# Soil Physical Properties Monitoring Oxygen for Success

By Dean Piller

**During my 20 years as a superintendent, I have faithfully taken soil tests to monitor the chemical and nutritional values of soil on greens, tees and fairways. While this information is critical in making sound management decisions on fertility programs, I recently learned I was overlooking the most important factor in developing management programs for promoting strong, healthy turf.**

A couple of years ago, I attended a seminar by Dave Doherty from the International Sports Turf Research Center (ISTRC) on soil physical properties. He discussed several concepts that will forever change the way I manage greens. Doherty emphasised how important gas exchange and oxygen are in the profile, and by monitoring the physical properties of soil profiles with regular testing, I would be able to make informed decisions when developing management programs. In a nutshell, through Doherty's observations at hundreds of golf courses across North America, he was able to identify the soil physical properties common in the greens that are easy to maintain, as well as those that fail or are very difficult to manage.

### START WITH BENCHMARK TESTING: THE FIRST REPORT CARD

The ISTRC lab, based in Olathe, Kan, provides two sets of data. The first set consists of physical evaluation, the evaluation of the root systems and the measurement of the organic matter in each 25.4-mm (1-in.) increment to a depth of 101.6 mm (4 in.). The second set of data contains the textural and particle-size analysis. The combination of this data provides information on the greens' infiltration rate in millimetres per hour (inches per hour), subsurface air capacity (non-capillary porosity), water porosity (capillary), bulk density and percentage of organic matter. The data this testing provides will help monitor the aging process of the putting surface rootzones, while also evaluating the effectiveness of current cultural practices. A well-built green is designed to provide a profile with 60 per cent solids, 20 per cent air-pore space and 20 per cent water-pore space. These values can provide the correct environment for a strong rootzone and healthy turf. As greens age, these values tend to shift dramatically if cultural programs are not designed to maintain original conditions through the removal of organic matter and the addition of sand topdressing to dilute the organic matter produced by the plant's life cycle.

I have found the information provided by the physical property soil tests to be invaluable when making informed management decisions regarding the necessary cultural programs for upcoming seasons. As superintendents, the data provided can also help illustrate to our employers that we have developed our cultural programs based on sound facts. And, such scheduled procedures are necessary for the long-term benefits of the course's putting surfaces.

### SELECTING TINE SIZE AND SPACING

Once the physical properties of your existing greens have been tested and determined, the necessary aeration schedule can be easily outlined. To help identify ideal physical properties, the International Sports Turf Research Center (ISTRC) established the following values for superintendents to work toward:

For example, the results of our first set of tests for green #1 back in January 2005 were:

| | |
|---|---|
| Infiltration rate: | 173 mm (6.81 in.) |
| Subsurface air capacity: | 9.83 per cent |
| Water porosity: | 41.63 per cent |
| Organic content: | |
| 0 to 25.4 mm (0 to 1 in.) | 3.94 per cent |
| 25.4 to 50.8 mm (1 to 2 in.) | 3.18 per cent |
| 50.8 to 76.2 mm (2 to 3 in.) | 2.26 per cent |
| 76.2 to 101.6 mm (3 to 4 in.) | 1.82 per cent |

Based on these results, ISTRC agronomists recommended we develop a program for this season to displace 25 per cent of the putting surface using the aeration tines' outer diameter (OD) in the calculation. By using the ISTRC's surface area calculator, different spacing and tine sizing can be inputted to come up with the best tine to achieve certain goals.

Many golf courses are switching to carbide-tipped aeration tines for longevity, which is probably a good idea. During our most recent aeration, we used a standard side-eject quad tine, and since they were not carbide-tipped, the tines were changed after every 1,858 m_ (20,000 sf) of aeration, or roughly every three greens. Halfway through the aeration of our 12th green, the tines were changed and we noticed the removed core was significantly different.

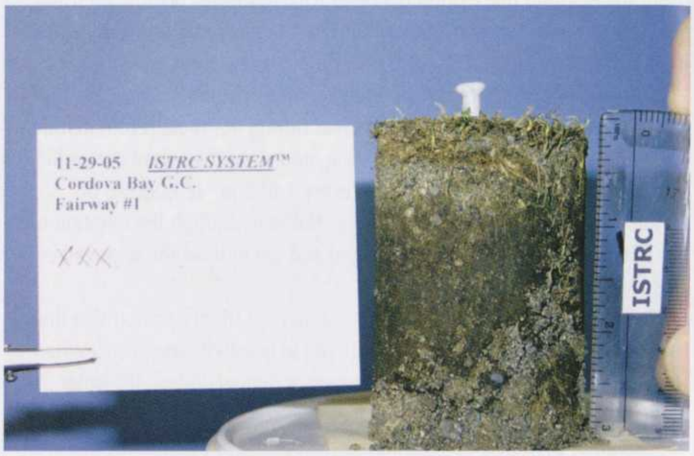
The difference in the core that was pulled out of an aeration tine that has been worn down by 8.3 mm (0.33 in.) in length is significant. When the tine is new, 3.75 per cent of the green is removed using the inner diameter (ID) and 10.04 per cent is removed calculating with the OD dimension of the tine. After 1,858 m_ (20,000 sf), the same tine has worn down by 6.35 mm (0.25 in.), but the ID and OD dimensions of the tine have changed, resulting in 6.24 per cent removal using the ID in the calculation and 9.01 per cent using the OD dimension.

This data suggests when using a standard aeration tine that will wear, it is important they are either changed more frequently or rotated in the order in which the greens are aerated each season. The purpose of this technique is so the amount of material moved from each green during the season is similar. Using soil tests to monitor the changing physical properties of the greens is a useful tool in management programs.

### ROOTZONE OXYGEN AND HARMFUL GASES

There are several factors affecting the oxygen levels in your soils, and core aeration is only the first step. Aeration is the venting of soil, which enables gases to move in and out of the soil profile. High water contents in soils cause oxygen deficiency for roots because water-filled pores block the diffusion of oxygen into the soil to replace those used by respiration. In fact, according to Nyle Brady and Ray Weil, authors of The Nature and Properties of Soils, the oxygen diffuses 10,000 times faster through a pore filled with air than a similar pore filled with water. Once soil temperatures warm up and we approach the growing season, oxygen can be rapidly depleted through consumption by actively growing turf roots or by soil microbes that are decomposing readily available supplies of organic matter. If organic matter decomposes under low-oxygen soil conditions, then gases such as methane ($CH_4$), hydrogen sulfide ($H_2S$) and ethylene ($C_2H_4$) are produced. Therefore, during the growing season when microbes are very active, it is essential your management programs focus on the constant addition of oxygen in a variety of methods to encourage the decomposition of organic matter and allow for adequate displacement of any harmful gases that may form during these processes. I believe the following tools and procedures are of primary importance for a solid Integrated Pest Management (IPM) program:

- **Hydroject.** During the growing season, when more disruptive methods are unacceptable, this tool may become a superintendent's best friend in terms of managing gas exchange in the soil profile.
- **Planet Aire.** This tool is gaining popularity due to the ease and speed at which aeration can occur. With this machine, a non-disruptive aeration can be performed on greens in as little as four hours.
- **Spiking with a 6.35-mm (0.25-in.) solid tine.** This procedure creates excellent chimneys for gas exchange to take place, and when combined with a light topdressing, minimal surface disruption occurs.


## PROPER GREENS DRAINAGE AND VENTING: AN IMPORTANT PIECE OF THE PUZZLE

Once a programme is implemented to monitor and manage the air-pore space in the greens, it is critical to ensure the drainage systems installed in your greens during construction are functioning and properly venting. This will allow oxygen flow into the rootzone as well as the flushing of the harmful gases created by microbial activity and by the plant during respiration that is consuming oxygen and producing carbon dioxide. In order for this to occur, cleanouts or blowouts need to be installed at the upper end of each drain tile loop, and air vents need to be installed where each drain line exits the green. Today, most golf courses are initially being designed with blowouts and vents installed during construction, however, most courses built several years ago did not include this important specification in the construction plans. If certain greens have proven to be a challenge in the past, locating the drains exiting the greens and flushing them to ensure the tiles are open and functioning well may help.

The concept of venting is best described by comparing greens to a basement. Envision a basement with several people living in it with no windows or doors to properly vent the room. It would not take long for uninhabitable conditions to develop and inadequate oxygen levels to exist due to the oxygen consumption by the inhabitants and harmful gases that would build up. If you took this same basement and installed a window at each end to allow proper aeration and venting, the room would become much more habitable and those living in the space would be much healthier as a result. The same holds true with your greens-by installing vents at either end, fresh oxygen can be drawn down into the greens table and the water will flow more freely through the tiles.

## TROUBLED GREENS: YOU WILL BE AMAZED BY WHAT YOU WILL FIND

This winter, we just completed the process of venting our greens and exposed several causes to the problems we have been experiencing over the years. Our 8th green has been difficult to manage, even though it is one of the largest on the golf course and is fully exposed to the sun. When we located the drain exiting at the back of the green, we found the tile had been cut during the installation of the irrigation system 16 years ago. On three other greens, we found drains that were plugged with roots from surrounding trees and some of the greens located beside ponds had the drainage tile entering the pond underwater, causing backup of the harmful gases unable to vent out of the end of the tile. Since we encountered various problems during the installation of the vents, we now refer to them as the 'observation ports.' During heavy winter rains, it is reassuring to visually inspect your drains and see the water pouring out of them.

## VENTING YOUR GREENS: THE PROCESS

On most of our greens, the venting process took approximately two days per green, three to four cleanouts were installed and two to three exit vents were set up.

## WATCHING THE GREENS CHANGE

Since the golf course was built, we have experienced varying degrees of black layer in some of our greens and had attributed this to the sand used during construction. However, after learning our greens' drainage was not functioning to the best of its ability due to the lack of venting, we expected to see improvement in the conditions after the implementation of our venting system.

## IRRIGATING WITH OXYGENATED WATER: THE NEXT STEP FOR CORDOVA BAY GOLF COURSE

Water in many soils contain small, but significant quantities of dissolved oxygen. When all the soil pores are filled with water, soil micro-organisms can extract most of the oxygen dissolved in the water for metabolic purposes, but this small amount is used up quickly. I am sure there are many processes that take place in the soil during a nice steady rainfall, and I have always wondered why plants and turf seem to respond so well to rainfall in comparison to the irrigation cycles we implement throughout the season. I believe one of the processes that occurs is an oxygenation of the soil because of a fairly high count of dissolved oxygen in the rainwater. In an effort to promote oxygen in our rootzones at Cordova Bay, we have taken additional measures by installing a Sea Air system. This system has been installed in our pumphouse and it treats the water by injecting dissolved oxygen into the wet well prior to being pumped onto the golf course. During the peak irrigation system from June to September, we have found the dissolved oxygen level in our wet well to be around 6 ppm. With the installation of the Sea Air system, we are now irrigating the golf course with water treated to 15-20 ppm. While it's too early to monitor the results, we do feel this system will bring us one step closer to promoting a healthy aerobic soil profile when managing quality turf.

The intent of this article is to emphasise the important role oxygen plays in managing healthy turf by evaluating all programs that can directly affect the level of oxygen in soil profiles. Hopefully, as a result, greens will become easier to manage and more money will be saved in the process.

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## References

Brady, Nyle C. and Weil, Ray R., Twelfth Edition 1999, The Nature and Properties of Soils.

**Cutlines:**

The International Sports Turf Research Center (ISTRC) provides cores that offer useful data for superintendents to work toward.

Hydrojects are very valuable tools in managing gas exchange.

During the installation of a cross piece for a greens' vent, a hole is cut in the bottom of a 22.7-l (5-gal) pail for a 101.6-mm (4-in.) standpipe, forming the base for a 254-mm (10-in.) steel base and grate.

Connecting into existing greens' drainage during installation of drain vents on Cordova Bay's 17th green.

Poor soil conditions and the presence of black layer before ventilation of greens' drainage.

Rootzone soil conditions improved dramatically with greens' drainage ventilation.

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**Surface area calculator**

**Enter your values for Table A**

**Table A**

| | |
|---|---|
| Tine ID (inches) | 0.289 |
| Tine OD (inches) | 0.473 |
| Tine Spacing Width (inches) | 1.250 |
| Tine Spacing Length (inches) | 1.400 |
| Depth of tines (inches) | 3.000 |

**Values for Table B are calculated automatically**

**Table B**

| | |
|---|---|
| Number of holes per inch | 0.571 |
| Number of holes per foot | 82.3 |
| Area removed by one tine (inches) | 0.066 |
| Area of hole created by one tine (inches) | 0.176 |
| Surface Area Impacted using tine ID | 3.75 per cent |
| Surface Area Impacted using tine OD | 10.04 per cent |

| | |
|---|---|
| Infiltration rate: | 152.4 to 254 mm/hour (6 to 10 inches/hour) |
| Subsurface air capacity: | 20 per cent |
| Water porosity: | 15 to 20 per cent |
| Bulk density: | 1.35 to 1.45g/cc |
| Water holding: | 10 to 15 per cent |
| Organic content: 0 to 25.4 mm (0 to 1 in.) | 1.5 to 2.5 per cent |
| Organic content: 25.4 to 50.8 mm (1 to 2 in.) | 1 to 2 per cent |
| Organic content: 50.8 to 76.2 mm (2 to 3 in.) | 0.5 to 2 per cent |
| Organic content: 76.2 to 101.6 mm (3 to 4 in.) | 0.5 to 1.5 per cent |