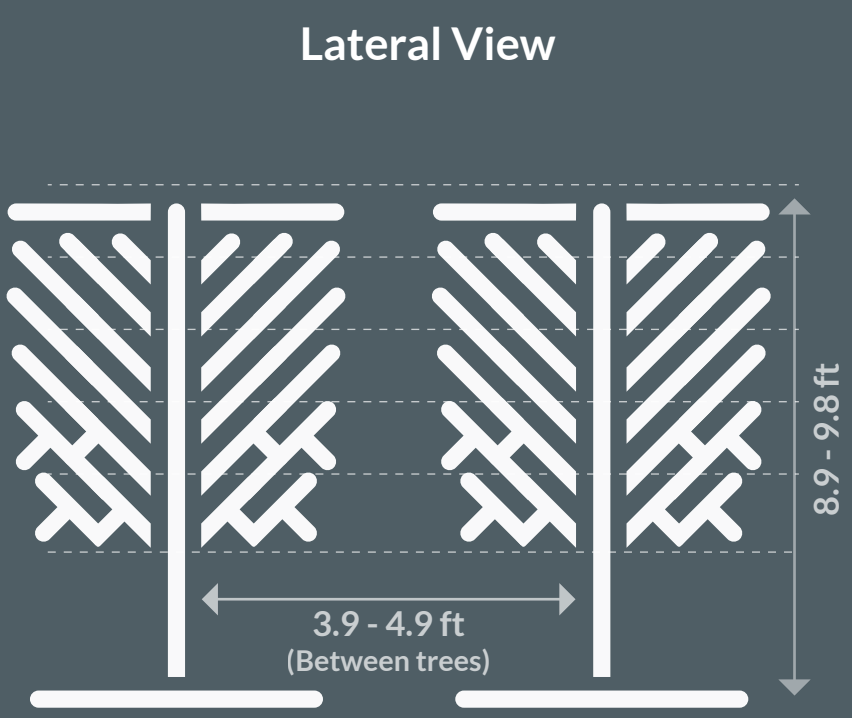


# 3 Training system in hedge

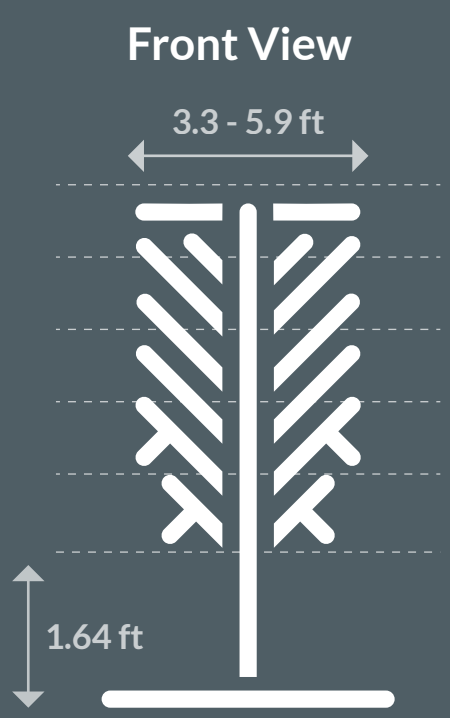
## Super high-density plantation with hedge management oriented to a small-volume and two-dimensional formation system

SHD plantings are based in narrow planting densities resulting on smaller and more bidimensional canopies when compared with the traditional ones. SHD plantings are well adapted to mechanization for pruning and harvesting with over-the-row machines, the ones used in grapes almonds and olives, but also for manual harvest when required.

# Citrus hedge is based on two-dimensional canopy made up of multiple branches that should efficiently occupy the smaller space allocated.




Side and front views of the hedge with its dimesions



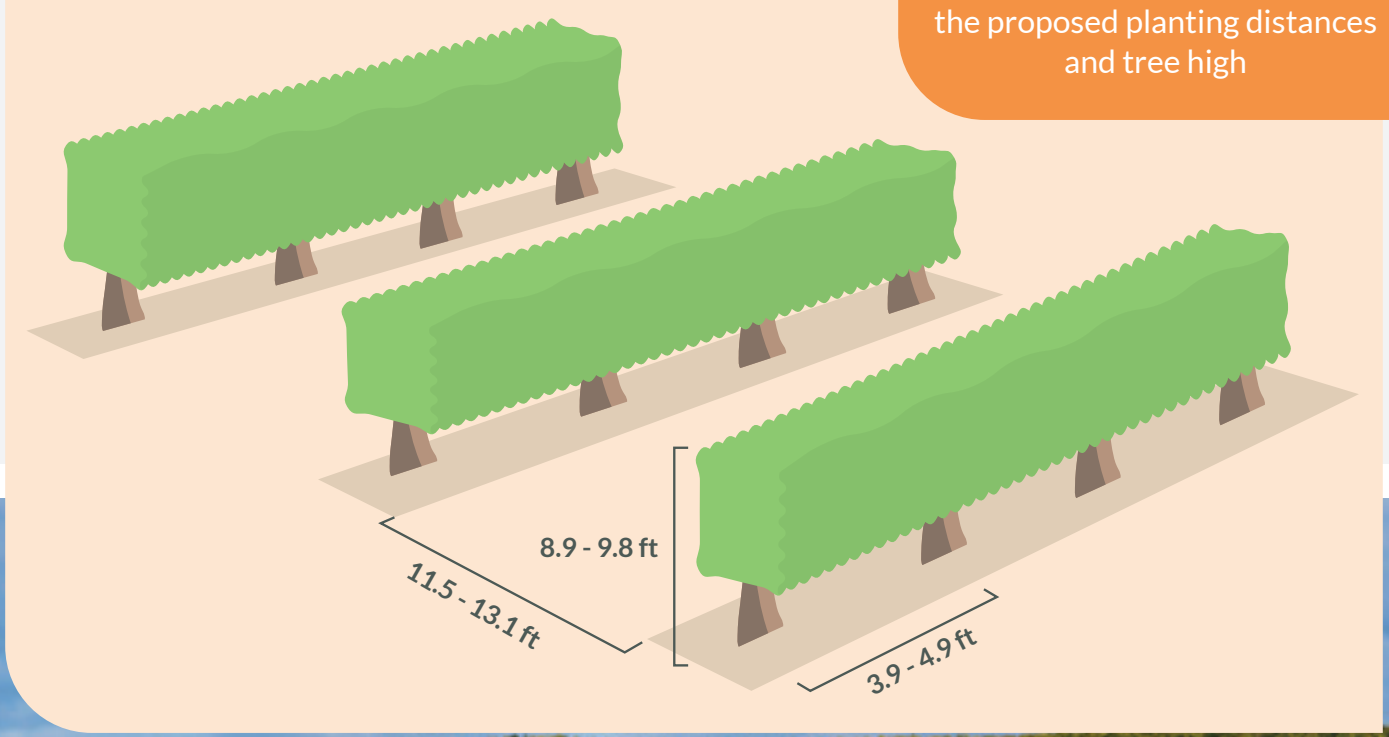

Hedge citrus dimensions with the proposed planting distances, tree width and tree height

Starting from a SmartTree® tree and through subsequent pruning trimming throughout the training period, the tree will fully develop, occupying the assigned space and reaching full production in the 4th or 5th year. The planting distances range from 11.5 to 13.1 ft between lines and from 3.9 to 4.9 ft between trees

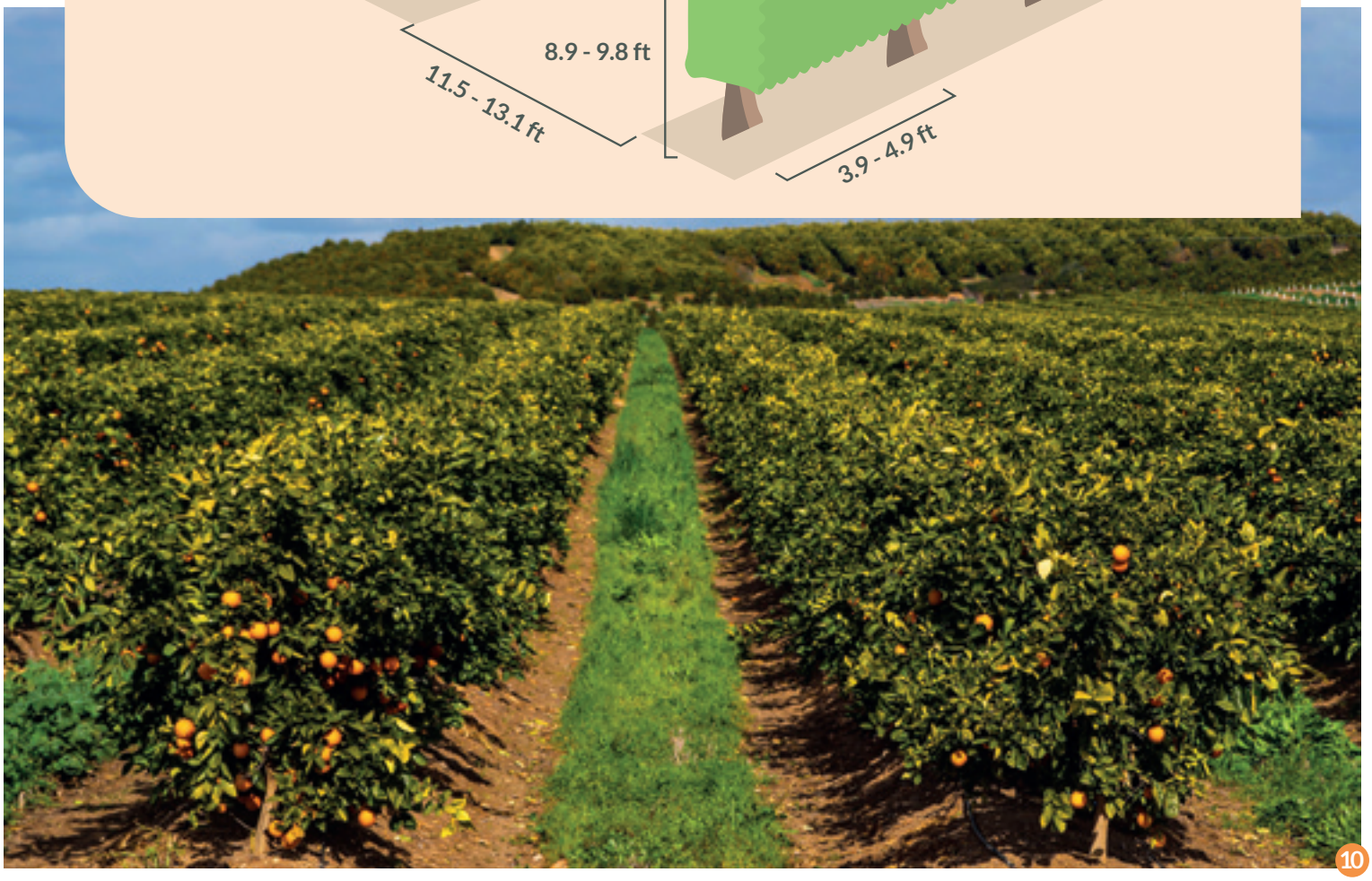
This is equivalent to planting densities of 963 to 675 trees/acre. The distance from the lowest branches to the ground should not be less than 1.64 ft to facilitate harvesting and to avoid the loss of fruit due to the movement of the ride-on machine.

The characteristics of plantation and the dimensions of the hedge allow variations and adjustments depending on the variety (vigor and growth habit), on the rootstock and the specific soil-climatic conditions where the plantation is located. Based on the management concepts set out above translate into a plantation whose design will not exceed 10 ft height and in any case must be adjusted to the dimensions of the over-the-row harvester machine when destination of fruits is for processing, so it means from 3.3 to 5.9 ft width. The common interrow distance used ranged from 11.5 to 13.1 ft and from 3.9 to to 4.9 ft in between trees.

Different models and dimensions of machines are nowadays available.




Hedge plantation of citrus with the proposed planting distances and tree high



The dimensions of the hedge described above allow for the mechanization of the summer pruning tasks (pinching off), treatments, soil maintenance, and harvesting in mechanical harvesting with over-the-row machines and even in manual harvesting (more accessible fruits without the need for ladders). In the first year of planting, pruning will be done manually. In the second and three year the pruning will be mechanical applied several times depending on the vigor and the growth habit of variety. In adult trees in order to keep the canopy volume controlled different times of mechanical pruning are applied.

## The first mechanical pruning after harvest will consist of topping and lateral pruning or hedging plus removal of lower branches of the hedge.

The second (June-July) and the third if needed (September-October) will be applied in the top of the canopy in order to remove the suckers and in the laterals if required. It's also recommended to apply alternatively mechanical and manual pruning, this one with the objective of removing some suckers and nonproductive/dry branches.

# The process of training trees in hedge from planting to adult trees is illustrated in the next pictures.

## Year 1




## Years 2 and 3




## Year 4 and beyond






Different green pruning and harvesting operations for citrus hedges from year 1 to year 4 of plantation and beyond. Experimental plots in IFAPA Las Torres, Alcalá del Río (Sevilla-Spain).

# Experiences on SHD IN CITRUS

## AROUND THE WORLD

Current experiences on SHD in citrus are today in progress in different countries as Spain, Brazil and United States, in order to know its agronomical performance and growers' profit.

# Performance of orange/tangerine varieties on new rootstocks in Andalucía (South Spain).

## Alcala del Río (Sevilla)

Several trials were established in June 2015 in order to determine the vegetative plant growth yield and fruit quality of different cultivars grafted on different size controlling rootstocks (FA-517, FA-5 and CIVAC-19). These trials were all carried out in the experimental plots of IFAPA (Instituto de Investigación y Formación Agraria y Pesquera, Alimentaria y de la Producción Ecológica) located at Alcalá del Río (Andalucía).

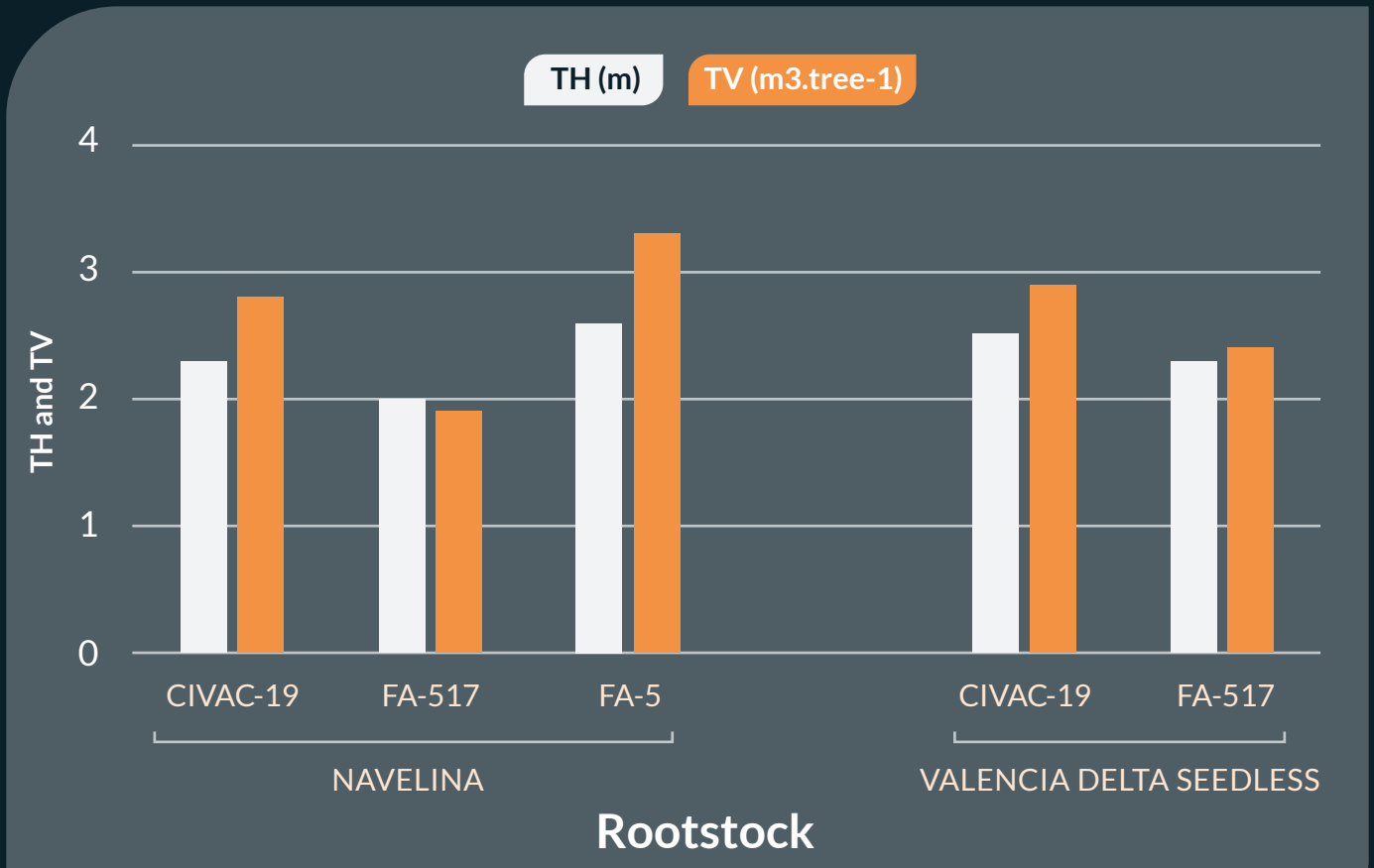
In the next table annual and cumulative yields obtained over the period 2018-2022 (three seasons) are presented. 'Navelina' grafted on CIVAC-19 provided the best yield in the last two seasons, followed by 'Navelina' on FA-5. Yields corresponding of 'Valencia Delta Seedless' grafted on CIVAC-19 and FA-517 show the best performance of CIVAC-19 compared to FA-517. No differences were observed when fruit quality (fruit diameter) was compared.

| Variety | Rootstock | Lb. acre$^{-1}$ 2018/2019 | Lb. acre$^{-1}$ 2020/2021 | Lb. acre$^{-1}$ 2021/2022 | Cumulative yield | Fruit Ø(in) Oct. 2021 |
|---|---|---|---|---|---|---|
| Navelina | FA-5 | 15,931 | 10,026 | 20,696 | 46,653 | 2.97 |
| | CIVAC-19 | 9,237 | 16,613 | 28,800 | 54,650 | 2.83 |
| | FA-517 | 13,996 | 11,019 | 9,492 | 34,507 | 2.98 |
| Val. Delta Seedless | CIVAC-19 | 21,605 | 10,816 | 32,097 | 64,518 | 2.42 |
| | FA-517 | 11,324 | 7,737 | 18,514 | 37,575 | 2.35 |

Annual, cumulative yields and mean fruit size of several citrus varieties at IFAPA Experimental farm in Alcalá del Río (Sevilla). Trees planted in June 2015 with a planting distance of 11.5 x 3.3 ft (3.5 x 1 m).

The effect of rootstock on tree growth and vigor (expressed as tree height and tree canopy volume) of 6-year-old trees (measured 2020-2021 season) of cultivars 'Navelina' and 'Valencia Delta Seedless' is illustrated in the next figure.

# The less vigorous rootstock for two varieties has been FA-517 and the most vigorous one with 'Navelina' was FA-5, and with 'Valencia Delta Seedless' CIVAC-19.




Tree height (m) and tree canopy volume (m3.tree-1) of 'Navelina' and 'Valencia Delta Seedless' grafted on different rootstocks and measured in February 2021. Trees were planted in IFAPA Experimental farm (Alcalá del Río, Sevilla) in June 2015.

## Hornachuelos (Córdoba)

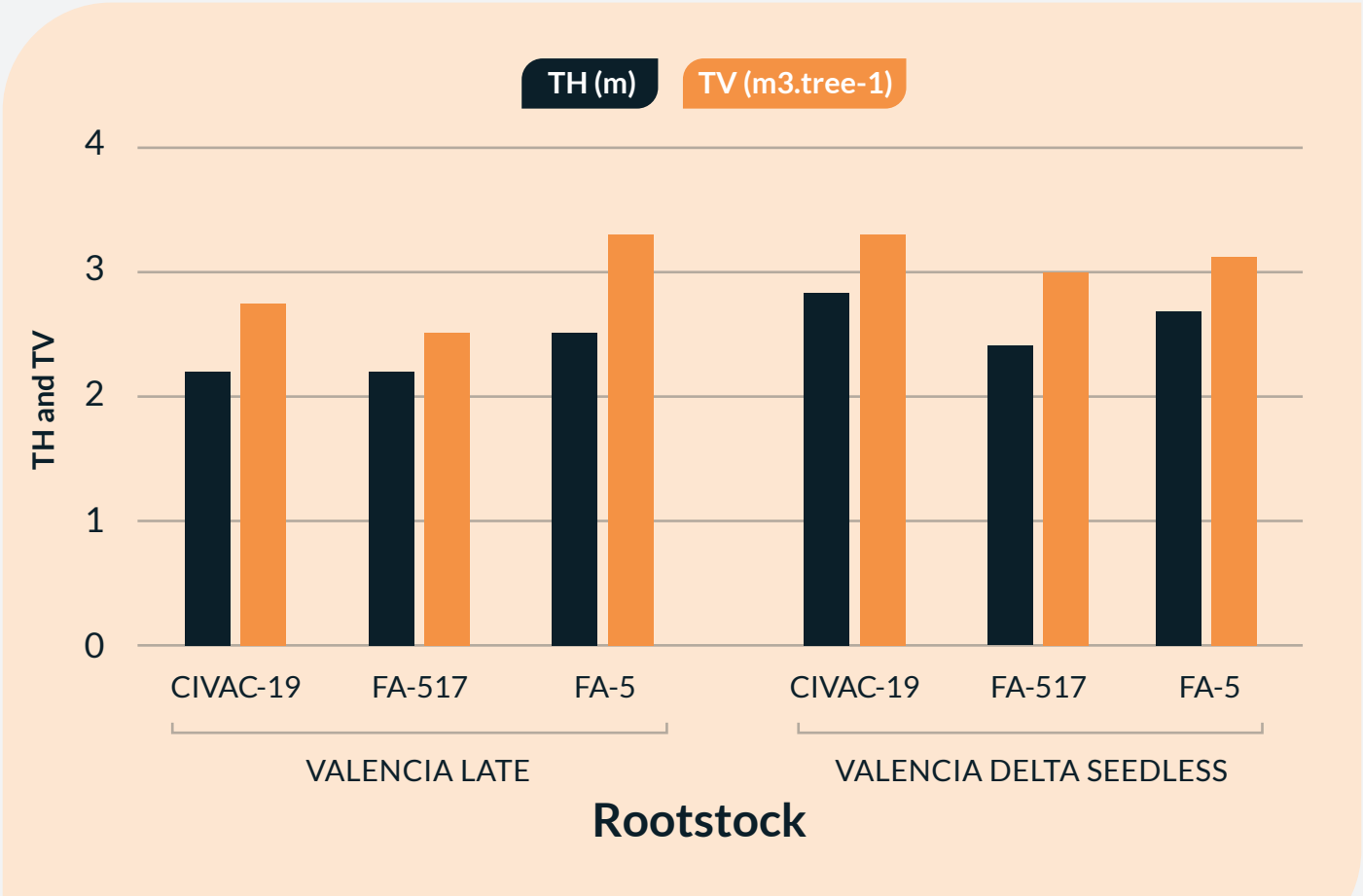
In June 2015 two complementary trials were stablished in commercial orchards in Moratalla Farm located in Hornachuelos. Data of yield and fruit quality were recorded during three consecutive harvesting seasons (2019 to 2022) by IFAPA and are shown in the next table. Cumulative yields of 'Valencia Late' were almost twice compared with 'Valencia Delta Seedless'. In 'Valencia Late' the best yields were obtained with FA-5 and CIVAC-19 rootstocks. 'Valencia Delta Seedless' performed similar with all rootstocks. No differences in fruit size were observed when the three rootstocks are compared.

| Variety | Rootstock | Lb. acre$^{-1}$ 2018/2019 | Lb. acre$^{-1}$ 2020/2021 | Lb. acre$^{-1}$ 2021/2022 | Cumulative yield | Fruit Ø(in) Oct. 2021 |
|---|---|---|---|---|---|---|
| Valencia Late | CIVAC-19 | 8,777 | 27,749 | 54,979 | 91,505 | 2.72 |
| | FA-517 | 7,552 | 24,671 | 45,655 | 77,878 | 2.64 |
| | FA-5 | 4,694 | 28,025 | 46,862 | 79,581 | 2.75 |
| Valencia Delta Seedless | CIVAC-19 | 4,082 | 6,703 | 52,252 | 63,037 | 2.82 |
| | FA-517 | 3,572 | 5,321 | 37,629 | 46,522 | 2.54 |
| | FA-5 | 2,551 | 6,252 | 26,886 | 35,689 | 2.88 |

Yields and mean fruit size (in) corresponding to 'Valencia Late' and 'Valencia Delta Seedless') grafted on three rootstocks (CIVAC19, FA5 and FA517) in Moratalla Farm. Spacing 'Valencia Late' 11.5 x 4.1 ft and 'Valencia Delta Seedless' 11.5 x 4,9 ft (3.5 x 1.5 m).

The effect of rootstock on tree growth and vigor (expressed as tree height and tree canopy volume) of 5 and 6-year-old trees (measured 2020-2021 season) of cultivars 'Valencia Late' and 'Valencia Delta Seedless' is illustrated in the next figure.

# With 'Valencia Late' the less vigorous rootstock has been FA-517 and FA-5 the most vigorous. 'Valencia Delta Seedless' shows similar response for all rootstocks.




Tree height (m) and tree canopy volume (m3.tree-1) of 'Valencia Late' (planted June 2015) and 'Valencia Delta Seedless' (planted June 2016) grafted on different rootstocks and measured in February 2021. Trees were planted in Moratalla Farm (Córdoba). Spacing: 'Valencia Late' 11.5 x 4.1 ft and 'Valencia Delta Seedless' 11.5 x 4.92 ft.

## Málaga

In this commercial orchard the lemon variety is 'Fino-49', planted in June 2018. From June 2021 this plot is in process of conversion to organic. Annual and cumulative yields are exposed in the table below showing interesting early and cumulative yields.

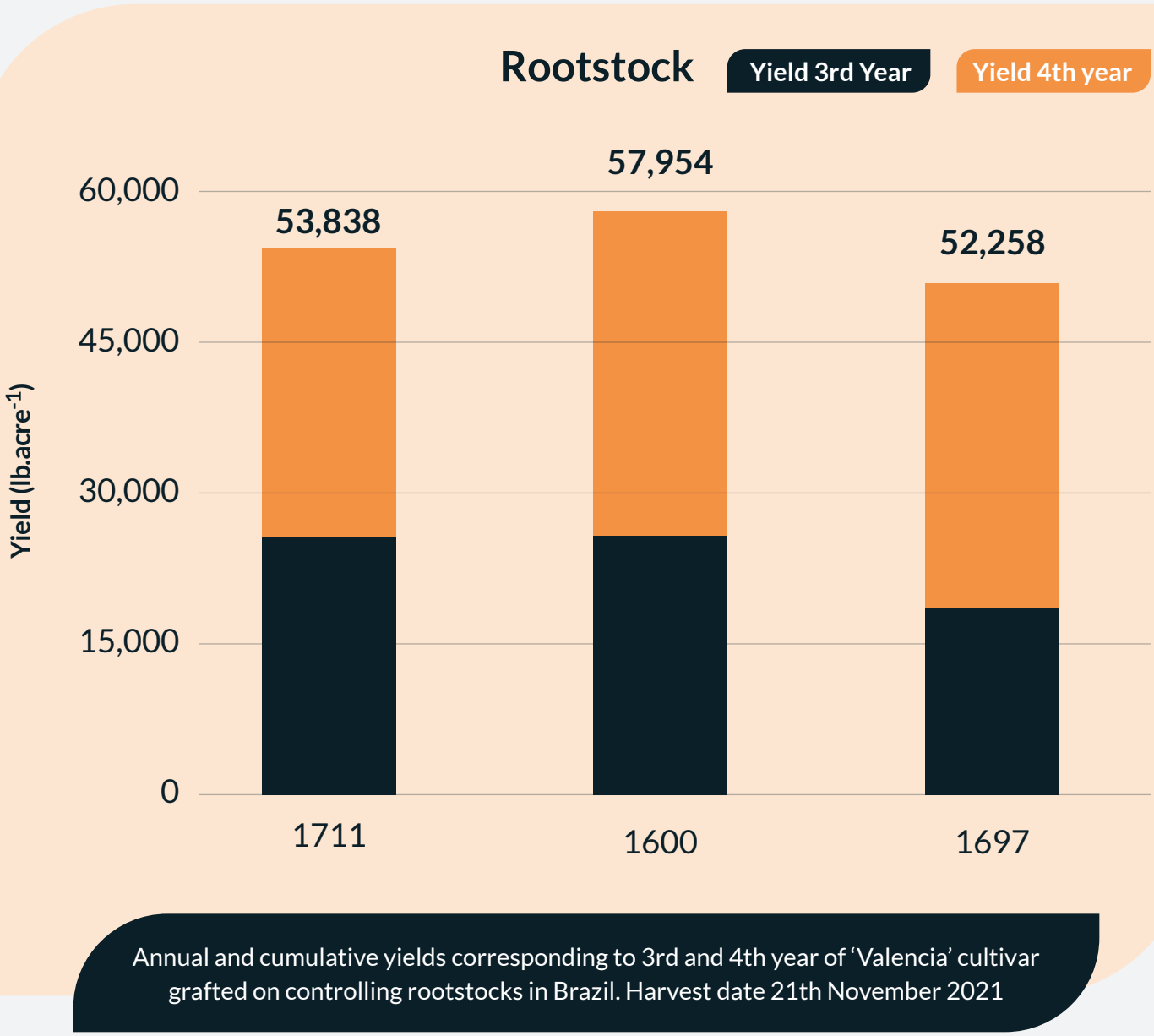
| Variety | Rootstock | Lb. acre$^{-1}$ 2020/2021 (3$^{rd}$ Year) | Lb. acre$^{-1}$ 2021/2022 (3$^{th}$ Year) | Cumulative 2020-2022 |
|---|---|---|---|---|
| Fino-49 | CIVAC-19 | 12,401 | 18,999 | 31,400 |

Annual and cumulative yields of lemon 'Fino-49' grafted on CIVAC-19 planted in June 2018 in a commercial plot in Málaga with a planting distance of 11.5 x 4.1 ft.

# Results about performance of size controlling rootstocks in Brazil

The experience was carried out in a commercial orchard of the company Agroterenas located in Santa Cruz do Rio Pardo (Sao Paulo, Brazil), using a planting distance of 16,5 ft x 5 ft (540 trees/ha). Trees of 'Valencia' cultivar were grafted on the size controlling rootstocks 1711, 1600 and 1697 and planted in October 2017.

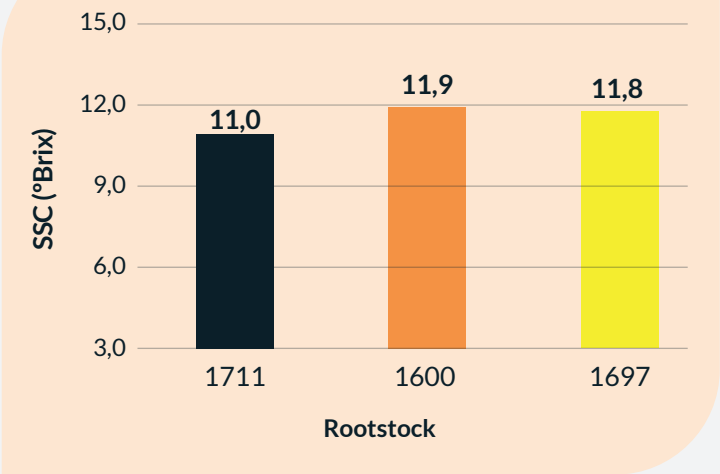
These rootstocks were obtained by the Centro de Citricultura Silvio Moreira in Cordeiropolis (Sao Paulo). The potential for both, fresh market and industrial destination was evaluated. In the next table the yield for fresh consumption corresponding to the 3rd year of planting are represented. The best performance was obtained with 1711 and 1600 rootstocks.

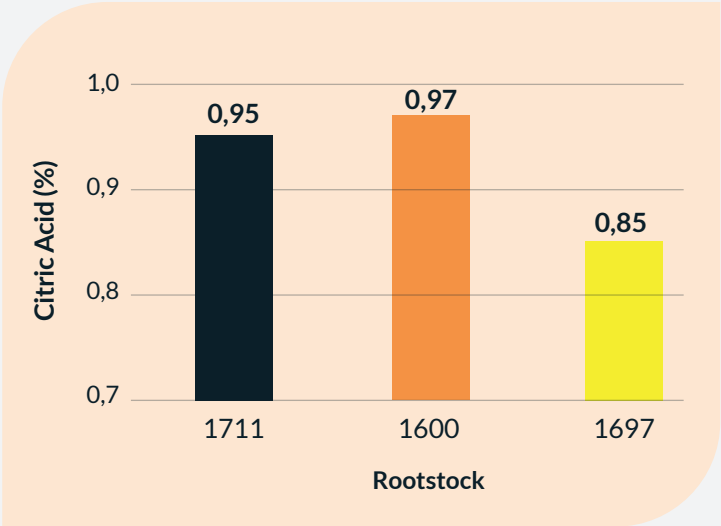


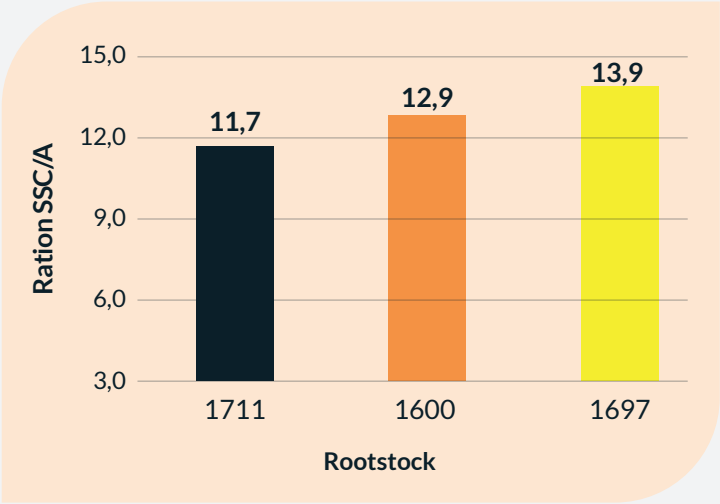

Annual and cumulative yields corresponding to 3rd and 4th year of 'Valencia' cultivar grafted on controlling rootstocks in Brazil. Harvest date 21th November 2021

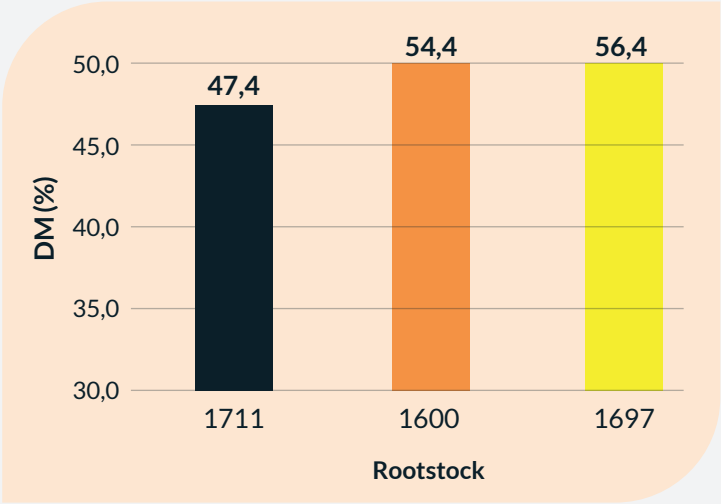
The data corresponding to the industrial quality of fruits coming from the same commercial plot in particular SSC (°Brix), Acidity (% citric acid), ratio SSC/Acidity and Dry Matter (DM %) content corresponding to cultivar 'Valencia' grafted on 1711, 1600, 1697 rootstocks is illustrated in the next figure.

Agroterenas SHD trial (Santa Cruz do Rio Pardo, Brazil) with several dwarfing rootstocks planted at 16.4 x 4.9 ft.



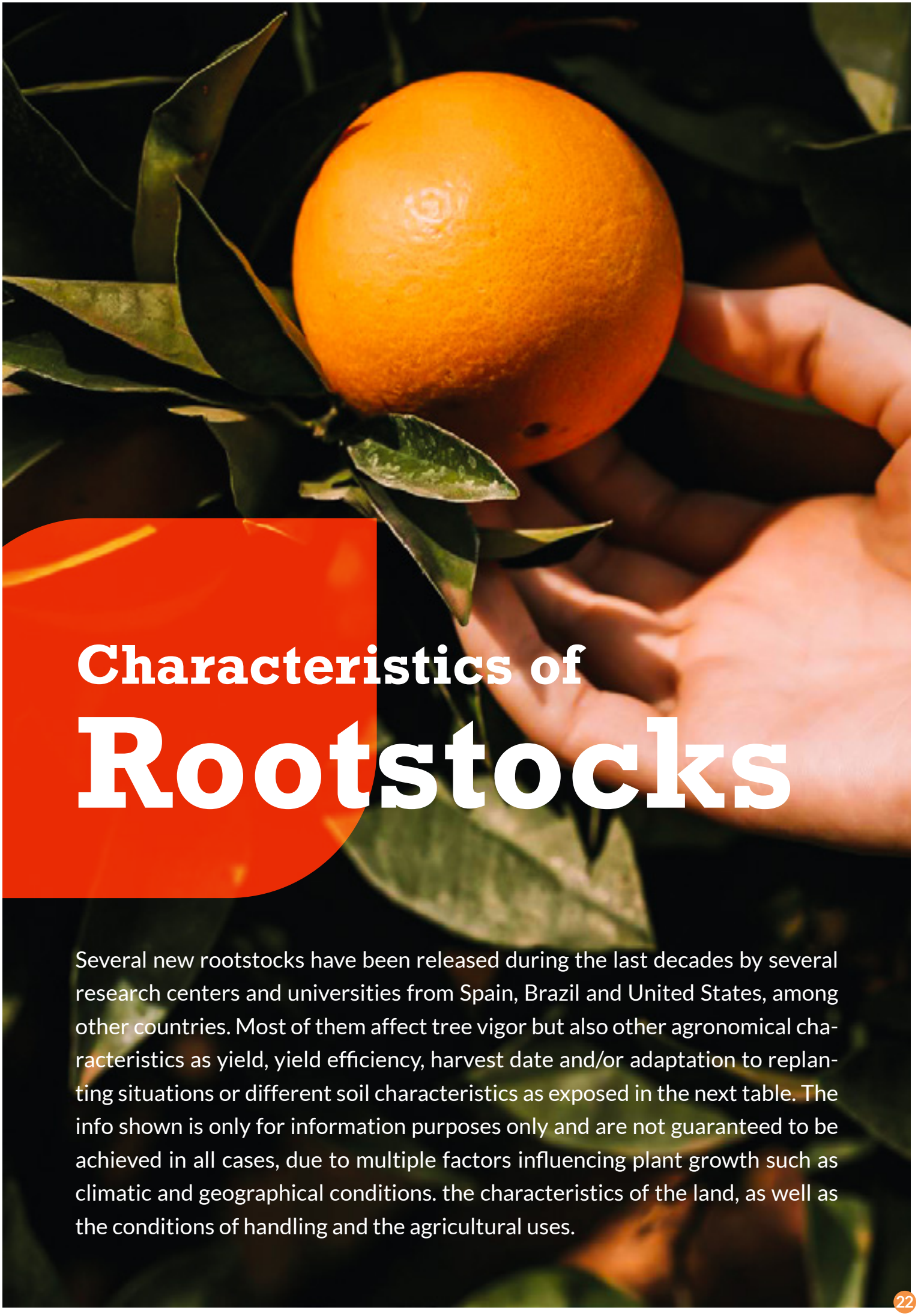




Data of industrial quality (SSC, Acidity, SSC/A, DM) corresponding to 4th year of 'Valencia' cultivar grafted on three size controlling rootstocks in Agroterenas (Brazil) in November 2021.

# Performance of size controlling rootstocks in United States

A trial with two orange varieties ('Valquarius' and 'Vernia') and the size controlling rootstocks: UFR-6 from University of Florida and US-897 from US Department of Agriculture USDA-ARS in Fort Pierce, FL, respectively, were established in May 2018 in Lost Lake Grove with a planting distance 11,8 x 4 ft. First yields with all combinations have been obtained in 2021-2022 season. Further studies will confirm the interest of these new rootstocks.

Lost Lake Grove trial (Florida, USA) with several dwarfing rootstocks, planting distance 11.8 x 4.0 ft.



# Characteristics of Rootstocks

Several new rootstocks have been released during the last decades by several research centers and universities from Spain, Brazil and United States, among other countries. Most of them affect tree vigor but also other agronomical characteristics as yield, yield efficiency, harvest date and/or adaptation to replanting situations or different soil characteristics as exposed in the next table. The info shown is only for information purposes only and are not guaranteed to be achieved in all cases, due to multiple factors influencing plant growth such as climatic and geographical conditions. the characteristics of the land, as well as the conditions of handling and the agricultural uses.

| | | C. Carrizo | Citrumelo 4475 | Forner-Alcaide N°5 | Forner-Alcaide N°517 | CIVAC 19 | CL 5146 |
|---|---|---|---|---|---|---|---|
| Vegetative and productive aspects: | Tree size | Standard | Standard | Standard | Semi-dwarfing | Semi-dwarfing | Dwarfing |
| | Productivity | Good | Good | Very Good | Good | Very Good | Very Good |
| | Fruit size | ●●● | ●● | ●●● | ●●● | ●●● | |
| | Ripening | ○○○○ | ○ | ○○○○ | ○○○○ | ○○○○ | |
| Physiopathies | Limestone | ★★ | ★ | ★★★ | ★★★ | ★★★★★ | ★★ |
| | Salinity | ★ | ★★★ | ★★★ | ★★★ | ★★★★★ | ★★★ |
| | Flooding | ★★★ | ★★★★★★ | ★★★★★ | ★★★★★ | ★★★ | ★★★ |
| Pests and Diseases | Tristeza Virus | Tolerant | Tolerant | Resistant | Tolerant | Tolerant | |
| | Phytophtora | ★★★★★ | ★★★★★★ | ★★★★★ | ★★★★★ | ★★ | ★★★★★ |

Tree and descriptive data of new citrus rootstock CIVAC-19, a co-obtention between IVIA and Agromillora Group (Spain).

## Legend

**Fruit size**

● — ●●●●

Smaller Size — Bigger Size

**Ripening precocity**

○ — ○○○○

Later — Earlier

**Resistance or sensibility to Phytophtora sp.**

★ — ★★★★★

More Sensitivity — More Resistance

# CIVAC-19

## General Information

**Hybrid**
Citrus reshni (var. Cleopatra) x Poncirus trifoliata

**Origin**
Citrus rootstocks Breeding Program in co-obtenation IVIA - Agromillora

## Resistances and tolerances

**Citrus Tristeza Virus (CTV)**
Tolerant. Presence of the 3 resistance genes by PCR

**Iron Chlorosis**
Tolerant to limestone. Better root activity irrigating without Fe than other rootstocks.

**Flooding**
Tolerant

**Salinity**
Very resistant

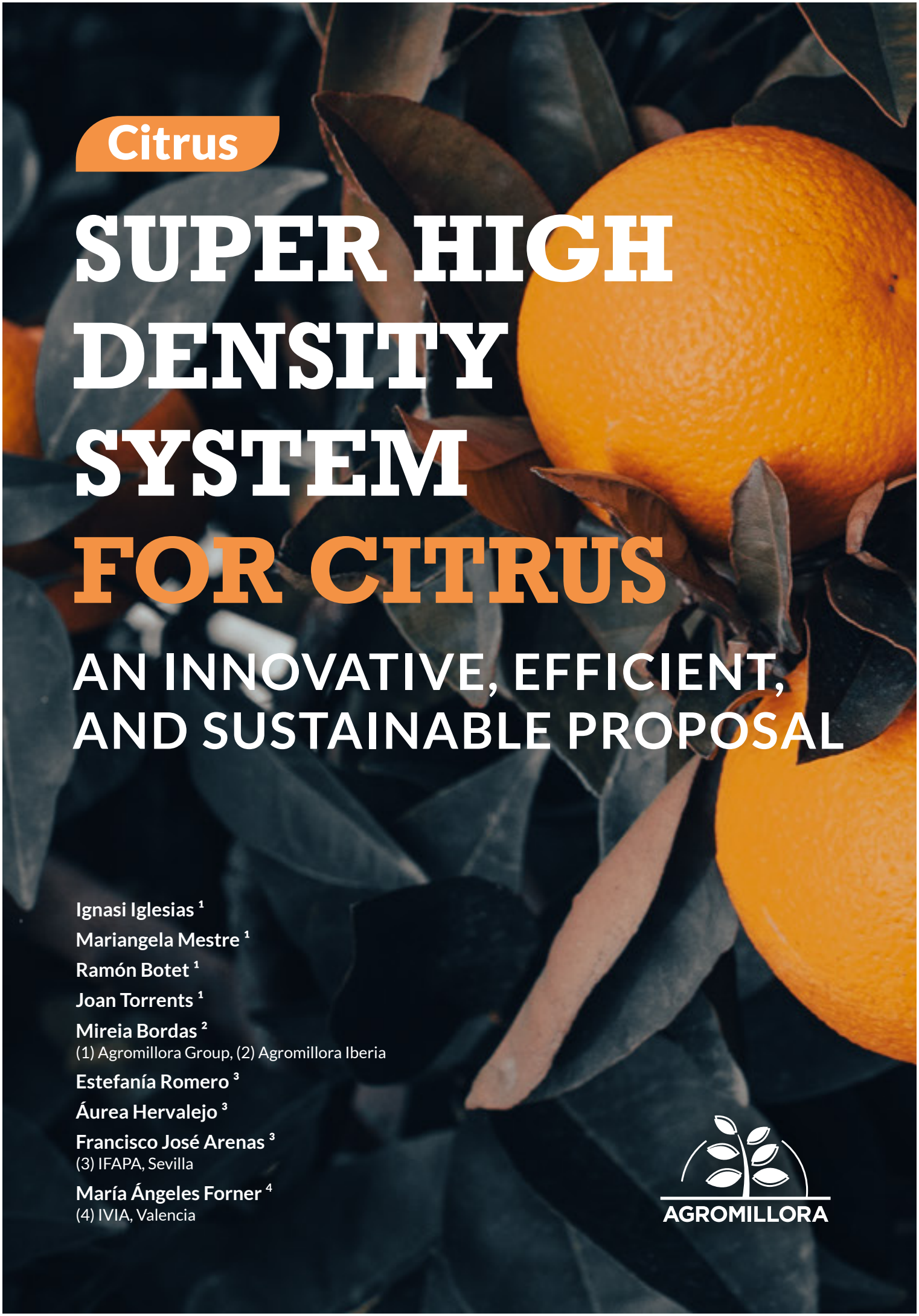
**Agronomic behavior**
Very high production efficiency, good fruit size and early ripening

**Vigor**
Semi-dwarfing

Hedge cultivation is a new agronomical model proposed for citrus cultivation, whether for fresh (hand harvesting) or industrial purposes (mechanical harvesting). It represents a disruptive change with respect to the traditional open vase system. The change in the tree architecture, from a voluminous shape canopy to a bi-dimensional shape with reduced volume, results in better accessibility to the canopy for workers in citrus plantations for fresh market and for machines (over-the-row harvesters) in citrus plantations for industry.

In addition to reducing production costs due to the greater efficiency of inputs such as labor, pesticides, irrigation water and/or fertilizers, this system allows to get early yields and provides a double ability: harvesting citrus for fresh consumption (hand harvesting) or for industry (mechanical harvesting).

This hedge system follows the path of other fruit species, characterized by the transition to smaller, two-dimensional canopies and efficient in the use of inputs; therefore, more sustainable environmentally and for producers' incomes by reducing the cost of production and being less dependent on labor



Citrus

# SUPER HIGH DENSITY SYSTEM FOR CITRUS

## AN INNOVATIVE, EFFICIENT, AND SUSTAINABLE PROPOSAL


Ignasi Iglesias [1]
Mariangela Mestre [1]
Ramón Botet [1]
Joan Torrents [1]
Mireia Bordas [2]
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Estefanía Romero [3]
Áurea Hervalejo [3]
Francisco José Arenas [3]
(3) IFAPA, Sevilla
María Ángeles Forner [4]
(4) IVIA, Valencia


AGROMILLORA