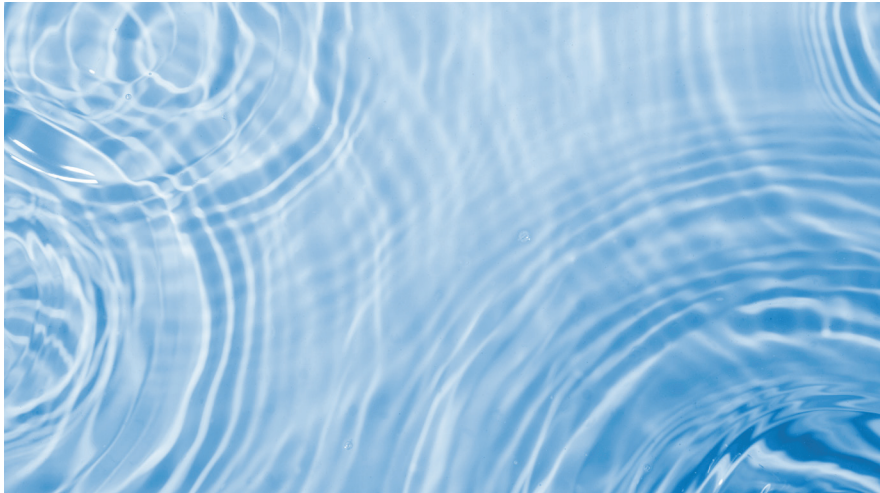




Dissolved Oxygen Resource Guide

 **BioTherm**®

2025-26



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A comprehensive guide to industry **dissolved oxygen** knowledge & expertise



What you can expect:

Our Dissolved Oxygen Resource Guide is a comprehensive collection of studies, articles, and industry insights that delves into every aspect of dissolved oxygen in cultivation.

This guide pulls together essential information from leading experts and research institutions, offering an in-depth understanding of the role dissolved oxygen plays in plant health, yield optimization, and system efficiency.

Whether you're looking to deepen your knowledge or stay updated on the latest advancements, this resource serves as a valuable tool for anyone involved in Horticulture, Cannabis, and Controlled Environment Agriculture (CEA).

This guide contains media articles published from industry magazines, educational articles from industry experts, and two dissolved oxygen case studies from growers themselves.

Take a look, and let us know if you have any questions as you explore this dissolved oxygen journey. We're right here with you!

01

Discover the Power of Nanobubbles:

Elevate Your Plant Growth with Cutting-Edge Oxifertigation Technology

by Dante Fernandez

Dissolved oxygen (DO) is the secret ingredient that can revolutionize your growing process. Whether you're cultivating plants in soil, hydroponics, or aquaponics, your plants' roots crave oxygen to thrive. The more efficiently you deliver oxygen, the stronger and healthier your plants will be. Enter nanobubble technology—a game-changing solution that dramatically boosts oxygen levels, supercharges nutrient uptake, and promotes faster, stronger growth.

Why Is Dissolved Oxygen Critical for Your Plants?

Your plants' roots need dissolved oxygen to "breathe." By maintaining optimal oxygen levels in your system, you're ensuring that roots convert sugars into energy, absorb nutrients more effectively, and develop vigorously. When oxygen levels fall, plants suffer, and problems like slow growth, poor nutrient uptake, and root rot take over.

Here's why dissolved oxygen should be at the heart of your plant-growing strategy:

- **Enhanced Root Health:** Oxygenated roots are healthier roots. Increased DO promotes better respiration, improves root development, and fends off diseases.
- **Faster Nutrient Absorption:** Healthy oxygen levels allow your plants to absorb crucial nutrients like nitrogen,

phosphorus, and potassium, driving rapid growth and higher yields.

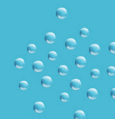
- **Elimination of Waterlogging Issues:** Oxygen-rich water prevents the anaerobic (oxygen-deprived) conditions that often lead to waterlogged soils and root damage.

Bubbles



- Rise to the surface
- No charge
- Small area, large volume

Nanobubbles



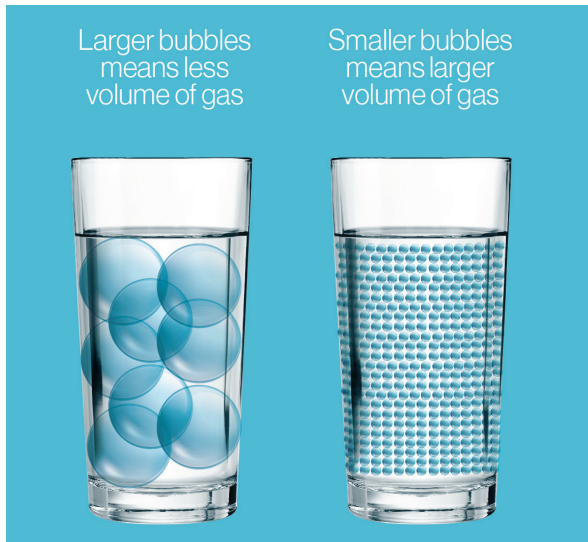
- Suspended in fluid
- Negatively charged
- Large area, small volume

Maximizing Dissolved Oxygen Levels with Nanobubble Technology

While temperature, water movement, and soil aeration influence oxygen levels, there's a simple way to ensure maximum dissolved oxygen for your plants: nanobubbles. These ultra-small, highly stable bubbles are a breakthrough technology that delivers oxygen deep into the root zone, providing continuous benefits that outlast traditional methods like air stones or pumps.

What Are Nanobubbles, and Why Do They Matter for Your Plants?

Nanobubbles are incredibly tiny—less than 200 nanometers in size—and packed with unique advantages that standard bubbles simply can't offer. To put it into perspective, a nanobubble is over 1,000 times smaller than the width of a human hair, making it invisible to the naked eye. Their minute size allows them to remain suspended in water far longer than larger bubbles, ensuring that oxygen is delivered exactly where it's needed most.

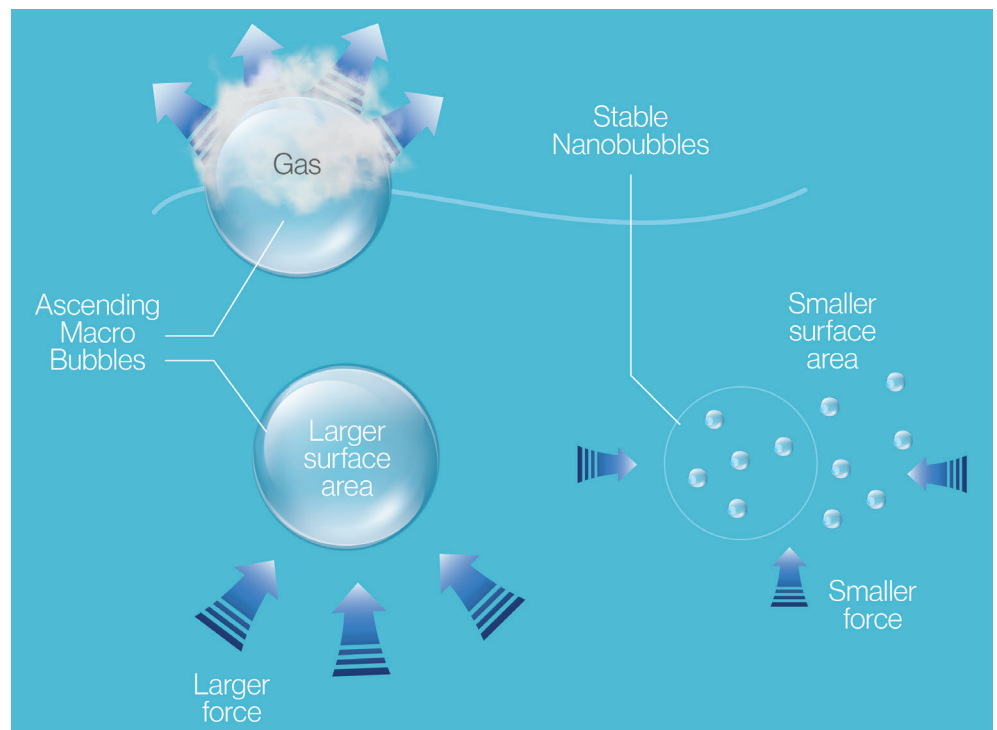


Here's how nanobubbles can transform your growing environment:

- **Supercharged Oxygenation:** Nanobubbles drastically boost dissolved oxygen levels, staying suspended in water far longer than regular bubbles. This means more oxygen reaches your plants' roots, promoting faster and healthier growth.
- **Exceptional Stability:** Unlike traditional bubbles that rise and burst quickly, nanobubbles remain in the water for days or even weeks, offering long-lasting oxygenation.
- **Unmatched Efficiency:** With a significantly larger surface area than regular bubbles, nanobubbles deliver oxygen more efficiently, ensuring that your plants receive the oxygen they need exactly where it's needed most.

How Nanobubbles Transform Plant Growth: The Benefits You Can't Miss

- **Increased Oxygen Delivery:** Nanobubbles penetrate deep into the root zone, where traditional bubbles can't reach, guaranteeing that your plants receive a steady, high level of oxygen. This leads to healthier, more resilient plants.
- **Stronger Roots, Faster Growth:** Well-oxygenated roots grow stronger and absorb nutrients more efficiently, driving explosive plant growth and development.
- **Enhanced Nutrient Uptake:** More oxygen in the root zone means more energy for nutrient absorption. With nanobubbles, your plants will take in nutrients more effectively, resulting in greener leaves, faster growth, and bigger yields.
- **Reduced Disease Risk:** Nanobubbles also generate reactive oxygen species (ROS), which have antimicrobial properties. These ROS help eliminate harmful bacteria, protecting your plants from diseases like root rot—especially in hydroponic and aquaponic systems.
- **Improved Aeration in Challenging Conditions:** Struggling with waterlogged soils? Nanobubbles keep oxygen flowing even in difficult environments, preventing harmful anaerobic conditions that could



stunt plant growth.

- **Continuous Oxygenation for Maximum Impact:** Thanks to their stability, nanobubbles continue oxygenating the water for long periods, providing ongoing support for your plants without the need for constant intervention.

Why Choose Nanobubble Generators for Your Cultivation?

If you're serious about plant growth, nanobubble generators are a must-have. By delivering superior oxygenation, you'll unlock these game-changing benefits:

- Healthier, Stronger Root Systems
- Increased Nutrient Absorption for Bigger, Faster Yields
- Reduced Risk of Pathogens and Root Diseases
- Long-Lasting Aeration and Oxygen Support

No matter what type of cultivation you're running—soil, hydroponics, or aquaponics—nanobubbles give your plants the oxygen boost they need to thrive. Ready to revolutionize your growing process and achieve better results than ever before? Invest in nanobubble technology today and see the difference for yourself!

**Get the Oxygen Boost Your Plants Deserve—
Contact Us Now to Learn More About BioTherm's
DGS™ Line of Advanced Nanobubble Generator
Systems!**





**Dissolved oxygen systems can be
used in these common irrigation
practices:**

Misters • Booms • Drip Irrigation • In-Line
Sidestream • Flood Benches • NFT • DWC



**Unlock the full potential
of your cannabis plants by
steering their growth with
precision and tapping into
the power of nanobubbles.**

02 Cannabis Crop Steering

How to Use Nanobubble Dissolved Oxygen for Crop Steering in Cannabis Cultivation

Crop steering is all about guiding your cannabis plants to grow the way you want—whether that's focusing on big, leafy growth during the vegetative phase or boosting bud production during flowering. By tweaking things like light, temperature, nutrients, and even dissolved oxygen in your irrigation water, you can push your plants toward specific growth patterns. One game-changing tool in this process is nanobubble dissolved oxygen (DO) technology.

Here's how it can help you steer your cannabis crop for maximum growth, yield, and quality.

What is Crop Steering, Anyway?

Think of crop steering as fine-tuning the growth of your cannabis plants. The idea is to manage conditions to emphasize either:

Vegetative growth, where you want strong roots and lush foliage.

Flowering, where you shift focus to bud production and resin development.

Each growth stage has different requirements for water, nutrients, light, and environmental conditions. Crop steering means you're customizing those factors at every stage to get the best results.

Meet Nanobubble Technology: The Next Big Thing in Cannabis Cultivation

Nanobubbles are super tiny gas bubbles—less than 200 nanometers—that stay suspended in liquid way longer than regular bubbles. When used in irrigation, nanobubbles increase the dissolved oxygen levels in the water significantly. This gives the roots a steady supply of oxygen, which is crucial for healthy growth.

Why Nanobubbles Matter for Cannabis Growth
Cannabis plants need oxygen for root health and nutrient absorption. Here's how nanobubble technology makes a difference:

1. Healthier Root Zones

- High dissolved oxygen levels help keep roots strong and prevent problems like root rot.
- With nanobubbles, oxygen is delivered directly to the rhizosphere (root zone), ensuring roots can absorb nutrients effectively.

2. Better Nutrient Absorption

- Increased oxygen means your plants can take in nutrients more efficiently, promoting stronger growth during the vegetative phase.
- As you steer toward flowering, nanobubble-treated water helps with the uptake of

3. Supports Beneficial Microbes

- Beneficial microbes thrive in oxygen-rich environments. Nanobubble-enriched water enhances microbial activity, which improves nutrient availability and helps protect against root diseases.

How to Use Nanobubble Technology for Crop Steering

Step 1: Get Your Setup Ready

- Start by adding a nanobubble generator to your irrigation system. Make sure it can deliver consistent DO levels (8-12 mg/L is ideal).
- Regularly check dissolved oxygen levels to keep them in the target range.

Step 2: Apply During Vegetative Growth

- Watering Strategy: Keep the substrate slightly moist but allow for some drying between waterings. This encourages healthy root growth.
- Nutrient Delivery: Use nanobubble-treated water for nutrient feeds to improve nitrogen uptake.
- Environmental Conditions: Pair this with high light intensity and temperatures around 75-85°F to drive vigorous vegetative growth.

Step 3: Shift to Flowering Phase

- Adjust Watering: Reduce the frequency to gently steer the plants toward flowering. Continue using nanobubble-enriched water to maintain oxygen levels.
- Focus on Flowering Nutrients: Switch to a nutrient formula rich in phosphorus and potassium, and keep using nanobubble-treated water for better nutrient absorption.
- Fine-Tune Conditions: Lower temperatures and humidity slightly to support bud formation.

Benefits of Nanobubble Technology in Cannabis Cultivation

1. Stable Oxygen Levels: Nanobubbles keep dissolved oxygen at optimal levels, promoting root health and overall plant strength.
2. Reduced Risk of Root Diseases: Better oxygenation helps avoid root rot and other oxygen-deficient issues.
3. Improved Yields and Quality: Stronger roots and better nutrient absorption translate to bigger, better buds with higher cannabinoid and terpene content.
4. More Sustainable Practices: Growers can optimize water use while still giving plants the oxygen they need.

Things to Keep in Mind

- Investment Costs: Setting up a nanobubble system may be pricey, but the long-term gains in yield and quality make it worth considering.
- Monitoring is Key: Keep an eye on oxygen levels and water quality to get the most out of this technology.
- System Compatibility: Make sure your nanobubble generator integrates well with your existing irrigation setup.

Bottom Line

Using nanobubble dissolved oxygen technology for crop steering can take your cannabis cultivation to the next level. By ensuring optimal oxygen levels and boosting nutrient uptake, you can fine-tune every growth phase—from lush vegetative growth to resin-rich flowering. As cultivation techniques evolve, integrating nanobubbles into your grow strategy can set you up for more consistent harvests, better quality buds, and sustainable practices.

Unlock the full potential of your cannabis plants by steering their growth with precision and tapping into the power of nanobubbles.



03

Water you Missing?

Three overlooked ways to enhance plant health with irrigation.

By **Jim Rearden**

Forty, even thirty, years ago, we watered our plants, dropped in a little fertilizer, and hoped for the best. Perhaps it wasn't quite that simple, but our main focus with irrigation was primarily making sure plants didn't dry out.

Today, greenhouse production is much more sophisticated, but what if you could get even more from your water? Research shows us that managing a few factors can help your plants get the most from irrigation. Here are the three we suggest starting with.

Biofilms

While sanitation is a critical part of every successful greenhouse protocol, we've learned that biofilms can sabotage quality plants faster than you think – and they are found in even the most pristine greenhouses.

Biofilms are the thin films inside pipes and tanks. They are a significant player in distribution of pathogens, particularly for simple pests like *Pythium*, *Phytophthora* and algae. While the typical assumption has been that sanitizing source water, whether well, rain or municipal, would result



in the cleanest water possible for greenhouse plants, what we didn't realize was that biofilms are a serious threat to the plant world – even in greenhouses built just six months ago. These biofilms provide a safe harbor for pathogenic microbes, and every time you turn on the water, some of those pathogens are distributed with the irrigation.

“Most of the time, it's not a high enough concentration to affect the plant – like you and I can fight off a cold most of the time,” says Al Zylstra, manager of DrammWater. “But once or twice a year, if you don't have your biofilms under control, you end up with an outbreak.” And if you don't completely remove the biofilms, those outbreaks become much more frequent.

Successful sanitation means not just sanitizing source water but also pipes, tanks, drip irrigation and irrigation systems to

remove biofilms. To do that, growers have several options.

“Pure chlorine cleans source water, but it doesn’t affect the hard-to-kill central glycocalyx of biofilms,” Zylstra explains. Chlorine dioxide will, but it has a long half-life, which means it takes a long time to kill biofilms. Because it lasts so long, it also has the potential to impact the root system of the plant, damaging the fine root hairs. It can also end up in drain water because it has such a long half-life. Activated hydrogen peroxide is milder than chlorine dioxide, and it is effective against biofilms. But it can also affect the plant’s root system and overall health.

Ozone, the most powerful oxidizer available, acts very quickly against pathogens – 3,500 times faster than chlorine. It kills on contact, and then it disappears without harming the plant. An unstable gas, it has a 20-minute half-life in the air, and a less than five-minute half-life in irrigation. As soon as it leaves the emitter, it undergoes a pressure change and is gone as soon as it hits the growing media.

Oxygen

Oxygen is required for life; it’s in water, so our plants have what they need from irrigation, right? Turns out, if you provide plants even more oxygen, they thrive even more.

We know roots need oxygen – that’s why farmers till fields, and why greenhouse growers spend so much time getting their media right. What we’ve also learned is that even if you don’t have your biofilm under control, you can slow its growth if you’re providing enough oxygen in the water. You can do that by infusing dissolved oxygen into the water.

But don’t plants get oxygen in irrigation water? Yes, but your plants need maximum available dissolved oxygen to get the nutrients they need. Second, typical well and city water only contains 4 to 8 ppm dissolved oxygen. Research indicates that the optimal dissolved oxygen level for plant production is 18 to 25 ppm.

Typically, injecting dissolved oxygen is a very energy-intensive process in which the bubbles produced help to rob

results, providing only minor increases in oxygen. The newest dissolved oxygen systems accomplish results without bubbles.

In the newest molecular oxygen infusion system, two conductors with a plasma arc inside them shear the oxygen molecules and grow them into O₃ (ozone), which we’ve already established is the most powerful oxidizer available. The system injects individual molecules of O₂ in between water’s H₂O molecules, where they remain in stable suspension throughout the irrigation process. When you inject ozone into irrigation systems, it kills any biological it encounters, because it is trying to get back to O₂ (oxygen).

These systems reach those levels of efficiencies through mass transfer, which produces stable liquid streams with very high dissolved oxygen levels – readings typically seen only in laboratories. Dissolving oxygen in water without bubbles allows the system to achieve the high stability needed to ensure maximum oxygen gets to plants and their roots. For example, in trials with the TOOB molecular oxygen infusion system, growers report a 15% reduction in nutrient costs and 11% yield increase. A plant’s metabolic rate is throttled by how much oxygen is exchanged. That’s why dissolved oxygen works – and even better, it’s one of the most economical ways to amend water.

Temperature

Irrigation water temperature is another crucial factor, because plants shut down at a certain temperature and express dissolved oxygen at other temperatures.

Above 80° F, there is no room for dissolved oxygen, especially in hot climates like Florida, the southeast and the southwest. There, the best approach is to chill water to retain dissolved oxygen and reduce microbial growth.

On the other end of the spectrum, most of the plant kingdom shuts down at 59° F – the root system stops when the water is too cold. Essentially, we’re shocking the plant, and its reaction is to stop growing. In trials at a Florida nursery, we encountered a crop that took a year to grow. We provided bottom heat to warm the root system and keep the temperature where it needed to be, and the production time decreased from 12 months to 7 months. Temperature matters.

Usually, we’re targeting temperatures of 68 to 72° F – that’s

Jim Rearden is president of BioTherm, designer of heat, hydro and optimized air technologies for greenhouse growers.

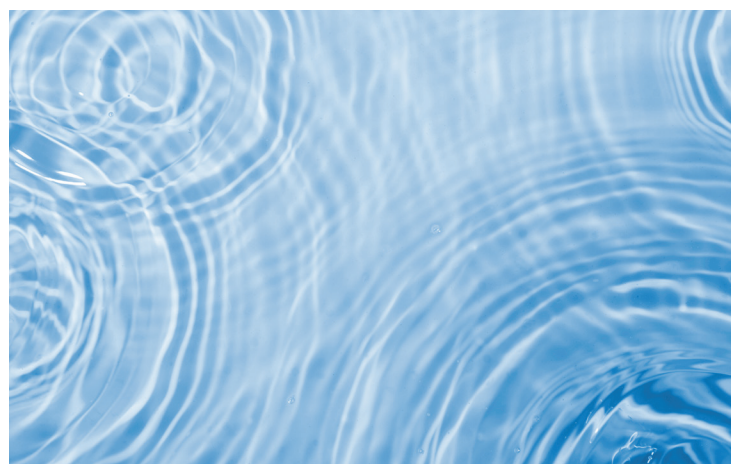
the sweet spot where both plant and root system stay active.

The biggest mistake a grower can make is not doing anything about water temperature, or thinking the only option is traditional strategies like water chillers. We see growers buying water chillers instead of buying a dissolved oxygen system. It's important to remember that the plant doesn't necessarily object to warmer temperatures; rather, it loses its ability to retain dissolved oxygen. If temperatures are too high, you could chill the water or you could add dissolved oxygen. Either works, and adding dissolved oxygen offers a host of additional benefits.

One of the most common mistakes we see is installing a system that's bigger than it needs to be. For example, when you water all plants in a four-hour space, your irrigation is pumping 85 gallons a minute. The water tempering system is designed to take water from 50 to 70° F, and that takes a large boiler or heat exchanger. Instead, put in a tank, and you have 20 hours a day to heat. Now, you have 17 gallons a minute that you have to heat, not 85. Average the system instead. Put it into a tank, and average it over an extended period of time instead of heating it on the fly.

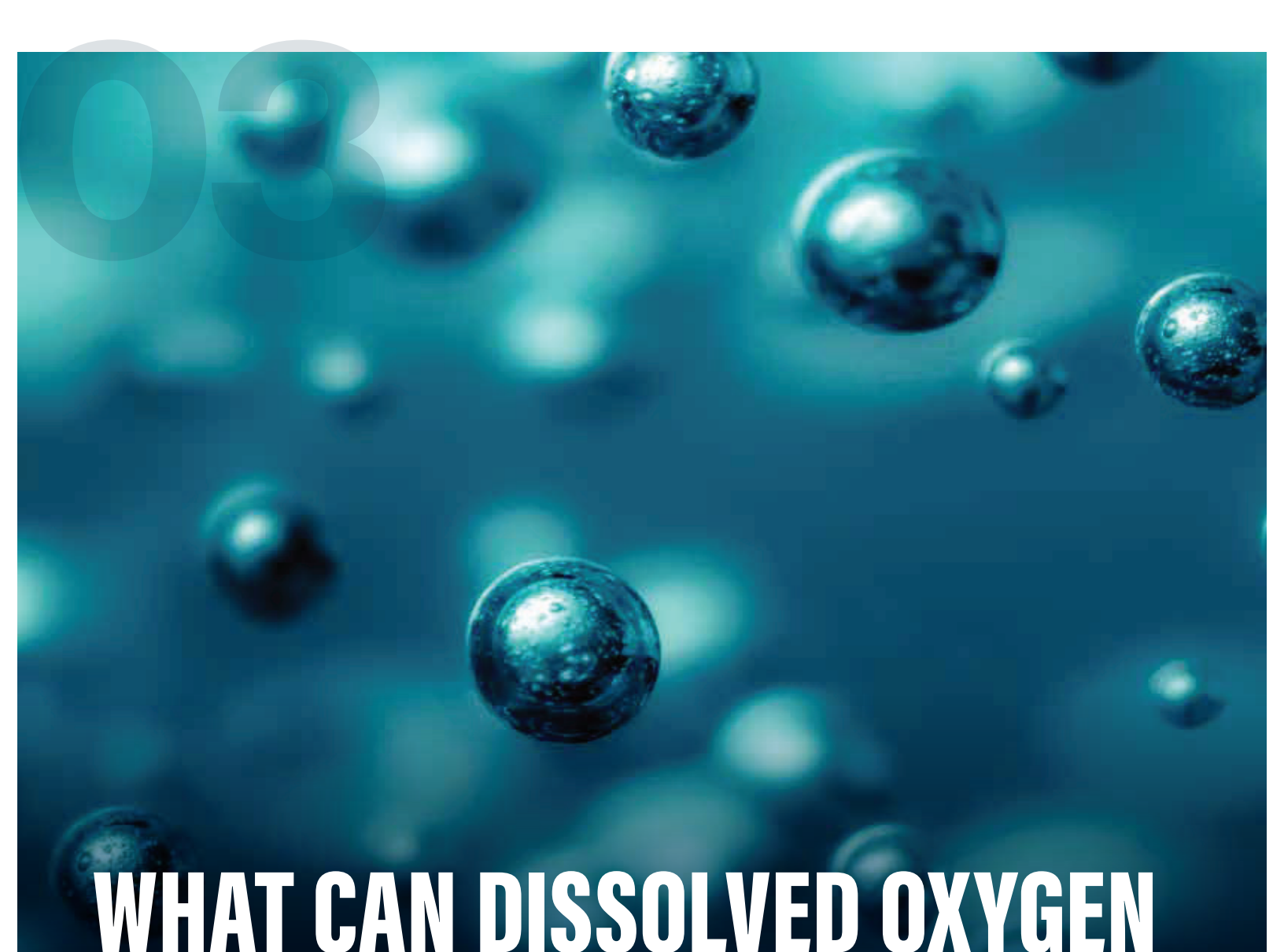
Something else we often see with growers in warmer climates: They believe they don't need to heat their water. But that may be because they don't know the temperature of their water. If a well is 1,000 feet down, the water may be 52 to 55° F. The same may be true if you pull water from a freshwater river, lake or stream. Likewise, don't think that because you live in the north you don't have to chill your water. Hot days and high sun on a tank can quickly change water temperature.

Margins keep shrinking, and what you could afford to ignore 10 years ago, now makes the difference in finishing a quality crop faster. ■



After installing a BioTherm dissolved
oxygen system, Produce Alive saw
15-20% more lettuce crop yield...

**...30% heavier plants and saved
20% on fertilizer** thanks to
higher DO levels. *-Produce Alive*



03

WHAT CAN DISSOLVED OXYGEN

Cannabis growers
are seeing benefits
to both yields and
input expenditures
through new
technology

BY JIM REARDEN

In cultivation, few things are absolute. One of them, however, is indisputable: Plants need oxygen to grow. The question is, how much?

Often, we assume that a grow gets what it needs from the irrigation water we provide. In reality, research — and practical application — show that infusing more oxygen into the water can help take plants to a new level. We see roots start faster, grow fatter and develop more of the root hairs that help them uptake nutrients.

Dissolved oxygen has been studied for years, but the difficulty has been how to successfully get the maximum amount of oxygen into the water. City and well water only contain 8 parts-per-million dissolved oxygen at the most, while studies have found that plants uptake the most nutrients at dissolved oxygen levels

of 18 to 25 ppm.

Injecting dissolved oxygen is extremely energy intensive. Most systems produce more bubbles than actual oxygen, so the result is only a slight increase in oxygen. Growers have noted that systems using air stones or early infusion technology have not provided the return on investment needed to justify the expense and trial of adjusting production in the grow. But the newest technology, molecular oxygen infusion, can increase dissolved oxygen levels without overproduction of bubbles or using much energy.

Molecular oxygen infusion uses a proprietary fiber module cluster constructed from a special mass transfer fiber. It has a unique property in that 1 cubic foot of it has 7,500 square feet of surface area. This enables the material to create a large inter-



DO FOR YOUR GROW?

face between water and oxygen.

As water passes over hollow, oxygen-filled fibers in a canister, it undergoes the oxygen infusion process. Each fiber is pressurized with pure oxygen. Very small pores are in the fiber, so that only oxygen, not bubbles, can pass into the stream. The oxygen molecules flow between the water molecules and then stay stable in suspension even during watering.

This is an extremely efficient way of infusing oxygen into the water, because it uses mass transfer to accomplish the infusion, making it more economical and more productive than other technology. In fact, levels of dissolved oxygen this high are usually only seen in laboratories. Accomplishing the infusion without bubbles keeps the molecules stable, ensuring that they get to the roots.

Dissolved oxygen and water temperature

If you're already using a dissolved oxygen system in your grow, but you aren't seeing the expected results, you might check your irrigation water temperature. One of the most common things we see is cultivators using water that's too hot or too cold. What they don't realize is that at those temperatures, either dissolved oxygen can't get in, or the plant is shut down and can't uptake it anyway.

A temperature of 59 degrees Fahrenheit or lower is the magic number that tells plants to protect themselves and stop growing. You may think that because you're in a warm area, you don't have to worry about your water being too cold, but if you are pulling your water from a spring or well, your temperature could be too low.

On the flip side, water temperatures above 80 degrees leave no room for extra dissolved oxygen and have the potential for increased microbial growth. Typically, we recommend cultivators aim for irrigation water temperatures between 68 and 72 degrees. In that range, you can be sure that the root system and the plant are both active and, thus, retain the most dissolved oxygen possible.

— Jim Rearden



The grower manages the oxygen concentration at every stage of the grow. Molecular oxygen infusion lets growers supersaturate the water at different levels for different growing scenarios. Cannabis growers have reported success with set points between 20 and 30 ppm. Providing more dissolved oxygen to plant roots is comparable to increasing oxygen levels in marathoners. It is performance enhancing of the purest kind — as soon as water exits the infuser, it is ready for use in irrigation.

As the roots expand, thicken and increase their pace of development, we see

other accompanying benefits. Plants begin to absorb nutrients more aggressively. In turn, they feed less, and some cannabis growers report being able to decrease their feeding costs by as much as 15%. Along with that come reports of yield increases as high as 11%.

And that shows better than anything what dissolved oxygen can do for your grow.

Jim Rearden is president of BioTherm, designer of heat, hydro and optimized air technologies for greenhouse growers. For more info, visit www.biothermsolutions.com.

Understanding Dissolved Oxygen

By Kurt Becker, Dramm

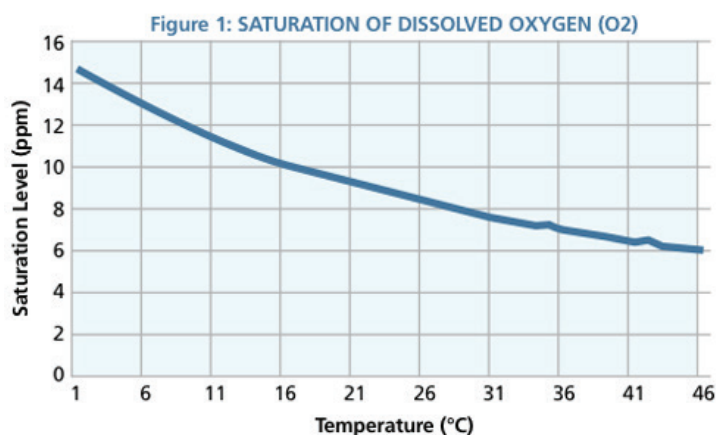
GROWERTALKS

Even the non-technical growers have an understanding and appreciation for the measurements used in greenhouse growing today. Monitoring and optimization of pH and Electrical Conductivity (EC) have become standard practice, improving plant health and quality throughout the industry. By measuring these two simple factors, most nutritional problems can be avoided. The measurement of Dissolved Oxygen (DO) is also proving to be just as critical to plant growth. As with the other two measurements, there are minimum levels required for a healthy plant. Also, by optimizing DO, as with pH and EC, we can see great improvements in plant growth and quality. However, far fewer growers are utilizing, or are even aware, of this measurement.

Many of the practices in botany already consider the effect that oxygen has on the root zone. In the field, we till the soil. Among other things, this adds air space to provide oxygen to the roots. In horticulture, growing media is selected with a consideration for porosity for the same reason. The benefits of oxygen to plant roots, and to the rhizosphere in general, is well established in the mind of the grower. However, most are unaware of the level of oxygen contained in their irrigation water and don't realize that there are methods to improve this level. Dissolved oxygen is simply the amount of oxygen (O₂) dissolved in water. It's one of the best indicators of the quality, and the life-supporting ability, of water. People

need the right amount of oxygen in the atmosphere to survive. And, just as fish need the right amount of dissolved oxygen in the water to survive and thrive, so do plants.

Measured in mg/l, as a percent of saturation (%) or in parts per million (ppm), dissolved oxygen levels are affected by the temperature and salinity of the water, and also by other chemical and/or biological demands (COD/BOD) of the water. Cold water can hold more dissolved oxygen than warm water (see Figure 1) and fresh water can hold more dissolved oxygen than salt water. The maximum amount of DO that the water can hold is called the saturation value. It's possible, and very often desired—especially in a greenhouse—to exceed the natural saturation point of DO in water. This is called super-saturation. At levels around 5 mg/l of dissolved oxygen, irrigation water is typically considered marginally acceptable for plant health. Most greenhouse crops, however, will perform better with higher levels. Levels of 8 mg/l or higher are generally considered to be good for



greenhouse production and much higher levels, as high as 30 mg/l or more, are achievable and can be beneficial. If the DO levels are below 4 mg/l, the water is hypoxic and becomes very detrimental, possibly fatal, to plants and animals. If there's a severe lack of DO, below around 0.5 mg/l, the water is anoxic. No plants or animals can survive in anoxic conditions. The irrigation water in many greenhouses has surprisingly low levels—often in the dangerous hypoxic range.

Unfortunately, without measurement and awareness of the dissolved oxygen in greenhouse irrigation water, problems caused by hypoxic water in plant growth often go undiagnosed or misdiagnosed. Happily, monitoring DO is fairly easy. Just as with pH and EC meters, there's a wide range of devices available at varying quality, accuracy and ease-of-use to test the level of dissolved oxygen in water.

When measuring DO, it's important to understand the oxygen demand in the irrigation system and in the roots. There are plenty of things that will use oxygen in this environment. This is the reason that you might test 8mg/l DO at a cistern or well head, but only 5mg/l at the plant. Organic material in the water, or biofilm in your pipes, will consume oxygen. For this reason, it's important to test in multiple locations and look for ways to remove as much of the biological demand as possible.

However, the detrimental effects of low-dissolved oxygen levels shouldn't be the only reason to measure. Increasing DO in irrigation water can not only prevent problems, but with super-saturated levels, it can increase quality and plant growth, reducing cropping time and overall health. High levels of dissolved oxygen promote healthy root growth. The root system requires oxygen for aerobic respiration, an essential process that releases the energy required for healthy root growth and a healthy plant.

Research shows that higher dissolved oxygen levels in the root zone of most crops results in a higher root

mass. A plant with more root mass grows healthier and faster. A plant's roots are where it gets the majority of its inputs for growth, including water and nutrients. Healthy roots with a good supply of oxygen have better respiration and are able to selectively absorb more ions in solution, such as the vital mineral salts nitrogen, phosphorus and potassium. When there's less oxygen in the water than there is in the plant, this reduces the permeability of roots to water, therefore reducing (even reversing) the absorption of nutrients.

A healthier plant is a more efficient plant

DO isn't just an additional nutrient one should pay more attention to because it makes a healthier plant; there are direct economic impacts, as well. When used properly, it can reduce the amount of nutrients and micronutrients required, as well as the amount of costly chemicals, such as fungicides. Additionally, evidence suggests that plant growth increases with super-saturation levels of DO, reducing cropping times and increasing fruiting or flowering yields.

Improving levels of dissolved oxygen can be done through various methods. Simple aeration or agitation can increase dissolved oxygen enough to prevent problems. Injecting air or, especially, pure oxygen can increase levels as well, but only as high as saturation levels. Paying attention to temperature can also help improve DO, as colder water can hold more oxygen. Additionally, water at atmospheric pressure will hold less oxygen than when under pressure. Think of a bottle of carbonated water: while under pressure, the water holds more carbon dioxide than it can when the cap is removed and the pressure is released. Once the bottle is opened, the CO₂ begins to gas-off from the water, effervescing. The same is true with oxygen. Adding oxygen to a pressurized system can increase the level of DO.

Ozonation is another method for increasing oxygen levels in solution. Like oxygen injection, injecting ozone gas will increase dissolved oxygen. However, ozone or O₃ is almost 13 times more soluble in water than O₂. This allows for much greater levels of oxygen to be dissolved into the water. As O₃ is very unstable and reverts back to O₂ quickly, it leaves super-saturated levels of dissolved oxygen in the water. As the system remains under pressure, the DO levels can be maintained at more than 300%

of the saturation level of DO.

While adding dissolved oxygen, ozone has an additional benefit in that it oxidizes organic material and biofilm in the pipes, reducing the oxygen demand and helping to maintain higher levels of DO.

Putting it to the test

Trials were conducted at Metrolina Greenhouses in Huntersville, North Carolina. Utilizing a portable water-treatment unit consisting of filtration and ozonation, the benefits of water super-saturated with dissolved oxygen were tested against their standard water sources. Three greenhouses were tested side-by-side using identical benching and booms. One used their pond water, one used their well water and the third used their pond water treated with the trial system. Consistently, the plugs in the third greenhouse using the ozone treatment had higher germination rates, faster cropping times, better root growth (see photo) and better leaf development. Measurement of their dissolved oxygen in the irrigation water used in the third house was 300% greater than in the other two houses (see Figure 2).

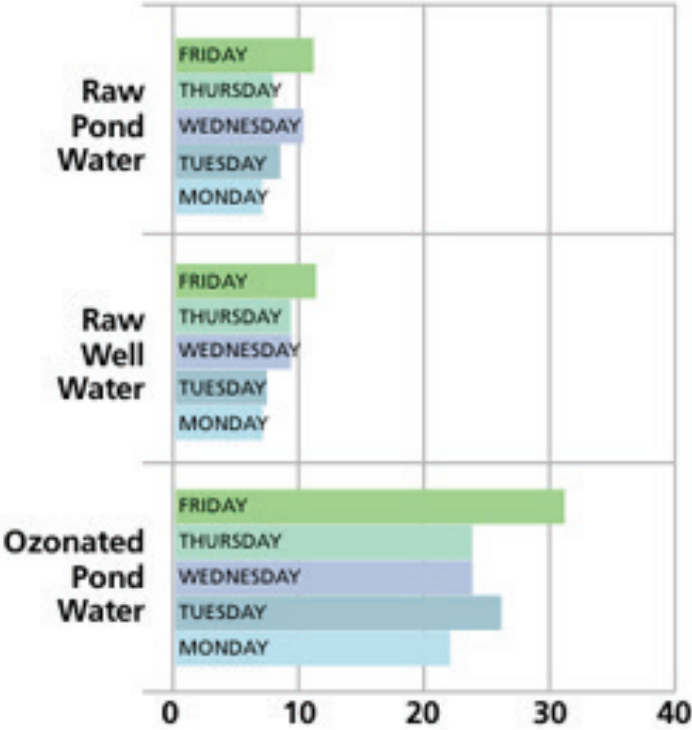
In a final summary of the trial and of their first year using their own, complete treatment system, Metrolina reported that they saw an average of two weeks shorter cropping time on most liners, with complete cropping time reductions up to four weeks.

More robust root systems with less damage and more drought tolerance were noted, as well as the removal of all biofilm from filters and pipes, and an overall reduction in their shrink by 66% from their previous three-year average.

These results are extremely impressive and achievable by others with proper equipment. However, growers can improve the health of their water in the short term by simply paying attention to the dissolved oxygen in their water. At a minimum, monitoring DO in irrigation water can help prevent problems or suggest different courses of action as problems arise.

In the long run, the ability to optimize oxygen levels could improve plant health quality, reduce crop times and eliminate shrink, just as the focus on other input optimization has in the past.

Figure 2. Metrolina’s dissolved oxygen (DO) in untreated vs. treated water. Measurements are ppm of DO.



Farmer's **Field Study**

Including dissolved oxygen root zone heating and quantum dot technologies and their effects on crop growth.



Study Objective

To demonstrate the growth enhancement capabilities of root zone heating, dissolved oxygen infusion and PARmodulating luminescent film. Additionally, demonstrating the ease of use of these systems for growers of all sizes.

Study was conducted from
June – October 2022.

Technologies used in study

Dissolved Oxygen

BioTherm O2 TOOB nanobubble generator,
O2 tank

Root Zone Heating

BioTherm Upstart Root Zone Heating Kit,
instant hot water heater

UbiGro

UbiGro UbiQD film

Dried Flower:

Crop	Test	Control
Dried Crop Yields	536 g	466 g
Dried Crop Loss	5 g	90g
Crop Yield After Loss Removal	531 g	376 g
Yield Enhancement compared to control	16% before crop loss; 30% after accounting crop loss/mold damage	

Fresh Frozen:

Crop	Test	Control
F.F. Crop Yields	4786 g	4246 g
F.F. Crop Loss	0 g	189 g
Pests Present	Botrytis	Botrytis
Difference in yield:	12% before accounting crop loss; 16% after crop loss	

Plants grown in tandem with these systems experienced less stress, higher yield, and an overall decrease in disease pressure. By allowing for enhanced metabolism, yields increased by 12-16% across the board.

Results were measured in dried flower and fresh frozen material. The fresh frozen lot (2 plants from each side) were harvested at the beginning of October. The dried flower plants were grown until mid-late October.

Soil temperatures varied wildly from control to test groups during the fall. The test group maintained their 72-degree F set point, whereas the control group would be 65 degrees at the hottest point of the day and rapidly dropped to 55 degrees F when direct sunlight was obfuscated towards the end of the day.

Farmer's Comparison Details:

Two rows of cannabis plants were arranged outdoors. One row had three test plants, the other three control plants. All six plants were the same varietal – Cara Cara #7.

On the test side, all three plants were heated with the UpStart Hydronic Root zone Heating Package, treated with O2 TOOB supplied dissolved oxygen infused irrigation water and were laid beneath a canopy of UbiGro film.

All plants were grown in soil, using amendments, compost,

amino acids, TM-7 and a Calcium/Magnesium fertilizer for nutrition. Phosphoric Acid was used to buffer solution pH. Activated charcoal filters were used to mitigate contaminant/chlorine/chloramine content in irrigation water. No pesticides were used during vegetative and flowering stages. During propagation, both control and test populations were dunked in Suffoil-X once (25b compliant pesticide.)

A full list of products, fertilizers, amendments, and inoculants are provided at the end of the study. Plants were initially propagated in April of 2022. These were then planted in 4" x 4" pots with soil. These plants were grown under indoor lighting until June 5th. Plants of the same size were selected to be planted into their final pots (about 12" tall each.) Mycorrhizal inoculant was used at every transplant to ensure vigorous growth and even out advantages between control and test groups. All plants finished in 30-gallon fabric pots.

Plants were watered every 3 days on average, with the treated side receiving between 16 – 24 ppm dissolved oxygen every watering. D.O. levels were recorded using a YSI ProSolo handheld dissolved oxygen meter, with optical sensor for accuracy and consistency. Fertilizers were used once a week, with amendments being added every 2-3 weeks. A cover crop was established to aid water retention as well as microbial biomass. Root zone heating was supplied using an UpStart heating module, an instant hot water heater and a series of MegaTube coils for heat distribution. Set point for root zone temperature was 72 degrees F. The UpStart

utilizes a soil sensor for monitoring and control purposes. The UbiGro was hung about ten feet over the test pots going down the length of the test row.

When plants switched from vegetative growth to flowering growth, changes in amendments were made (veg to bloom formulation) but everything else stayed the same.

Crop Observations

Dissolved Oxygen

One of the more notable observations was the increased stress resilience plants experienced when being treated with D.O. When dehydrated, D.O. treated plants regained full vigor within a few minutes, with the control taking 30 minutes, minimum, before returning to peak vigor.

Root Zone Heating

Towards the end of the season (September) The Upstart root zone heating kit maintained a steady 70 Degrees F whilst the control side maintained anywhere from 70 degrees at the hottest point of the day but dropped rapidly to around 55 Degrees F. Soil Microbiology goes dormant below 65 Degrees F.

Other notes:

Amounts of mold between the two was shocking – with the dried control group losing 90 grams of dried flower as compared to the 5 grams lost on the treated side. For fresh frozen, 189 wet grams were lost on the control side and zero on the treated side. Difference in mold rates is linked to how long both sects were grown for – the dried had two or three more weeks of growth as compared to their fresh frozen counterparts.

Which crops benefit from increased dissolved oxygen levels?

Leafy Greens

(lettuce, spinach, kale) – Enhanced root oxygenation improves nutrient uptake, increases yield and speeds up growth. Some say increased DO levels help increase flavor profiles!

Cannabis

Higher DO levels support root health, reduce disease risk, and boost plant vigor. Check out the white paper on page 17!

Tomatoes

Increased DO enhances root zone aeration, leading to improved yield and fruit quality.

Cucumbers

Beneficial for root development and reducing susceptibility to root diseases.

Herbs

Higher DO promotes faster growth and higher essential oil content.

Roses

Enhanced root oxygenation leads to stronger roots and better flower quality.



"With BioTherm's dissolved oxygen system, we were able to **double** our **lettuce yield**.

It's overall a healthier plant.
Sweeter, juicier... it's changed our crop completely."

-Bare Roots Produce

White Paper Dissolved Oxygen

by James Hewittson

Dissolved oxygen effects - cannabis production

Crops grown: Indoor cannabis

In late 2022, a local indoor-cannabis grower agreed to participate in a trial regarding dissolved oxygen infusion and its effects on cannabis production. James agreed to treat his plants with dissolved oxygen infused irrigation water sourced from a BioTherm O2 TOOB® Nanobubble Infuser.

James had been growing in this space for years, growing the same cutting every cycle. Despite having as many features as dialed in as possible, he still struggled to break his usual 12 lbs. harvest. The goal here was to see how dissolved oxygen affected his crop health, fertilizer usage and final yield. The plants in question were grown under (12)

750W HPS grow lamps and were kept as close to an optimal VPD range as possible (1.64 kPa during day; 1.25 kPa at night.)

All plants were Ice Cream Cake, a common varietal grown amongst cannabis growers in Northern California. James had grown this same cutting multiple cycles in a row, and was very familiar with growth patterns, individual varietal nutrition and typical yields.

Room was completely sealed with no active air turnover, utilizing a mini split A/C system for humidity/temperature control. Plants were all grown in a soilless potting mixture consisting of peatmoss, perlite and coco coir. Worm casting teas were applied for additional soil microbiology while Heavy 16® was used for all primary macro-, secondary macro- and micronutrient needs.

CONTROL:

Reservoir D.O. Reading: 2-3 ppm

(12) 750W HPS Grow Lights

Nutrient Cost: \$900

Reservoir Nutrient Reading: 2,400 ppm

Irrigation Schedule: 2-3x Daily @ 45-60 seconds each

Yield: 12.00 Lbs.

D.O. TREATED:

Reservoir D.O. Reading: 24 ppm

(12) 750W HPS Grow Lights

Nutrient Cost: ~ \$450

Reservoir Nutrient Reading: 1,250 ppm

Irrigation Schedule: 1-2x Daily @ 45-60 seconds each

Yield 13.783 lbs.

CO₂ was supplied aerially at night and kept at 500ppm total CO₂. Plants within his grow room were irrigated with dissolved oxygen infused water, with dissolved oxygen content set at a consistent 24ppm.

In past harvests, 12.00 lbs. of dried flower were standard maximum yield for James. After incorporating dissolved oxygen infusion, James noticed his plants retained water more efficiently, with irrigation reduced from his normal 3x daily routine to 1-2x per day. Soil moisture content was recorded via a soil moisture probe, and irrigation schedule was changed based on these values. Outside of increased water retention, a halving

of fertilizer input was noted as well, with normal regimen consisting of a 2,400ppm concentration of soluble fertilizers being reduced to just 1,250ppm despite maintaining enhanced growth rate.

Overall, James saved roughly \$450 on fertilizer costs simply by adding dissolved oxygen infusion to his plant-care regimen. After cycle was harvested, dried and trimmed, he ended up with 13.783 lbs of dried flower – a 12.94% increase compared to his normal yield of 12.00 lbs. James now recommends dissolved oxygen infusion to any grower wanting to increase quality yield while saving money on inputs.

Dissolved oxygen vs. Nanobubbles

Dissolved Oxygen (DO) refers to oxygen molecules that are dissolved in water, readily available for plant roots to absorb. Nanobubbles, on the other hand, are microscopic gas bubbles (including oxygen) that remain stable in water longer and provide a more sustained release of oxygen as they dissolve. While both increase oxygen availability, nanobubbles offer enhanced oxygen delivery and retention compared to standard DO levels.

Dissolved Oxygen Quick Facts

Optimal Root Health

Dissolved Oxygen (DO) levels above 6 mg/L in irrigation water promote healthy root systems, which are crucial for nutrient uptake and disease resistance, particularly in crops like leafy greens and cannabis.

Improved Nutrient Absorption

Adequate DO levels in the root zone enhance nutrient absorption efficiency. This is especially beneficial for fast-growing crops like leafy greens, ensuring vigorous growth and higher yields.

Stress Reduction

High DO concentrations help reduce root zone stress in cannabis plants, minimizing the risk of root diseases such as pythium, especially in hydroponic or aquaponic systems where root health is critical.

Growth Rate Boost

Maintaining optimal DO levels can accelerate growth rates by improving metabolic processes. Cannabis and leafy greens both benefit from faster growth cycles, leading to shorter harvest times and potentially increased profits.



08

Beyond Bubbles:

Supercharging Your Plants with Oxygen

By **Jim Lepard**

Supercharged plants. Sounds rather pleasant doesn't it? But what exactly are we talking about? A supercharged growing environment is one where no single thing your plants need is in short supply. Think of it as a series of links in a chain. The rate of your plants' development is only ever going to be as fast as the weakest link allows.

So what are these links? Well the obvious examples include: plant genetics, light levels, temperature, CO₂, and relative humidity. The not so obvious example is oxygen. This odorless, colorless gas plays a critical role in plant growth and bloom. In fact, despite being all around us, it could be the crucial component that is holding your plants back...

The Key Benefits of Oxygen for Plants

Oxygen usually makes up 45% of the dry tissue weight of a plant. It is a macro-element, along with nitrogen, phosphorous, hydrogen, carbon, potassium, sulfur and magnesium.

Oxygen provides essential energy for plants to turn their sugars into cell structure. In other words, plants need oxygen to grow! Oxygen is also used



by plants to control their stomata — tiny but crucial “breathing apparatus” in their leaves.

We tend to think of plants creating oxygen as the end product of photosynthesis but, as with many natural processes, the complete picture is more cyclical. Plants also use oxygen in two major ways. They uptake it through their roots and they absorb it via their leaves.

At night most plants reverse the process of photosynthesis and switch to burning carbohydrates and oxygen while producing carbon dioxide and water. So it's important to make sure that oxygen levels are maintained in the indoor garden, especially at night when plants aren't producing it via photosynthesis. Most growers achieve adequate levels of oxygen at night by using extraction fans to bring in a steady supply of fresh air.

Dissolved Oxygen

Many growers overlook the important of dissolved oxygen levels in their nutrient solution. When oxygen levels in a nutrient solution are raised, you essentially give your plants the ability to process more gases and water vapors, resulting in a cooler, faster growing and higher yielding plant. Root systems work more efficiently when highly oxygenated. This is because oxygen affects the electrical charge of water and nutrients allowing the roots to uptake using less energy.

Increased oxygen levels also help to reduce water borne pathogens and fungi, such as the dreaded pythium and saprophytic fungi. By elevating oxygen levels, the grower instantly creates a more suitable environment for aerobic bacteria (our friends). The more friendly bacteria we have, the greater their effectiveness in combating any anaerobic bacteria (our enemy).

Cooler water is capable of holding on to more oxygen than warmer water. So when a nutrient solution starts to warm up, its 'hold' on dissolved oxygen decreases. For example, the oxygen content of a fully aerated solution 68°F (20°C) is around 9ppm, whereas at 86°F (30°C), it drops by over 16% to 7.5ppm.

Popular Methods of Increasing Oxygen Level

Growers who appreciate the importance of dissolved oxygen have historically tried a variety of methods to increase levels in their nutrient solution. It's fairly straightforward to improve level, but far harder to achieve 'supercharged' levels.

1. Surface to Air Contact

A submersible pump is placed into the nutrient solution reservoir. When switched on it creates surface turbulence in the nutrient solution which increases its contact with air. The barrier between the water and air is broken (like a waterfall hitting a pool allowing oxygen to be absorbed into the water). The more turbulence at the surface, the greater oxygen absorption.

2. Forced Aeration and Air Stones

This is one of the most popular methods used by growers today. Air pumps and compressors are used together with air stones or perforated pipe placed in the bottom of the nutrient tank. An air stone is traditionally a piece of limewood or porous stone but can also be made from fiberglass. When air is pumped into the stone it creates very fine bubbles. As

these fine bubbles rise in the nutrient tank, some of the oxygen is absorbed by the nutrient solution.

There is currently some controversy surrounding the efficacy of air stones. One theory suggests that larger bubbles rising in the nutrient solution absorb smaller suspended bubbles on their way up and air dissipates out of the solution. In one test the oxygen levels in a nutrient solution actually dropped after running the air stone for 50 minutes! Other growers (and aquarium owners) swear by them!

3. H₂O₂ (Hydrogen Peroxide)

Hydrogen peroxide is known for increasing oxygen levels and its high oxidizing properties. When H₂O₂ is first introduced to the nutrient solution there is a spike in oxygen levels and the plants receive a boost of oxygen. However, the oxygen levels quickly drop off, especially with an air pump and aeration or agitation of the water via a water pump circulating through the system. Along with the higher amount of oxygen, comes the high level of oxidation. This is fine if the plants are suffering from any fungi or pathogens that may be in the system. However the indiscriminating oxidizing effect of H₂O₂ can also attack a healthy root system.

4. Air Diffusers

The large scale solution. Air diffusers force concentrated atmospheric oxygen into the nutrient solution. These systems achieve very high oxygen levels but they have to be regulated carefully and tend to be used by large commercial greenhouses that can afford the room and cost of such equipment.

5. Electrolysis

Oxygen is produced through electrolysis when a DC current is passed through an anode and cathode in an acid or salt solution. As the solution passes by the anode and cathode the current separates the oxygen atom from the hydrogen atoms at a molecular level, leaving the oxygen suspended in the water. The plant absorbs some of the beneficial hydrogen but because hydrogen is 16 times lighter than oxygen, most of it is disbursed through the surface of the water. The benefit of this method of raising oxygen levels in a nutrient solution is that oxygen is not being forced into the water. The oxygen is actually being generated from the water, within the water.

Still not convinced about the importance of oxygen? Then check out this basil crop, brought back from the brink of death

after a spell of freakishly hot weather! How? Oxygen levels were raised in the nutrient solution using electrolysis. The basil was infested with pythium (root rot) but started to recover almost immediately!

If your plants are not fighting root rot and disease, there's no doubt that you will harvest bigger, heavier crops — without the need for chemical pesticides or supplements.

Now take a deep breath. Feels good doesn't it?

Article published in Urban Garden Magazine, 2011



Healthy white roots appearing days after the nutrient solution was regularly treated with oxygen.



Basil roots 10 days after the beginning of electrolysis treatment.



Incredible! After being all but overcome by pythium, the roots of this basil plant have been restored to health after 21 days of electrolysis treatment.

"The speed of [plant] development is shocking - they are visibly taller, fuller, bigger, and happier."

"It's easy to tell when your plants are supercharged. You don't need any fancy meter for that — it's visually apparent! Every time you open the door to your garden your plants almost roar at you! The speed of their development is shocking — even over a single day — they are visibly taller, fuller, bigger, and happier. I love it when my garden is cranking like this." — Kevin, indoor gardener, N. California.

Dissolved Oxygen Success Stories

From cannabis to cucumbers, there's results for everyone.

09



01

I've been in the cannabis industry for over a decade and the BioTherm DGS™ is the first irrigation product that lives up to its claims. In the first six months I've seen a 15% reduction in nutrient costs and **over 20% increase in yields** during the same time frame.

The product is easy to use and install, and the BioTherm team is always available to answer any questions. My irrigation system requires less cleaning because of the increased dissolved oxygen levels and I couldn't be happier with my purchase. The DGS is a must-have for all growers... large or small.

Jesse Patrick, Managing Partner | OGC Non-Profit Collective

Using the BioTherm DGS™ system showed me that we have all been missing a primary element in growing Cannabis, I've been a believer in using airstones in my res for all the years I have grown, but the oxygen saturation from the DGS™ is far beyond any other method. I have documented a 20% increase in root mass and a **15% increase in flower weight**.

By being able to keep my dissolved oxygen level at 25 PPM reliably, my nutrients are more effective, which has allowed me to reduce nutrient usage.

Quentin Van der Veer, Grower | Denver, CO



02



03

We installed the DGS™ system this spring hoping to improve the quality of water coming from our irrigation ponds. Typically, we have had very low DO levels of 6-8 PPM. After installing the DGS on our irrigation warming tank, we now have **DO levels of 18-25 PPM**.

Our spring crop has been the strongest and cleanest in 16 years of growing. Our growing media and we have been growing cucumbers and cannabis with a fully-automated hydroponic system. The plants are definitely cleaner, with better color and increased production. I am thrilled with the results.

Brian Lagerwerf | Alway Fresh Greenhouses, Ontario, CAN

We're seeing a 20% increase in yield in the oxygenated group vs. the control. These are the same strains on the same benches in the same room. The oxygenation makes the most immediate noticeable difference in the vegetation stage causing the leaves to become a deep green. I feel that using the DGS system is akin to using CO2.

At harvest, we recorded **.4 pounds more yield per light**, using dissolved oxygenated water.

Kevin Worrell | Washington State



04



▲ Did you know...

Dissolved oxygen's concentration in water directly influences the health and growth of plants in hydroponic and aquaponic systems. Higher levels of dissolved oxygen improve nutrient uptake and root respiration, leading to faster growth and healthier plants. In fact, plants can grow up to 20-30% more efficiently with optimal dissolved oxygen levels in their root zones compared to low-oxygen environments!

10

Grower Stories

Meet the Growers: How BioTherm's Climate Solutions are Helping Plants Thrive and Growers Succeed.

Our "Grower Stories" series provides an inside look at how innovative growers are utilizing BioTherm systems to improve their greenhouse operations. Each grower shares their unique experience, highlighting how BioTherm's advanced climate technologies have helped them boost productivity, reduce energy consumption, and create an ideal environment for healthy plant growth.

These stories serve as a testament to the proven reliability and effectiveness of BioTherm solutions, offering valuable insights for other growers looking to optimize their facilities. By hearing directly from those who have experienced the benefits firsthand, the series aims to inspire and educate the next generation of successful growers.



@biothermsolutions
Connect with us on our
socials!



Scan the QR codes with your smartphone to watch the videos!



Innovative

Dissolved Oxygen

Systems

Advanced Systems Available

We understand that not all facilities fit into a one-size-fits-all approach, so we are happy to custom-engineer the perfect system for your production facility. Reach out to your local rep for more details!

11

Dissolved Oxygen Systems

BioTherm DO System Overview

Dissolved oxygen is the missing nutrient in your irrigation water. Increasing dissolved oxygen (DO) levels in your irrigation system is one of the most innovative ways to enhance your plants' health and production. Our dissolved oxygen solutions are simple and efficient, easy to install, and scalable for your irrigation needs.

DGS Dissolved Gas System

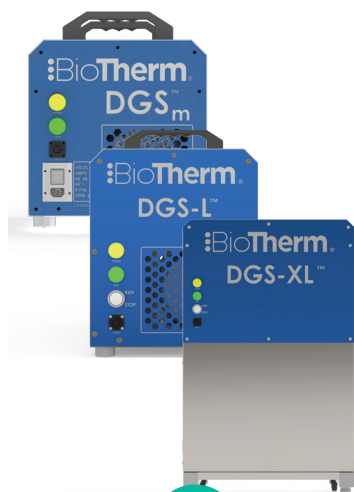
The DGS Series is our plug and play dissolved oxygen system. Capable of handling up to 20,000 gallons per day, and can be used in a reservoir tank, in-line, misters, booms or deep water culture (DWC).

OGS™ Oxygen Gas System

The OGS uses advanced technology to generate oxygen, ensuring that water supplied to plants has optimal dissolved oxygen levels. The OGS is designed for easy installation and integration into a DGS oxygen system. The plug & play design means that it can be quickly set up with minimal technical expertise.

DO Stat™

Your crop depends on consistency, and dissolved oxygen (DO) is a difficult variable to control, but the BioTherm DO Stat works with the DGS systems to optimize DO levels at your set point. The DO Stat reads dissolved oxygen and temperature in your irrigation line or tank, and controls the oxygen infusion process.



01

DGS Systems

Plug & Play, Various Flow Rates



02

Oxygen Generation System

Produces 93% pure O2



03

DO Stat

On-demand DO Control



Follow Our Updates

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to growers since 1980.

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