

Citricultor

Fundecitrus

SCIENCE AND SUSTAINABILITY
IN CITRICULTURE



It's more than food.

It's health!

A PRACTICAL, REFRESHING AND NUTRITIOUS BEVERAGE, ORANGE JUICE NOT ONLY BOOSTS THE IMMUNE SYSTEM, BUT ALSO CONTRIBUTES TO GLUCOSE REGULATION, CARDIOVASCULAR HEALTH AND A BALANCED GUT MICROBIOTA



LISTEN on the main platforms



INDEX

Citricultor

CITRICULTOR magazine is a free publication edited by the Fundo de Defesa da Citricultura - Fundecitrus. Fundecitrus, a world reference in science for citriculture, is a non-profit private institution established in 1977 and maintained by citrus growers and processors in the state of São Paulo, Brazil, to foster the sustainable development of the Brazilian citrus belt.

Contact information

Cell Phone/WhatsApp: + 55 (16) 99629-2471

Email: comunicacao@fundecitrus.com.br

Website: www.fundecitrus.com.br

Responsible journalist:

Rafael de Paula (MTb 62.159/SP)

Coverage and publishing:

Rafael de Paula, Rodrigo Brandão and Daniele Merola (Rebeca Come Terra); and Michael Harteman

Graphic design: Juliana Retamero and Fernando H. Ximenez

Review: Viviane Moura

Assistant: Érika Luiza Pereira

Translation: Marly Moro



BRAZILIAN CITRUS BELT

The São Paulo and West-Southwest Minas Gerais citrus belt, located in the Southeast region of Brazil and comprised of approximately 350 cities, is the main orange juice producing region in the planet: three out of five glasses of orange juice consumed in the world are produced here. In this region, citriculture creates 200 thousand direct and indirect jobs and collects 189 million dollars in taxes.



INTERVIEW

Franco Lajolo and Neusa Hassimoto, researchers at the University of São Paulo (USP), take an in-depth look at studies examining the health benefits of daily orange juice consumption



GREENING

Explore how research on resistance has evolved and how plants capable of combating the disease are being developed



ORANGE JASMINE ERADICATION

How public policies have been supporting strategies to protect citriculture and ensure sustainability in the sector

ECONOMY

Extracted from oranges, pectin is a versatile ingredient for the cosmetics and food industries



"When consumed regularly, **orange juice** promotes cardiometabolic health"

RESEARCH SHOWS THAT ORANGE JUICE, WHEN INCLUDED IN A HEALTHY DIET AND CONSUMED WITH MEALS, HELPS REDUCE INFLAMMATORY MARKERS, IMPROVE GLUCOSE CONTROL AND LOWER BLOOD PRESSURE BY UP TO 5%

// Oranges contain a lot of sugar, which is associated with obesity and, consequently, the development of diabetes."

Whenever you read or hear something like this, remember that this claim is far from being supported by science. An orange (weighing around 130 g) contains about 60 kcal. On the same weight basis, a banana contains 115 kcal, grapes 90 kcal, mango 80 kcal, apple 70 kcal, and pineapple, peach, papaya and melon 65 kcal.

A review of the global scientific literature, the eight completed clinical trials (with a ninth currently underway), and the 25 scientific papers published in prestigious international journals resulting from the extensive research program launched in 2013 under the leadership of Professors Franco Maria Lajolo and Neuza Hassimotto have shown that the case is precisely the opposite: when consumed daily and regularly, with main meals and as part of an

appropriate dietary plan—that is, if an individual is expected to consume, for example, 2,500 calories per day, the 240 kcal provided by 500 mL of orange juice should be included within that total—orange juice contributes to maintaining homeostasis and helps regulating blood glucose levels.

In the clinical trials conducted by the research groups of the Food Research Center (FoRC) at the Department of Food and Experimental Nutrition (FBA), School of Pharmaceutical Sciences (FCF), University of São Paulo (USP), in São Paulo, participants consumed between 400 mL and 500 mL of orange juice per day, divided into two servings of 200 mL to 250 mL each, one with lunch and the other with dinner. Naturally, the parameters of interest in each study were measured before and after the intervention in order to assess the effects of orange juice consumption.

None of the participants gained weight during the studies.

And the results were remarkable: orange juice reduces oxidative stress; has anti-inflammatory properties; increases HDL ("good" cholesterol) levels while lowering LDL ("bad" cholesterol) levels; contributes to the maintenance of homeostasis (the body's ability to maintain a stable internal environment); promotes a balanced gut microbiota (the community of trillions of microorganisms, including bacteria, viruses and fungi, that is involved in the metabolism of nutrients and bioactive compounds and supports immune system function); and helps lower blood pressure. (See infographic on page 11).

"Orange juice plays a very important role in human health," says Lajolo. This is no ordinary statement. The conclusion comes from the most cited Brazilian researcher of all time in his field (Agriculture; Food Science; Nutrition & Dietetics), according to the Elsevier Stanford Ranking (September 2025).

“

WHEN ORANGE JUICE IS CONSUMED WITH MEALS—FOR EXAMPLE, AT LUNCH AND DINNER—AS PART OF A BALANCED DIET, NO GLYCEMIC SPIKE IS OBSERVED

WHEN AND WHY DID THE RESEARCH PROJECTS ON CITRUS BEGIN?

Lajolo: Our research on citrus fruits, oranges and orange juice at FoRC began in 2013, driven by the social, economic and nutritional importance of oranges. We started with a comprehensive review of the global scientific literature on the subject and then developed research projects that received support from organizations such as FAPESP (the São Paulo Research



Neuza Hassimotto



Franco Maria Lajolo

Images: Galeano Films

Foundation, which supports FoRC) and CNPq (the National Council for Scientific and Technological Development, an agency linked to Brazil's Ministry of Science, Technology and Innovation). With this funding, we established research groups, and the studies continue to this day.

WHAT DID THE REVIEW SHOW?

Hassimotto: The review serves primarily to avoid duplicating existing research and to generate hypotheses for new studies. Overall, it showed that oranges are an important source of vitamin C, magnesium and potassium.

AND WHAT HAVE THE MORE THAN TEN YEARS OF RESEARCH AT FORC, LED BY YOU, REVEALED?

Lajolo: There have been several original findings. In addition to being an important source of vitamin C, magnesium and potassium, the clinical trials conducted by our research groups have shown that the flavanones present in orange juice have antioxidant properties, helping to prevent oxidative stress; exert anti-inflammatory effects, reducing inflammatory markers in the body; play a role in modulating lipid metabolism, increasing HDL, the "good" cholesterol, while lowering LDL, the "bad" cholesterol; contribute to the maintenance of homeostasis, particularly with regard to blood glucose control; help maintain a balanced gut microbiota; and, finally, in what I consider our most significant recent finding, the clinical

trials point to a relationship between orange juice consumption and lower blood pressure. Volunteers and patients who participated in the studies experienced reductions in blood pressure of up to 5%.

NOW, TWO QUESTIONS. FIRST, WHY IS MAINTAINING A BALANCED GUT MICROBIOTA IMPORTANT FOR HEALTH?

Hassimotto: We observed that the daily, regular consumption of orange juice has a positive effect on the gut microbiota, which plays a role in processing the bioactive compounds found in certain foods. In the case of oranges, these compounds are flavanones, which the microbiota transforms into substances that, once absorbed, are responsible for many of the beneficial effects observed following orange juice consumption. What is particularly interesting is that, by promoting a balanced microbiota, orange juice also helps improve the efficiency with which bioactive compounds from other foods are transformed and absorbed when they depend on the microbiota to perform this function. Examples include flaxseed, walnuts, red berries, grapes, apples, broccoli and kale.

MY SECOND QUESTION CONCERNS SOMETHING THAT MAY SEEM CONTRADICTIONARY. ORANGES CONTAIN SUGAR, RIGHT? SO HOW CAN THEY HELP REGULATE BLOOD GLUCOSE LEVELS AND SERVE AS AN ALLY IN THE FIGHT AGAINST DIABETES?

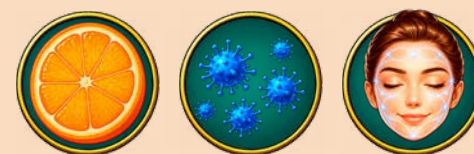
Hassimotto: First of all, all fruits contain sugar; some contain more, others less. But it does not seem wise to me to exclude them from the diet. When oranges or orange juice are consumed regularly—not between meals, but with meals, such as at breakfast and dinner or at lunch and dinner—as part of an appropriate diet formulated according to international dietary guidelines, no glycemic spike is observed. Why? Because flavanones partially inhibit the digestive enzymes responsible for breaking down starch into sugars that will be absorbed by the body, helping to maintain glycemic balance. In this way, by contributing to the maintenance of homeostasis, orange juice can indeed be an ally in the prevention of diabetes and insulin resistance. And, importantly, we did not observe weight gain in any of the participants in the clinical trials we conducted.

IS ORANGE JUICE IMPORTANT FOR HUMAN HEALTH?

Lajolo: Yes, science has shown that, when consumed appropriately, orange juice is an important food for human health. But we are talking about food, not medicine used to treat a disease or a symptom. Orange juice helps modulate a variety of metabolic functions, but it must be consumed regularly as part of a balanced diet. That is when it can deliver its benefits, because that is how its effects are achieved. 🍊

THE MAIN ORANGE NUTRIENTS AND BIOACTIVE COMPOUNDS AND THEIR ACTION IN THE HUMAN BODY:

VITAMIN C



An essential nutrient for collagen synthesis, vitamin C helps strengthen the immune system, enhances the absorption of plant-based iron and acts as an antioxidant, helping to combat free radicals.

POTASSIUM



An essential mineral for nerve impulses, muscle contraction, fluid balance and protein synthesis. It also helps regulate blood pressure.

MAGNESIUM



An essential mineral for muscle, neuromuscular, bone and metabolic function. It also helps regulate blood pressure, protects cardiovascular health and contributes to healthy bowel function.

FLAVANONES

Phenolic bioactive compounds found in citrus fruits such as oranges, lemons and grapefruit. In oranges and orange juice, they provide important health benefits, including:



Antioxidant effect

Reduce oxidative stress and promote cell protection.



Anti-inflammatory action

Help reduce chronic low-grade inflammation ("silent" inflammation, which typically causes no noticeable symptoms), a condition associated with obesity, diabetes and cancer.



Cholesterol

Help increase HDL ("good" cholesterol) and reduce LDL ("bad" cholesterol), improving the lipid profile.



Homeostasis

Contribute to maintaining the body's internal balance, including glycemic control.



Blood pressure

Help reduce the blood pressure by up to 5%, the key modifiable risk factor for cardiovascular events, like infarction and stroke.



Intestinal microbiota

Promote a balanced gut microbiota, the community of microorganisms in the intestine that performs several functions beneficial to health, including strengthening the immune system, extracting energy from food, aiding mineral absorption and synthesizing vitamins.



Evolution of research on greening-resistant plants

FUNDECITRUS-LED RESEARCH IS ADVANCING OUR UNDERSTANDING OF THE GENETICS OF DISEASE RESISTANCE, PAVING THE WAY FOR THE TRANSFORMATION OF A NATURAL DEFENSE INTO A PRACTICAL SOLUTION FOR THE FIELD

With no cure yet available and a devastating impact on productivity, greening remains the greatest challenge facing both the citrus industry and the scientific community. Following the discovery of non-commercial citrus plants resistant to the disease, Fundecitrus researchers in the field of biotechnology have been working to understand the mechanisms underlying this resistance and to identify viable pathways for transferring these traits to commercial varieties. The first signs of this potential gained attention in 2019, when hypotheses were confirmed showing that certain citrus species native to Oceania, such as *Eremocitrus* and *Microcitrus*, were capable of

either avoiding infection by the disease or exhibiting greater tolerance to contamination by the bacterium, respectively.

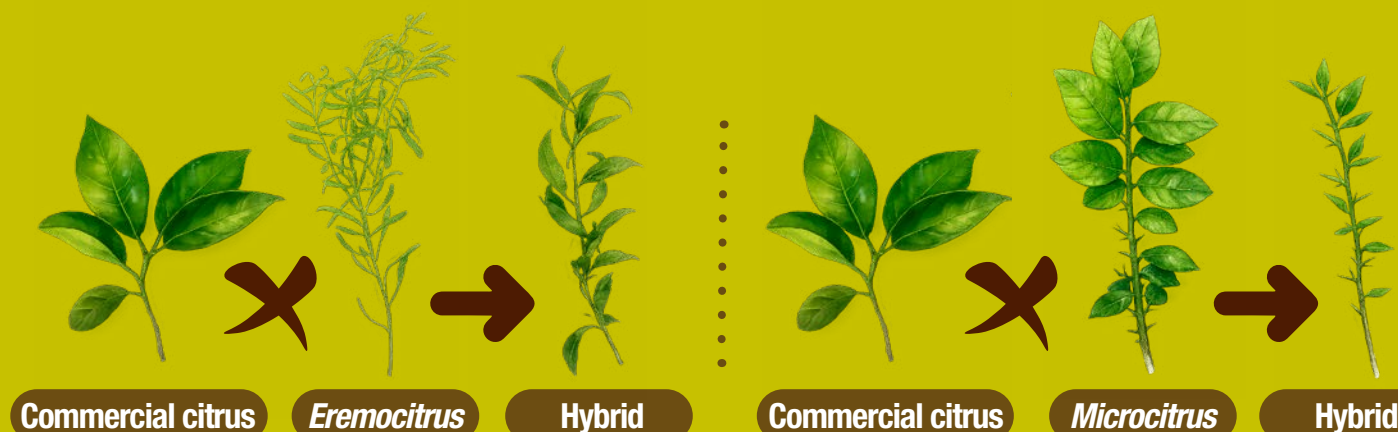
Since then, the project has advanced significantly, moving beyond the mere observation of the phenomenon to a deeper, more complex and challenging stage: understanding where, within the DNA of these plants, the genetic basis of resistance lies and how it can be harnessed by commercial citrus production. At Fundecitrus, this line of research has become established as one of the institution's most strategic areas of scientific investigation.

The project is led by Fundecitrus researcher Monica Neli Alves. Directly comparing the DNA of a resistant plant with that of a susceptible one, such as

sweet orange, is no simple task. The differences between them extend far beyond resistance to greening: leaf, flower and fruit morphology, growth habits, agronomic traits and thousands of genetic variations make such a direct comparison both complex and imprecise. As a result, the researchers adopted a different strategy. "Instead of simply comparing the species as a whole, the project began working with controlled crosses between greening-resistant and greening-susceptible plants. These crosses generate populations of offspring that, while genetically more similar to one another, exhibit different responses to the disease. Some inherit resistance, while others inherit susceptibility," she explains.

CONTROLLED CROSSES

Crosses between commercial citrus varieties and resistant or tolerant wild species, such as *Eremocitrus* and *Microcitrus*, are among the strategies being pursued by researchers to develop plants capable of withstanding greening and securing a more sustainable future for citrus production



COMPARATIVE ANALYSIS

It is in this comparison among “siblings” that genetics begins to reveal its role more clearly. By analyzing which regions of the DNA are frequently found in resistant offspring and are also present in the resistant parent (but absent in susceptible individuals), researchers can identify genetic regions associated with resistance traits, known as QTLs (Quantitative Trait Loci, regions of the genome associated with a particular characteristic). These regions do not necessarily correspond to a single gene. They may involve dozens or even thousands of genes acting together. “For this reason, the project avoids referring to a single ‘resistance gene’ and instead adopts a more realistic perspective. Resistance to greening is a complex trait, and it may be controlled by multiple regions of the genome that interact with one another,” the researcher explains.

GENETIC MAPS

Identifying these QTLs requires a crucial intermediate step: the construction of genetic maps for the populations under study. “These maps function as a snapshot of the DNA of the offspring being analyzed, showing what each

BREEDING PROGRAM AND CITRUS RESISTANCE

1 CONTROLLED CROSSES

Microcitrus/Eremocitrus
(Non-commercial resistant or tolerant varieties)

Susceptible orange
(Commercial traits)

Hybrids



Resistant plants are crossed with susceptible oranges to produce offspring (hybrids)

2 PSYLLID TEST AND MONITORING

40 - 80 - 120 - 182 days

The hybrids are inoculated with the greening bacterium using infective psyllids under controlled conditions



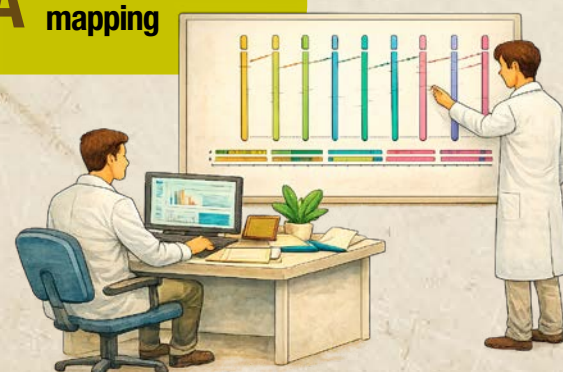
2.A Population of hybrids
Resistant or Tolerant



3 DNA SEQUENCING



3.A Genetic mapping



4 IDENTIFICATION OF QTLs

2.A + 3.A



DNA regions associated to resistance (QTLs) are identified

5 ACCELERATED BREEDING



Molecular markers enable the rapid identification of resistant offspring, accelerating breeding cycles and the development of greening-resistant commercial orange varieties.

6 GENE IDENTIFICATION

The DNA of commercial orange varieties could be edited to behave like that of resistant plants

plant inherited, for example, from the resistant parent and the susceptible parent. With these maps in hand, it becomes possible to associate genetic information with the observed response of each offspring [resistant or susceptible] and identify the regions of the genome most strongly correlated with resistance,” she explains.

The greatest practical benefit of this process is the development of molecular markers. These DNA markers allow researchers to identify resistant plants without having to rely on lengthy and complex inoculation tests using the bacterium’s insect vector, one of the main bottlenecks in greening research. This is due, in part, to the fact that the bacterium associated with greening cannot be cultured in the laboratory, which limits experimental work and makes inoculation assays dependent on either the insect vector or grafting with infected plant material. With molecular markers, however, breeding programs can advance much more rapidly. Instead of waiting years to confirm whether a plant is resistant, Fundecitrus researchers will be able to analyze its DNA at an early stage and determine whether it should remain in the breeding program.

BREEDING

According to Nelson Wulff, manager of Fundecitrus' Biotechnology Department, the institution's strategy combines classical plant breeding with modern molecular genetics tools. The

goal is to incorporate resistance traits from Oceanian species into plants that progressively acquire the commercial characteristics of orange varieties. "This process requires multiple generations of crosses, generally involving species that contributed

to the origin of modern oranges, such as mandarins and pomelos. With each new generation, molecular markers help select only those individuals that retain resistance, accelerating a process that would have taken decades in the past," he explains.

At the same time, knowledge of these resistance-associated regions opens the door to even more advanced approaches, such as gene editing, in which specific regions of the DNA of commercial sweet orange varieties could be modified to mimic those found in resistant plants. Although this approach is still under development, it represents a promising avenue for future research. 🍊

HOW THE PROJECT STANDS TODAY



Mônica Neli and Juan Arenas in a greenhouse where hybrid plants are maintained for ongoing research

The project currently comprises nine populations derived from different crosses between resistant Oceanian species and susceptible Asian species. Altogether, these populations include 1,682 hybrids, of which 665 have already undergone inoculation and are being evaluated for resistance classification. On the genetics side, more than 600 hybrids have been sequenced, two genetic maps involving *Microcitrus* populations have already been completed, and a third map, based on *Eremocitrus*, is currently under construction. These maps will be integrated with the resistance data to advance the identification of genetic regions associated with greening resistance. The work involves a complex research infrastructure, including thousands of plants maintained in greenhouses, intensive use of bioinformatics and close coordination with the teams responsible for rearing and managing the insect vector used to inoculate plants with the greening-associated bacterium. "This is an essential step for ensuring reliable results, and one that could only be achieved after many years of prior research on the interactions among the plant, the insect and the bacterium," explains Fundecitrus researcher Juan Arenas, a member of the project team.

NEW PATHS

In addition to its primary objective—the development of resistant plants—the project has paved the way to several other lines of research. "Studies on gene expression, metabolite production, phloem anatomy, and the use of these plants as rootstocks or interstocks are now being conducted by different research teams, forming a true network of investigation focused on resistance," explains Wulff.

This research network brings together leading national partners, such as Eduardo Girardi of Embrapa Cassava and Fruits, as well as international collaborators, including CSIC/UPV in Spain, represented by Leandro Peña, a senior researcher in citrus biotechnology and transformation; CIRAD in France, with researchers Patrick Ollitrault, Barbara Hufnagel and Raphaël Morillon, specialists in citrus genetics, genomics and physiology; and the Department of Primary Industries in Queensland, Australia, with the participation of citrus breeder Malcolm Smith. Many of these research efforts are conducted within the framework of CPA Citros.

255.20 million orange boxes

ORANGE CROP FORECAST POINTS TO LOWER PRODUCTION IN THE CITRUS BELT AMID IRREGULAR WEATHER, GREENING EXPANSION AND ALTERNATE BEARING

The 2026-2027 orange crop in the citrus belt of São Paulo and the Triângulo Mineiro/Southwest Minas Gerais region is expected to total 255.20 million 40.8-kg boxes. The forecast, released by Fundecitrus on May 8, confirms a scenario of declining production in the world's leading orange juice-producing region, driven by a combination of irregular weather, the spread of greening and the effects of alternate bearing in citrus groves. The projected volume

represents a 12.9% decrease from the previous crop, which closed at 292.94 million boxes, and is also 14.7% below the average recorded over the past decade.

The decline is primarily attributed to a lower number of fruits per tree, increased premature fruit drop throughout the production cycle and the natural alternate-bearing pattern of citrus trees. Despite positive factors such as a higher average fruit weight and an increase in the number of bearing trees, these gains were not enough to offset the losses observed in the field.

CROP SEASON PROFILE

Weather conditions played a decisive role in the development of the crop. According to the Orange Crop Forecast (PES), conducted by Fundecitrus, the drought recorded in May 2025 caused water stress

in citrus groves and directly influenced flowering patterns. In regions with a greater prevalence of irrigation, the return of adequate water availability stimulated the first bloom. Even so, above-average temperatures in September compromised part of fruit set. In less irrigated areas, meanwhile, the combination of intense heat and limited rainfall between July and September restricted the initial development of the first bloom.

The return of rainfall beginning in October changed the outlook. With more regular and abundant precipitation, the second bloom gained strength and became the dominant bloom of the crop. Even so, the high temperatures recorded in December also affected part of the fruit set, although their impact was mitigated by the abundant rainfall between



December and March, a period that is essential for sustaining fruit development. According to Guilherme Rodriguez, manager of the Orange Crop Forecast (PES), these weather patterns have impacts that extend beyond productivity. "This combination of temperature extremes and water deficits during critical periods not only compromises the productive potential of citrus groves, but it also alters the traditional flowering pattern," he says.

GREENING PRESSURE INTENSIFIES

In addition to climate fluctuations, the spread of greening remains one of the citrus industry's greatest challenges. The latest survey conducted by Fundecitrus in September 2025 found that the disease is already present in 47.6% of the orange trees across the citrus

belt. According to Fundecitrus Executive Director Juliano Ayres, the new forecast reflects an increasingly challenging environment for the sector. "This crop season has been affected by climate variability and increased greening pressure, with impacts on fruit set, fruit load, and premature fruit drop. Despite gains in average fruit weight and the technological advancement of groves, the current scenario demands strict management practices and continuous monitoring," he says.

FEWER FRUITS, BIGGER ORANGES

Although total production is lower, oranges are expected to reach harvest at a larger size. The forecast indicates an average fruit weight of 160 grams per orange, higher than that recorded in the previous crop se-

ason. This result is a direct consequence of the lower fruit load per tree, combined with higher water availability during part of grove development. With fewer fruits competing for resources, trees were able to allocate more energy to the growth of the remaining oranges.

PRODUCTIVITY GOES DOWN AND LOSSES RISE

Average productivity for the crop season is estimated at 697 boxes per hectare, a 13.8% decline compared to the previous season. With the exception of the other early-variety group, all varieties analyzed showed lower yields. Among the factors that weighed most heavily on crop performance are the premature fruit drop rate, estimated at 23.7%, and the total loss rate,

projected at 31.3%. The spread of greening, the incidence of citrus leprosis, the expected occurrence of El Niño during the second half of 2026, and the trend toward a later harvest also contribute to growing concern across the industry.

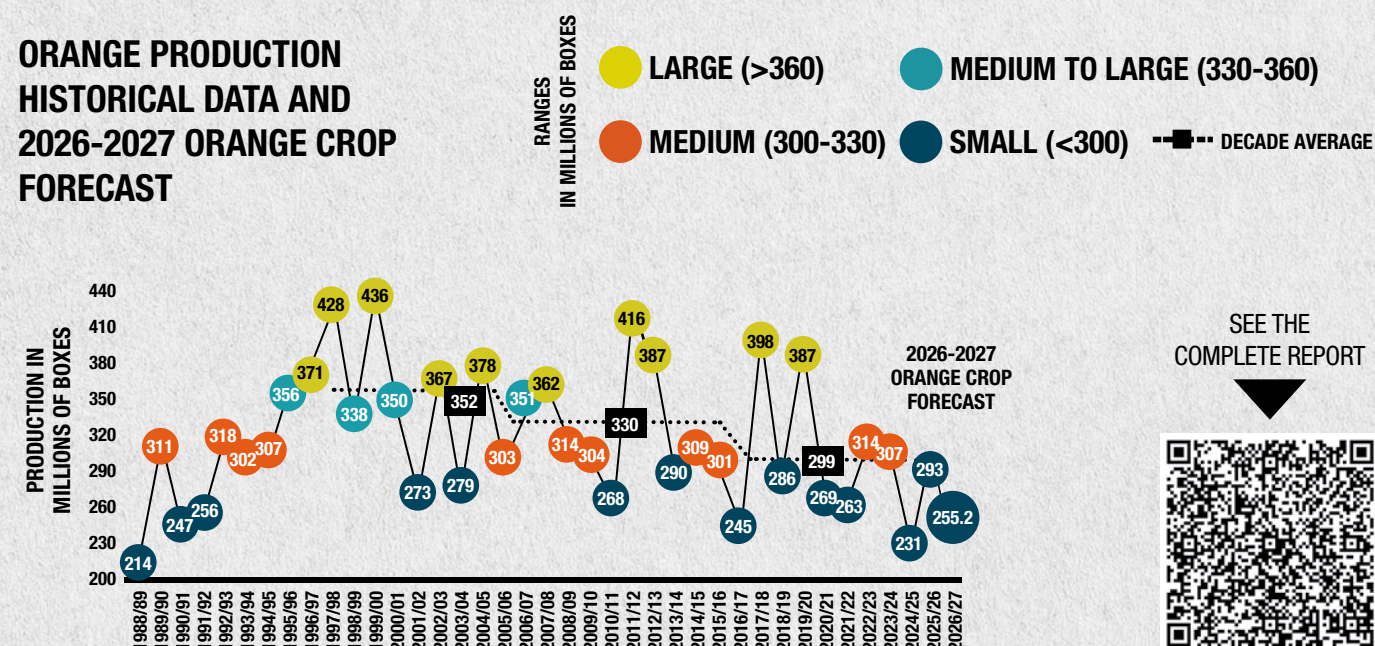
Part of the increase in loss rates is also the result of enhancements to the methodology adopted by Fundecitrus, which now incorporates fruit-stripping data collected during harvest to improve measurement accuracy. 🍊

FRUITS SHOULD BE LARGER AT HARVEST. THE EXPECTED AVERAGE WEIGHT IS 160 GRAMS PER ORANGE

FRUIT STRIPPING AT HARVEST: A MORE ACCURATE METHODOLOGY

For the 2026-2027 Orange Crop Forecast, Fundecitrus incorporated fruit stripping at harvest as a new methodological step in the PES, with the objective of increasing the accuracy of field fruit-loss data. Based on objective measurements, fruit stripping is carried out through the counting and weighing of fruits in the field. At the beginning of the crop season, projected losses are calculated based on the fruit drop rate observed in the tree canopy and on a statistical correction factor. At the end of the season, however, these indices are replaced by the actual fruit loss rate, measured directly during harvest through a new fruit-stripping operation, which makes it possible to account for the fruits that effectively remained on the tree until harvest. The survey involved more than 1,000 trees distributed across different regions of the citrus belt, encompassing groves of various ages and orange varieties, thereby ensuring the statistical representativeness of the crop forecast. According to Guilherme Rodriguez, monitoring will continue throughout the production cycle. "Production continues to be monitored by Fundecitrus, and the forecast will be updated throughout the crop season, particularly in response to fruit drop and the final size of the oranges," he says.

ORANGE PRODUCTION HISTORICAL DATA AND 2026-2027 ORANGE CROP FORECAST



DROP RATE:
23.7%



PRODUCTION PER HECTARE:
697 BOXES



PRODUCTION PER TREE:
1.38 BOX

From garden to grove: collective action against greening

FROM URBAN LANDSCAPING TO STATE PUBLIC POLICIES, THE REMOVAL OF ORANGE JASMINE PLANTS IS MOBILIZING GROWERS, MUNICIPAL GOVERNMENTS, AND PLANT HEALTH AUTHORITIES IN A COORDINATED EFFORT TO PROTECT CITRUS GROWING AND ENSURE THE SECTOR'S LONG-TERM SUSTAINABILITY

Its fragrance is pleasant in the garden. In the field, however, it poses a silent threat. Orange jasmine, also known as night-blooming jasmine, is a common sight along sidewalks, in backyards, and on rural properties across Brazil. Ornamental, hardy, and known for its distinctive fragrance, it has become a popular landscaping plant in urban areas. At the same time, it has drawn the attention of plant health authorities because it serves as a host for the psyllid, the insect that transmits greening. As a result, the connection between urban gardens and commercial citrus groves is no longer a distant one—it has become a plant health concern.

In response to the spread of greening, Brazil's Ministry of Agriculture and Livestock (MAPA) issued SDA/MAPA Ordinance No. 1,326 on July 4, 2025, updating the National Huanglongbing Prevention and Control Program (PNCHLB).

The ordinance establishes specific requirements for orange jasmine (*Murraya paniculata*), including a ban on the transport of plant material of this species in areas where greening occurs, as well as the removal of existing orange jasmine plants within a 4-kilometer radius of commercial citrus properties whenever the insect vector is detected on those plants. In addition, the new regulation prohibits the planting of orange jasmine within these border areas.

Furthermore, some states have adopted more restrictive measures, such as São Paulo. The state's Resolution SAA-24/2025 prohibits the planting, sale, production, and transportation of orange jasmine in all municipalities, regardless of the occurrence of greening. The rationale is straightforward: to reduce the number of shelters and breeding sites available to the insect, thereby slowing the dissemination

of the disease. By finding refuge in orange jasmine plants, the insect vector is able to sustain the disease transmission cycle.

ENFORCEMENT

In the state of São Paulo, responsibility for implementing these measures falls to the state's Agricultural Defense Service, which is linked to the Department of Agriculture and Supply. Efforts extend to both rural properties and urban areas in an approach that combines enforcement and outreach. According to Veridiana Zocoler de Mendonça, manager of the State Citrus Health Program, activities were intensified following the publication of the regulation. "We carried out a task force that resulted in the eradication of 13,759 orange jasmine plants. The presence of host plants poses a real threat to citrus growing. We receive reports, provide guidance

to residents and growers, and recommend replacing them with non-host species," she explains.

The challenge, however, goes beyond enforcing the regulation. Orange jasmine continues to be valued for its ornamental appeal and distinctive fragrance, and many property owners remain unaware of its connection to the disease. "It does little good for growers to follow every protocol if the insect can still find refuge in urban areas. More than enforcement, what is needed is awareness," she emphasizes.

IMPACT

The spread of greening has already led to the eradication of more than 70 million trees across the citrus belt of São Paulo and Minas Gerais states. Its effects are being felt in productivity, fruit quality, and growers' bottom line, as they are required to invest more in frequent inspections, spray applications, the removal of infected trees, and the establishment of new groves.

By restricting the planting of orange jasmine, citrus-producing states are reinforcing a preventive strategy: breaking the link that sustains the insect vector's life cycle. The so-called "Orange Jasmine Law," as it has become known within the industry, symbolizes a shift in perspective that the fight against greening extends beyond the farm gate. In combating the disease, the urban garden is also an extension of the grove.

REPORTS

Since 2023, São Paulo's Agricultural Defense Service has maintained a dedicated channel for repor-

ting abandoned or poorly managed groves, as well as the presence of orange jasmine along sidewalks, in hedges, and in landscaping projects. "The reporting form can be submitted anonymously and should include as much location information as possible. An agronomist conducts an inspection and, if necessary, initiates proceedings for the plant's removal. The more detailed the report, the faster the response," explains Mendonça. The state has already recorded more than 430 greening-related reports, ranging from abandoned groves to the presence of orange jasmine after the ban came into effect.

INCENTIVE

Restrictions on the planting of orange jasmine have also become part of municipal public policy initiatives. In the state of São Paulo, the adoption of specific legislation can earn municipalities points under the Município Agro Program – São Paulo State Ranking, coordinated by the Department of Agriculture and Supply. The program evaluates criteria such as agricultural production, sustainability, rural infrastructure, and plant and animal health protection. Municipalities that promote the removal of orange jasmine from urban areas improve their standing in the ranking and may receive official recognition, as well as access to financial awards and partnership agreements. "Cities that encourage the replacement of orange jasmine receive points under the program's evaluation criteria. Many have already been encouraged by citrus-related institutions to adopt specific regulations," says Mendonça.

MATO GROSSO DO SUL:

EXPANSION AND PROTECTION

Following the approach adopted in São Paulo, Mato Grosso do Sul, a state that has emerged as an important area for citrus expansion, has intensified enforcement efforts and adopted more restrictive measures through State Law No. 6,293/2024, which prohibits the planting, sale, and transportation of orange jasmine throughout the state. The legislation is reinforced by complementary municipal regulations in cities such as Campo Grande, Sidrolândia, and Três Lagoas, extending the reach of the restrictions and enabling direct action by the city governments. The State Agency for Animal and Plant Health Protection (Iagro) coordinates these efforts in accordance with the state regulation. According to the agency's president, Daniel Ingold, the measure protects the state's plant health assets and strengthens the professionalization of the production chain. "We eradicated approximately 6,000 orange jasmine plants in 2024 and 2025 through inspections of nurseries and areas near commercial citrus groves. Greening is not just a citrus grower's problem—it is a strategic plant health challenge. The legislation was not created to punish, but rather to protect the investments of those who believe in the state," he says. For Ingold, the current moment is decisive. "The citrus industry in Mato Grosso do Sul is experiencing historic expansion, and plant health is our greatest asset. Eliminating orange jasmine today means safeguarding tomorrow's harvest."

Orange jasmine is one of the main host plants for psyllids

AWARENESS

Controlling psyllids on orange jasmine plants located in urban areas is no simple task. The recommendation is to replace orange jasmine with ornamental or fruit-bearing species better suited to urban landscaping, a measure that goes beyond aesthetics and enters the realm of plant health protection. The numbers help illustrate the scale of the problem. According to a Fundecitrus survey, greening affected 47.63% of the orange trees in the citrus belt of São Paulo and the Triângulo Mineiro/Southwest Minas Gerais region in 2025, an increase of 7.4% compared to 2024.

According to Ivaldo Sala, coordinator of Fundecitrus' Technology Transfer Department, the presence of orange jasmine in urban areas serves as an invisible link in the chain of disease spread. "The psyllid feeds, reproduces, and then migrates to commercial citrus groves. The legislation reinforces the need for public awareness and responds to the concerns of citrus growers who live with this risk. Citrus growing depends on collective action," he says. In addition to supporting the replacement of host plants, Fundecitrus has intensified educational initiatives, including school visits, public awareness campaigns, the installation of informational banners, and technical guidance on preventive control measures, the eradication of orange jasmine plants, and the use of healthy seedlings. The strategy is to integrate urban and rural areas into a unified front against greening. 🍊



Fundecitrus' team replaces greening-infected citrus plants by ornamental and fruit species that are not psyllid hosts

GREENING IS SERIOUS STUFF

Science reaching the grove



FUNDECITRUS' TECHNOLOGY TRANSFER DEPARTMENT SERVES AS A BRIDGE BETWEEN RESEARCHERS AND CITRUS GROWERS, BRINGING KNOWLEDGE AND MANAGEMENT STRATEGIES TO SUPPORT THE FIGHT AGAINST GREENING

Bringing science into the grove is the mission of Fundecitrus' Technology Transfer team. Since 1979, the department has served as a bridge between scientific knowledge and citrus growers, transforming research findings into practical recommendations for grove management.

Working throughout the citrus belt of São Paulo and the Triângulo Mineiro/Southwest Minas Gerais region, as well as in emerging citrus-growing areas of Mato Grosso do Sul, Fundecitrus' team of agronomists brings technical guidance, management practices, and innovations directly to growers. The goal is to strengthen grove health and productivity in the face of the citrus industry's greatest challenges.

Agronomist and department coordinator Ivaldo Sala recalls that the work began with ini-

tiatives focused on preventing citrus canker. "In the early years, the focus was on preventing the disease from entering groves and providing guidance on the control of diseases such as Citrus Variegated Chlorosis (CVC) and Citrus Sudden Death (CSD)."

"With the arrival of greening in 2004, the team had to evolve and expand its strategies to support growers in addressing the industry's most pressing plant health challenges," he says.

Today, the department's work is structured around four pillars: Technology Transfer, Psyllid Alert, External Control, and Disease Surveys, which operate in an integrated manner to support decision-making in the field.

TECHNOLOGY DISSEMINATION

Technology Transfer is one of the cornerstones of the department's work. Throughout

the year, the team promotes a broad capacity-building agenda that includes events, training programs, and technical field visits.

Among these initiatives are Citros em Foco (Citrus in Focus), held in different regions of the citrus belt, as well as Field Days, participation in Citrus Week, in-person training programs, online courses, and technical assistance provided directly to citrus properties.

The department also provides technical manuals and guidance on the use of tools developed by Fundecitrus, helping growers apply research findings to the day-to-day management of their groves.

PSYLLID ALERT

Developed by Fundecitrus, Psyllid Alert is considered the world's largest psyllid mo-

TECHNOLOGY TRANSFER PILLARS



Technology dissemination



Psyllid Alert



External control



Disease survey

monitoring system and operates in partnership with citrus growers. The tool compiles data on psyllid populations and the presence of new flushes in monitored areas, making it possible to identify periods of greater risk and adopt more effective management strategies.

Psyllid monitoring is one of the key strategies for protecting citrus groves in Brazil. The system currently includes 38,442 yellow sticky traps installed across 2,051 properties, covering 337,775 hectares of citrus. Of these, 35,198 traps are monitored by citrus growers themselves, while 3,244 are monitored by Fundecitrus, further strengthening the integration between research and field operations. "More than a monitoring system, Psyllid Alert functions as a collective intelligence ne-

twork. By bringing together information from thousands of traps, it transforms data into strategic knowledge, anticipating risks and helping contain the spread of greening," explains Sala.

EXTERNAL CONTROL

As part of the External Control pillar, the team of agronomists promotes awareness of the importance of citrus farming and the economic impacts that greening can have on local communities.

These initiatives also extend to urban areas and include the replacement of citrus trees and orange jasmine plants—both hosts of the psyllid—in backyards, along sidewalks, and in public spaces with ornamental or fruit-bearing species.

Between 2018 and January 2026, approximately 5.7

Presentations at schools about citriculture and greening prevention foster education and community engagement



million plants were replaced through partnerships involving citrus growers, municipal governments, the Agricultural Defense Service, the Department of Agriculture and Supply, and other institutions.

The team also conducts educational activities in schools aimed at raising awareness among children and their families about the importance of the citrus industry and the need to control greening.

The fight against the disease depends on coordinated action among growers, neighboring communities, and society as a whole. "This work is the result of a relationship of trust that has been built over the years between Fundecitrus and citrus growers, strengthening regional disease control. The engagement of municipalities has been essential to this process," the coordinator emphasizes.

THE MISSION OF TECHNOLOGY TRANSFER IS TO BRING SCIENTIFIC FINDINGS TO THE GROVE, TURNING THEM INTO PRACTICAL GUIDANCE FOR DAY-TO-DAY GROVE MANAGEMENT

DISEASE SURVEY

Another pillar of the department's work is the annual disease survey conducted across the citrus belt in collaboration with the Orange Crop Forecast (PES) team and Fundecitrus researchers. The study measures the incidence of greening-infected trees in the different citrus-growing regions and serves as a foundation for planning management strategies and investment decisions.

TECHNICAL PRESENCE

IN PRODUCING REGIONS AND EXPANSION AREAS

Fundecitrus' Technology Transfer Department is made up of 10 agronomists working across the main citrus-producing regions and citrus-growing expansion areas. The team is present in:



MONITORING THAT PROTECTS THE GROVES

With the support of the Technology Transfer team, thousands of traps have been deployed across citrus properties to monitor psyllid populations.

- 38,442** ▶ yellow sticky traps deployed;
- 35,198** ▶ traps monitored by citrus growers;
- 3,244** ▶ traps monitored by Fundecitrus;
- 337,775** ▶ hectares of citrus-growing areas monitored;
- 2,051** ▶ properties monitored;
- 21** ▶ regions served in São Paulo, Triângulo Mineiro, and Mato Grosso do Sul

EXPANSION

The expansion of citrus growing into new regions has also broadened the scope of the Technology Transfer Department's activities. States such as Mato Grosso do Sul and Minas Gerais have begun receiving monitoring actions through the Psyllid Alert system, as well as external control initiatives, bringing to these areas the regional management model that is already well established in the citrus belt. "The expansion into more distant regions requires a greater effort from the team. The goal is to ensure that these growing ci-

trus-producing areas adopt the most effective management strategies from the outset," says Sala.

APPLIED SCIENCE

Controlling greening requires more than isolated actions within individual groves. Effective disease management depends on information, continuous monitoring, and coordinated action among growers. In this context, the Technology Transfer Department has established itself as a key component in bringing science to the field and strengthening regional management strategies.

The spread of the disease has shown that controlling greening requires a collective effort. When citrus growers work together and properly implement the available technologies, it is possible to keep the disease under control. "All Fundecitrus recommendations are based on rigorous research conducted in partnership with universities. More than simply bringing technology to growers, we reinforce the importance of cooperation among citrus growers. Information, research, and collaborative action remain the most effective tools for protecting the citrus industry," he concludes. 🍊

AVALIA PSILÍDEO

REACHES THE NEW CITRICULTURE FRONTIERS

Fundecitrus has expanded the reach of the Avalia Psilídeo tool to areas emerging as new frontiers of Brazilian citrus production, strengthening technical support for growers at a strategic time of grove expansion in the states of Minas Gerais and Mato Grosso do Sul.

The platform is designed to support more informed decision-making in psyllid management by providing up-to-date information on the effectiveness of insecticides tested against field-collected populations, helping growers define more effective control strategies.

According to Fundecitrus researcher Wellington Ivo Eduardo, the results have been encouraging in these expanding citrus-growing areas. "Pyrethroids and neonicotinoids have shown good efficacy. In these regions, it is essential that growers rotate insecticides using at least five different modes of action to reduce the risk of selecting psyllid populations resistant to insecticides," he emphasizes.



Fundecitrus initiative that supports producers in adopting good labor practices, promoting safer, responsible, and legislation-compliant management.



What else can an orange offer?

FROM FOOD STRUCTURE TO
COSMETICS, PECTIN EXTRACTED
FROM ORANGE PEELS BROADENS
THE FRUIT'S CONTRIBUTION TO
HEALTH AND WELL-BEING



The orange offers much more than juice. Among the by-products gaining prominence in the citrus value chain, pectin occupies a strategic position by connecting the grove, industry, and technology—while also delivering health benefits. Extracted primarily from the spongy white layer of citrus fruit (albedo), located between the peel and the pulp, this natural soluble fiber adds value to the raw material and highlights the potential for the fruit's full utilization. "Pectin is a natural soluble fiber found in the cell walls of plants, especially fruits. It acts as a 'cement' that provides structure to plants," explains engineer Olney Greilberger, manager at Tate & Lyle, a

company operating in the food ingredients sector.

With more than 40 years of experience in the citrus industry, Greilberger has witnessed the evolution of the sector for decades. He participated in energy conversion projects, worked for companies such as Citrosuco, Bascitrus, and Citrofrut (Mexico), and since 2009 has been directly involved in the pectin value chain, developing suppliers and improving processes to obtain citrus peel with the quality required for fiber extraction.

The pectin production process involves a series of technical steps that vary depending on the intended application. The end result is a fine pow-

der formulated according to the specifications of each industrial segment. "Production includes raw material washing, extraction through acid hydrolysis, separation and filtration, alcohol precipitation, purification, drying, and milling, culminating in a standardized powdered product ready for commercial use," he explains in detail.

Greilberger explains that although pectin is now associated with a highly technological industry, it has a long history. It was identified as a gelling agent (capable of forming a gel) between 1824 and 1825 by the French chemist Henri Braconnot, who coined the name from the Greek pektikos ("to coagulate" or "to solidify").

Commercial production began in Germany in 1908, and since then its applications have become increasingly diverse.

VERSATILITY

In practice, pectin is widely used as a gelling, thickening, and stabilizing agent in a variety of products. Its best-known application is in the food industry, where it provides texture and consistency to products such as jams, confectionery products, fillings, toppings, gummy candies, yogurts, dairy beverages, juices, nectars, sauces, and baking goods. However, its uses extend well beyond food applications.

Pectin is also widely used in the pharmaceutical and cosmetics industries, where it is incorporated into formulations for dietary supplements, liquid suspensions, wound dressings, shampoos, and creams. In addition, it plays a role in the development of biodegradable materials, aligning with the growing sustainability agenda.

METABOLIC HEALTH

While pectin stands out in industry for its technological functionality, in the human body it plays an important role in intestinal and metabolic health. Dietitian Aline Alves de Santana, a researcher at the Food Research Center

EXTRACTED FROM ORANGE PEEL, PECTIN CONNECTS THE GROVE, INDUSTRY, AND TECHNOLOGY, ENHANCING THE FRUIT'S VALUE AND EXPANDING ITS PRESENCE ACROSS DIVERSE MARKETS

(FoRC) of the School of Pharmaceutical Sciences at the University of São Paulo (USP), explains that the main benefits of pectin found in orange peel include increased satiety, reduced cholesterol levels, and improved glycemic control. "In the intestine, bacteria ferment this fiber and produce short-chain fatty acids, which are associated with anti-inflammatory effects as well as intestinal and metabolic health," she says. According to

PECTIN AND ITS MULTIPLE APPLICATIONS



Supplements



Liquid Suspensions



BEYOND THE FOOD INDUSTRY, PECTIN IS ALSO WIDELY USED IN THE PHARMACEUTICAL AND COSMETIC INDUSTRY



Wound Dressings



Shampoos and Creams

research findings, pectin also has a prebiotic effect, stimulating the growth of beneficial bacteria and promoting a balanced gut microbiota.

The benefits do not stop there. The dietitian adds that pectin forms a viscous gel in the intestine, binds to bile acids, and reduces cholesterol absorption, contributing to the prevention and mana-

gement of dyslipidemia. "In addition, it slows gastric emptying making digestion more gradual and reducing carbohydrate absorption, which helps improve glycemic control," she explains.

From peel to standardized powder. From industry to the promotion of well-being. The journey of pectin illustrates how an orange by-product can play a strategic

role in the production chain while aligning with trends in health, innovation, and sustainability.

By combining technology, functionality, and nutritional benefits, the citrus industry continues to demonstrate its ability to capture the full value of the fruit, showing once again that the orange has much more to offer than juice alone. ●

PECTIN:

AN ALLY OF INTESTINAL AND METABOLIC HEALTH



Citrus Grower-Friendly Companies encourage actions to control pests and diseases and the dissemination of Fundecitrus information.





Fundecitrus

SCIENCE AND SUSTAINABILITY
IN CITRICULTURE

ORANGE TREES YIELD FRUIT-AND PROGRESS

GREENING
IS SERIOUS STUFF

We can all contribute to the fight against greening