Dissolved Oxygen May Impact Turf Respiration

By Greg Archambeau

Progress, whether cultural or industrial, is driven by advances in technology as customers demand innovation to solve evolving problems. Golf course aeration has undergone many changes over the past 100 years as superintendents strive to relieve compaction and provide their turf with oxygen, the most crucial element for turf survival. Mechanical means of introducing oxygen have become quite advanced, but the next generation of aeration technology will focus on water quality and how it affects soil oxygen levels.

New technologies are now available that greatly increase the dissolved oxygen level of irrigation water for preventative treatment of anaerobic root zones.

Review of turfgrass respiration

Under normal environmental conditions, turf respiration enables the root to absorb soil oxygen, water and nutrients and transport them to above ground plant tissue. Plant roots absorb oxygen from soil macropores and oxygen dissolved in soil moisture, using it like animals do in breathing. Oxygen has two means of introduction to the soil —mechanical aerification and irrigation. Changes in the soil atmosphere are most frequently brought about by flushing soil pore spaces with water. In addition, water will have more oxygen and less carbon dioxide dissolved in it. Thus, it will be better suited to promote plant growth (Roberts, 1990).

Superintendents haven't focused on enhancing the oxygen content of water because the technology was lacking. Frequent irrigation and poor drainage of the root zone often result in a lowering of available soil oxygen as both macropore and micropore spaces are filled with water containing small amounts of dissolved oxygen. High temperatures and higher humidity increase the respiration rate of the plant, demanding more oxygen because of increased oxygen depletion.

Once the dissolved oxygen is depleted, the plant's health declines until the excess water drains from the macropores or more dissolved oxygen is supplied. Since oxygen diffusion through water is approximately 10,000 times more limited than through air (Berndt, Vargas, Melvin, 1989), irrigation water must contain as much dissolved oxygen as possible before it reaches roots and seals them in a membrane of moisture. Even complete knowledge of soil-air dioxide (O_2 concentrations doesn't allow an assessment about whether a soil is adequately aerated. In soil, the rates of gaseous diffusion are restricted by the water surrounding the organisms (Simojoki, 2001).

An understanding of the diffusion rate and how water can act as a barrier to soil oxygen is why dissolved oxygen can no longer be overlooked when discussing sufficient aeration.

Mechanical aerification soon led to core extraction and the creation of vent holes using solid tines. Unfortunately, it's typical for less than 10 percent of the soil volume to be exposed to atmospheric oxygen after these treatments. This is one of the main benefits of using water's natural ability to transport dissolved oxygen. When discounting hydrophobic regions, water will deliver oxygen to 100 percent of the green's soil volume.

In the 1960s and 1970s the USGA Green Section stimulated interest in root-zone soil mixtures that were more resistant to compaction than most soils, yielding good internal water and gas infiltration and retention. The industry responded with deeper-reaching tines, followed by water injection cultivation (WIC) which helps relieve compaction and increase infiltration rates. Summer treatment with WIC and solid-tine cultivation (STC) significantly increased infiltration rates of water and reduced soil salinity for in-use practice putting greens (Green, Wu, and Klein, 2001).

Sections of soil that are not wettable can also become oxygen deficient. If water is not able to adequately penetrate the depths of a 2-inch to 8-inch root zone, it does not take much to realize that soil gases are trapped as well and oxygen deficiencies are emerging.

Surfactants can have a big impact on treating hydrophobic areas and returning moisture to sections of the green that are struggling. They also transport oxygen dissolved in water to the turf root zone, promoting root growth and enhancing soil system biodegradability — which helps improve water use (Roberts, 2002). Therefore, wetting agents not only bring water to sections of the soil previously impenetrable to water, but that water brings a fresh supply of dissolved oxygen.

As far back as the early 1900s, attempts were made to aerate or loosen the soil to establish a favorable balance of soil oxygen in greens. Initial practices involved spade-fork cultivation, and the 1940s even spawned brief uses of dynamite.

Lack of dissolved oxygen

Existing aeration practices have focused on modifying the soil profile to introduce more oxygen and re-establish a larger number of macropores. Microdiffusion Inc.'s focus is on modifying the oxygen capacity of the soil water or moisture, not the macropore and micropore spaces.

Superintendents strive to get more dissolved oxygen in their lakes to promote healthy aerobic activity, but may overlook the repercussions of water that is low in dissolved oxygen being sprayed on their greens.

Irrigation lakes often become stratified during hot summer months. A stationary irrigation intake valve located near the bottom of the lake can result in water with the poorest quality and lowest dissolved oxygen levels being applied to the turf. Remedial maintenance will be required to maintain adequate turf quality and overcome the negative use of such water.

In addition, the greens also are stressed by partially decomposed organic matter that competes with the turf for oxygen at the soil surface. On many greens, the stress is so great that the turf can't survive. (Smart, 1999).

Recent research emphasizes other problems associated with oxygen deficiencies. Plant roots need oxygen as the terminal electron acceptor of the respiratory chain to gain energy for adenosine triphosphate synthesis if oxygen is not readily available (Simojoki, 2001).

A biologically mediated process called denitrification will use nitrate or other oxidized forms of nitrogen as the terminal electron acceptors for respiration instead of oxygen. This can happen in a root zone that isn't commonly considered anaerobic. In fact, when turf is watered through irrigation or from rainfall, small sites within the soil profile can become oxygen limiting (Horgan, 2003). As soil temperatures rise, nitrogen losses will increase as the turf's elevated respiration triggers more denitrification and a decreased efficiency in fertilizer use.

Horgan's study proved that fertilizer losses can be significant even after light irrigation because not enough oxygen is available. Based on this data, the next step for denitrification research should focus on loss of nitrogen after irrigating as a function of the water's amount of dissolved oxygen.

Dissolved oxygen treatment

Microdiffusion core technology takes advantage of of water's ability to hold and transport dissolved oxygen, as well as its ability to penetrate root zone.

Paramount to the technology is the increase in dissolved oxygen as water passes through the hand-water aerator. The initial level of dissolved oxygen, however low, does not limit the performance as the pump-like system will re-oxygenate the water to normal levels and beyond. The hand-water aerator can raise the oxygen content of water to over 30 parts per million (ppm) and it does not bubble away (see Figure 1).

This equates to over 500 percent more dis-

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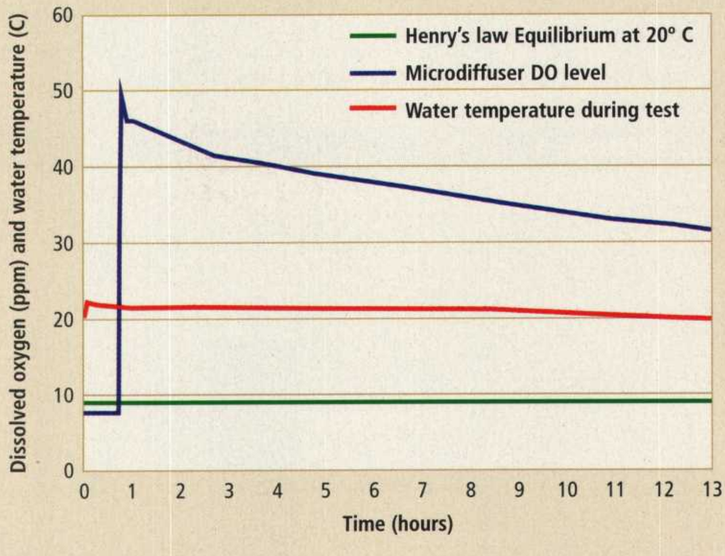
FIGURE 1

Oxygen retention curve (ORC) for microdiffusion system tests



The blue line is the water's dissolved oxygen (D.O.) level before, during and after processing. The peak D.O. level is when the unit was turned off. The slow release of the oxygen shows that after 13 hours the water still has more D.O. than what is defined as 100 percent saturation by Henry's Law (green line).

Source: Dr. Milton Engelke, Texas A&M.

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solved oxygen during the summer when typical irrigation water is at or below 6 ppm.

What will ultimately standardize this new realm of root zone aeration is twofold:

• how many ppm of oxygen are being dissolved in the water; and

• how slowly does the dissolved oxygen dissipate.

The higher the sustained level of dissolved oxygen, the longer the soil water can contribute to biological respiration. "Previously, academics have only been able to attain dissolved oxygen levels approaching 11 ppm with existing technologies. In a worst case scenario Microdiffusion's equipment still produces water in the 25 ppm range," says Milton Engelke of Texas A&M. "What I find even more intriguing is the oxygen release curve, which proves that the oxygen is truly dissolved at those elevated levels and remains available for use by the soil system for hours after application."

Continuing research

Engelke's research verifies that the hand-water aerator can consistently achieve dissolved oxygen levels in the 25 ppm to 35 ppm range. His research on bentgrass and bermuda core samples confirms that the dissolved oxygen is being used within the root zone. During the experiments, an interesting discovery was also made. Along with the highly oxygenated water, tests were run with normal city water and oxygen-deficient water for comparison.

Leachate was collected for each sample after the application of water and not only was the extra dissolved oxygen being released in the root zone, the deficient water was removing oxygen from the root zone. This is worth noting for superintendents who have low dissolved oxygen levels, as the water shows a higher affinity for the soil oxygen than the soil does, removing oxygen as it leaches through the profile.

We are currently involved in hydroponic research to monitor increased nutrient uptake rates, overall plant health and plant respiration for regular water vs. oxygenated water. Research has proven that for many turf-like plant species the best growing conditions cannot be achieved with standard levels of dissolved oxygen.

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CORRECTION

Editor's Note: Due to an editing error, the article appearing on pg. 56 of *TurfGrass Trends* in May contained a misleading headline and was missing two charts. The headline should have read, "Can Biostimulants Improve Bentgrass Root Growth?" The missing charts are reproduced below.

For the complete story with the correct headline and all four charts, please go to *http://www.turfgrasstrends.com/turfgrasstrends/article/articleDetail.jsp?id=54396.*

FIGURE 1

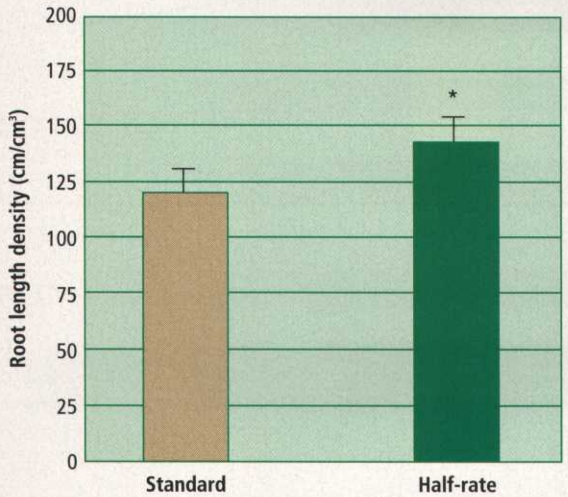
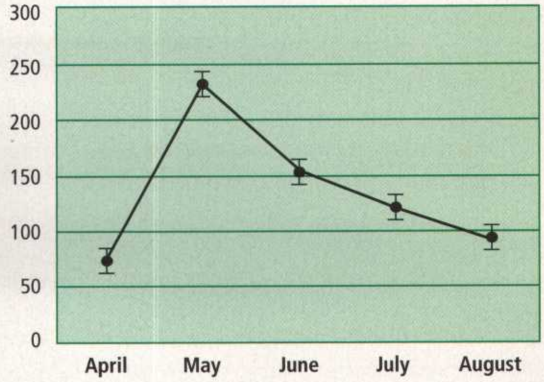


FIGURE 2

Mean root length density (cm/cm3) in monthly soil cores taken over the course of the OPGS experiment. Data from all fertilization levels and OPGS treatments are combined. Bars represent 1 SE.



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Under conditions of marginal oxygen supply, the plant may not appear to be suffering, but the effect on water and mineral uptake and transport from inadequate oxygen in the root zone, can lead to an increase in physiological disorders (Morgan, 2000).

In cultures of 0, 4, 8 and 16 ppm, the healthiest specimens were grown with the highest concentration of dissolved oxygen (Gilbert and Shive, 1941). Until now, levels of 16 ppm or higher were not feasible outside of a lab setting. Continued research in this area will draw new conclusions about how highly oxygenated water can help alleviate turfgrass stress as well as have an impact on fertilizer, fungicide and pesticide use.

Archambeau has a bachelor of science in chemical engineering and is currently the business development manager for Microdiffusion located in Southlake, Texas.

Author's note:
Preliminary university research on our highly oxygenated water was conducted last year by Texas A&M and is available upon request or at www.microdiffusion.com. Case studies with current customers as well as cooperative research with other superintendents is underway and we are looking forward to reporting those field results within the next 6 to 12 months.

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