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NANOBUBBLES CUT LEAF CHLORIDE BY ~75% IN SALINE-IRRIGATED CITRUS

The Cítricos del Andévalo estate in Huelva, part of Grupo Don Simón — 1,200 hectares of citrus on Spain's saline groundwater belt.

Customer: Cítricos del Andévalo

Dates:	Location:	Unit:	Key Results:
June 2024 – May 2025	Huelva, Spain	Indalo	• ~75% reduction in leaf chloride vs. untreated control • 7× higher dissolved oxygen at the dripper (10.96 vs. 1.5 ppm) • Reduced biofilm and suspended solids at dripper outlets • Visibly denser canopy and stronger fruit set in treated parcel

The Challenge

Citrus Production on Saline Groundwater

Cítricos del Andévalo operates 1,200 hectares of citrus in Huelva, supplying the Don Simón juice and beverage business. Like much of southern Spain's citrus belt, the operation depends on groundwater with high electrical conductivity, a persistent constraint on yield in this region.

In these conditions, sodium and chloride accumulate in the plant. Leaves develop marginal chlorosis and necrosis, trees lose vigor, and productivity declines. Chloride competes directly with nitrate, potassium, and calcium uptake, limiting overall nutrient efficiency and capping output from otherwise well-managed groves.

At the same time, the irrigation system degrades under the same water conditions. Biofilm and suspended solids accumulate at dripper outlets, reducing distribution uniformity and increasing maintenance requirements.

For operations like Cítricos del Andévalo, the challenge is structural: water quality limits both plant performance and system performance.

The Solution

Nanobubble-Treated Irrigation Water

In June 2024, a Moleaer Indalo nanobubble generator was installed on a 3.2-hectare sector. An adjacent sector of the same variety, age, and management served as the untreated control.

The system injects 90% pure oxygen into the irrigation line, treating a flow of 32 m³/h. Foliar samples were collected across three time points (September, October, and January), with a minimum of 50 trees sampled per sector. Dissolved oxygen, conductivity, and ORP were measured at the dripper outlets, alongside ongoing visual assessment of canopy and fruit development.

Nanobubbles fundamentally change how gases behave in irrigation water. Oxygen is introduced as nanoscale bubbles (<200 nm) that remain suspended and move through the system without coalescing. This enables oxygen to travel through drip lines, interact with biofilm at the emitter level, and reach the root zone in a dissolved, bioavailable form.

The result is higher oxygen levels and a shift in how water behaves in the system and how roots interact with it.

Moleaer INDALO G installed on the irrigation headworks at Cítricos del Andévalo, June 2024.

Results

Leaf Chloride Reduced to ~25% of the Control

Across all sampling dates, leaves from the nanobubble-treated area carried significantly lower chloride concentrations than the untreated control, typically 4 to 6 times lower.

This reflects a change in how salts move through the soil-plant system. With improved oxygen conditions at the root zone, roots operate more efficiently and the mobility of dissolved ions shifts, supporting the leaching of accumulated salts below the active root zone and reducing passive chloride uptake.

The outcome is a tree under less osmotic stress, able to allocate more energy toward growth, fruit development, and reserve accumulation.

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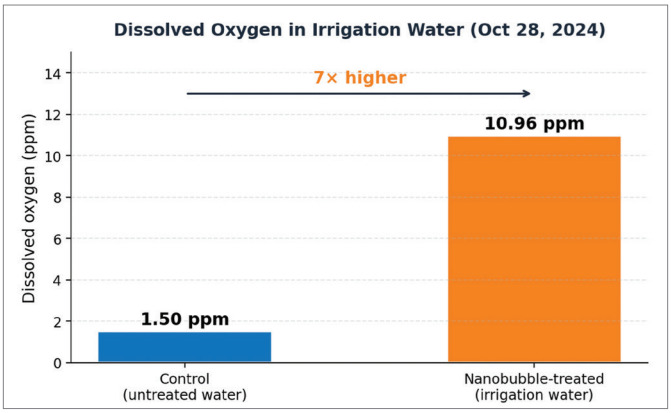
A Change in Oxygen at the Point of Delivery

Measurements at the dripper outlets confirmed the upstream conditions driving these effects. Dissolved oxygen in the treated sector reached 10.96 ppm, compared to 1.5 ppm in the untreated control. ORP also shifted into a more oxidative range.

Delivering oxygen-rich irrigation water directly at the emitter improves root respiration and supports more efficient water and nutrient uptake under stress conditions.

Rather than relying on bulk oxygenation upstream, nanobubbles enable oxygen to persist through the distribution system and be delivered where it is needed, at the roots.



Dissolved oxygen at dripper outlets, October 28, 2024.

Cleaner Irrigation Infrastructure and More Uniform Delivery

Suspended solids measured at the dripper outlets were significantly lower in the treated sector, indicating reduced biofilm accumulation within the irrigation lines.

This has direct operational implications including:

- Improved distribution uniformity
- Reduced manual flushing maintenance
- More stable system performance over time

By addressing biological fouling within the system, nanobubbles both improved plant outcomes and the consistency of water delivery across the field.

Talk to an expert about applying nanobubbles in your irrigation system:
moleaer.com/industries/agriculture

Untreated *control parcel, same date — visibly thinner canopy with more bare ground between rows.*

Treated *parcel, September 2024 — three months into the trial.*

Untreated *control parcel, January 2025. Sparser fruit set and visibly weaker canopy.*

Treated *parcel, January 2025. Heavy fruit load on adjacent trees, with the INDALO G unit at the irrigation header.*

Visible Gains in Canopy Density and Fruit Set

Differences in plant condition became visible early in the trial. Within three months, the treated sector showed a denser canopy and more uniform growth. By January 2025, the treated parcel carried a significantly stronger fruit load than the adjacent control.

These outcomes reflect the combined effect of improved root-zone conditions, reduced salt stress, and more consistent irrigation delivery.

Impact

A Direct Lever on Salinity Constraints

Salinity is one of the most persistent constraints on citrus production across southern Spain and similar growing regions globally. Conventional mitigation strategies –additional leaching, soil amendments, or varietal changes– require increased inputs and do not directly address how water behaves within the system.

At Cítricos del Andévalo, nanobubble-treated irrigation shifted the condition of both the water and the plant:

- Leaf chloride reduced to roughly one-quarter of the control
- Dissolved oxygen increased by a factor of seven at the emitter
- Biofilm reduced within irrigation lines
- Canopy density and fruit set visibly improved

For growers operating on saline water, this represents a practical, system-level approach to improving performance, by changing the behavior of irrigation water itself.