DIGGING IN THE DIRT

Many golf course maintenance practices are based on feel, while others require scientific test results to make proper decisions. A common scientific test is a chemical soil test, which measures the content of elements in the soil.

The common elements are macronutrients – nitrogen, phosphorus, potassium, calcium, magnesium and sulfur – and micronutrients – iron, copper, manganese, zinc, boron, molybdenum and chlorine. A soil test – along with pH; conductivity; the calculated distribution of calcium, potassium, sodium, and magnesium (base saturation); and cation exchange capacity – provide the basis for fertilizer and amendment applications to soil. Chemical soil testing is standard operating procedure, and many superintendents spend money on such tests.

Most chemical soil tests address about 13 of the 16 to 20 essential elements for plant survival. Other important elements that aren't normally tested for are carbon, hydrogen and oxygen. Some estimates of carbon content in soil come from organic matter testing. Hydrogen is related to pH levels, but you don't think of applying hydrogen to soils as an essential element. Elemental hydrogen rarely occurs in nature. Rather, hydrogen occurs as organic compounds with carbon, and there are no specific deficiency symptoms for hydrogen. Chemical soil tests don't address oxygen levels in the soil. From a nutrient standpoint, oxygen is a major component of organic compounds. It's the oxygen content in soil that drives most chemical reactions that are necessary for life functions. Without oxygen, nothing happens.

THE PROPER BALANCE

So how is oxygen in soil measured? Soil is a three-phase system consisting of solids, water and gas (oxygen and carbon dioxide). The measurement of these components is done through physical soil testing. The formation of soil and its characteristics depends on the combined effect of physical, chemical and biological processes. Theoretically, a healthy soil consists of a balance of these three phases. When out of balance, turfgrass plants suffer.

The understanding of the proper balance between solid, water and gas is reflected by the recommendations for putting green construction in which the demand for healthy grass is required even under the most extreme environmental conditions. The accepted method for building a new root zone was introduced about 50 years ago, specifying volume of 50 percent solid and 50 percent pore space. Pore space is equally occupied by water and air. Generally, this is accomplished by using a specific particle-sized sand with the addition of a specific amount of organic matter or other amendment. This is a good starting point for the optimum soil root zone, but over time, the percentage of each phase changes. It's beneficial to know how to measure the change and how to

BY JIM CONNOLLY

manage the physical property of the soil.

Total pore space is divided between two types of pores based on size; capillary (very small pores) and noncapillary (very small). Large pores are necessary for free drainage water and air movement, while small pores are necessary for holding moisture. As greens age, capillary pores increase as much as 60 percent at the expense of noncapillary pore space. Because roots grow primarily in large pores where there's free air and water movement, it's easy to see a reduction of large pores results in less root mass. Additionally, infiltration rates can decrease as much as 70 percent or more, resulting in wet greens, compaction and related negative influences on turfgrass health.

Another important observation is the formation of layers of organic matter or lenses of sand, silt or clay. Evaluating a putting green profile in each layer-inch increases the understanding of how a root zone changes in layers. Other physical parameters such as bulk density, sand particle size, silt and clay, change as a green ages. All these factors have a negative impact on turfgrass health because the measurements move further away from optimum.

PHYSICAL COMPOSITION

For years, turfgrass managers have known aeration and topdressing benefit turfgrass health. The frequency and intensity of aeration and topdressing is a guessing game unless superintendents have a way to measure the changes as a result of these practices. Most golfers know greens need aeration once or twice a year. But what if greens need three or more aerations, or there's a need to buy higher quality topdressing sand that costs 50 percent more than what's currently used? Or what if topdressing is needed more frequently? How do you explain increasing the budget by $100,000 to buy more sand and better equipment and hire more workers? Without a physical soil test that provides useful data, superintendents can't state with certainty or justify maintenance programs. Physical soil tests are equally important, if not more so, than chemical soil tests that are used to develop fertilizer programs.

The physical composition at the 1-inch depth in the green profile is different from the 2-inch depth and the 3-inch depth. Putting green soils age in layers and can be observed easily by studying a core sample or cup-cutting plug. Organic matter is highest in the first inch and is progressively less at deeper depths. The accumulation of fine sand from irrigation water or topdressing will be identified in a physical test in 1-inch increments.

TEST REPSONSES

The following factors are brief explanations and possible responses to a nondisturbed soil test result.

Infiltration rate. A new green should have infiltration rates of 6 to 12 inches. After several

Knowing your soil's physical condition is the key to plant health

years, infiltration rates could decrease to less than 1 inch. Infiltration rate results will tell you only how far from optimum you are but won't identify the reason why infiltration rates are low or high.

40-cm water holding percentage. The result gives an overall picture of how wet a green will remain after gravity removes free water. Ten to 20 percent is normal for a well-drained green. If the results are higher than 20 percent, the organic matter, clay or percentage of fine sand also might be high.

Bulk density. Low bulk density numbers can indicate high organic matter levels. If organic matter levels are normal, low bulk density might be an indication of thatch.

Organic matter. Organic matter content of a root zone only makes sense when tests are done at different depths. It's important to know where the organic matter is concentrated. A 4-inch homogenized soil sample might have an organic matter content of 3 percent, but 80 percent of this organic matter might be in the top inch of the green.

It's important to establish a baseline number for organic percentage in each inch of the soil profile to a depth of at least 4 inches. Once you know the organic matter percentage and where it's concentrated, an aeration program that specifies depth of aeration and size of tine can be established. For example, if the goal is 2.5 percent maximum organic matter in the top 2 inches and your levels are 5 percent, 50 percent of the green must be removed through aeration. The aeration hole size and spacing will dictate the percentage of the green removed by aeration. (See chart above.)

Aerification displacement chart

Tine size	1.25" x 1.25" centers	1.5" x 1.5" centers	2.0" x 2.0" centers	2.5" x 2.5" centers	5" x 5" centers
¼" hollow tines	3.14%	2.18%	1.23%	0.79%	
3/8" hollow tines	7.07%	4.91%	2.76%	1.77%	
½" hollow tines	12.57%	8.73%	4.91%	3.14%	
5/8" hollow tines		13.64%	7.67%	4.91%	
5/8" hollow vertidrain					1.23%
¾" hollow tines				7.07%	1.77%
¾" hollow vertidrain					1.77%
1" hollow tines					3.14%
1" hollow vertidrain					3.14%
7/8" drill & fill (7" centers)					1.23%
Graden verticutter (15 blades @ 1" spacings)	1 mm blade 3.93%	2 mm blade 7.87%	3 mm blade 11.81%		

Note: Quadtine setup – regular top eject on 3/8" & 1/2" hollow tines –not side eject
- 1/4" quadtines remove as much material as regular 1/2" hollow tines
- 3/8" minimum for ease of topdressing fill if replacement of material is required
- For double aerification make two passes at 37 degrees to minimize overlap

Source: International Sports Turf Research Center

Subsurface noncapillary porosity. For existing greens, achieving 50 percent solid and 50 percent pore space would be next to miraculous. Pore space should be divided equally between capillary and noncapillary pores for new greens. In older greens, achieving at least 18 percent noncapillary pore space will ensure enough large spaces for free drainage, oxygen/gas movement and root development. If noncapillary pore space is less than 10 percent, it could be because of high organic matter or poor particle size distribution.

Capillary or water porosity. Water will remain in capillary pores against gravity and can lead to waterlogged conditions. Clay and high organic soils can have capillary porosity higher than 38 percent. This condition usually results in less than 10 percent available pore space for drainage water. Soils that remain wet for long periods of time have trouble with supporting and

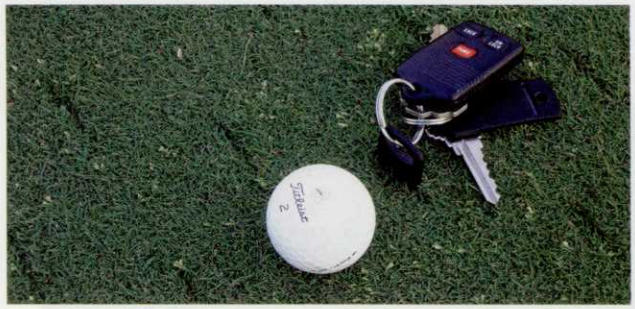
1. Black layer isn't always deep in the soil. Because of a deeper layer (sand), water infiltration and air content can be reduced dramatically close to the surface. 2. Organic matter is highest in the first inch and is progressively less at deeper depths. 3. Visual observation of a healthy green might not appear perfect, but a physical test revealed this soil to be near perfect. 4. An older sand green shows the build-up of organic, fine sand; silt and clay; large sealed air spaces; and the benefit of a single core aeration hole, which is fillled with roots. 5. Finer textered soil laid on top of sand is a detriment to turfgrass health. Photos: International Sports Turf Research Center

supplying necessary gas exchange and oxygen for biological and chemical reactions that favor healthy roots and plants.

Particle size analysis. The proper distribution of sand, silt and clay for the construction of new golf greens has been documented by many soil scientists and golf associations. A physical test that mixes or homogenizes a 4- to 6-inch sample from a green doesn't help to identify how layers might form in the green profile. A PSA that shows the distribution in each inch of profile can provide several pieces of valuable information:

1. It shows the history of how the green has matured. Perhaps a clay layer exists at 4 inches that just happens to be about 10 years ago when superintendent "X" topdressed with soil. Or, perhaps the top inch has a high level of fine sand and high silt. When evaluating a sand supplier, you'll find topdressing sand is full of fines and silt.

2. Layers of dissimilar materials might reveal why infiltration rates are low.



Slicing or spiking can relieve low oxygen symptoms temporarily, increase infiltration and improve soil health without extreme disruption of putting conditions. Photo: Jim Connolly

3. The PSA results at 5 inches show the original green root-zone mix is perfect, but all the material between 1 and 5 inches is garbage.

4. The PSA shows that during the last several years of proper topdressing and aeration the top 4 inches has improved dramatically compared to the root-zone mix below 4 inches.

New golf courses spend thousands of dollars ensuring greens mix meets proper physical requirements. The same level of diligence regarding the physical conditions of greens should be carried out every year. Lack of data regarding the physical condition of greens soil is a cause of poor putting green performance. Physical soil testing is, perhaps, one of the least used and most valuable tools available to turfgrass managers. **GCI**

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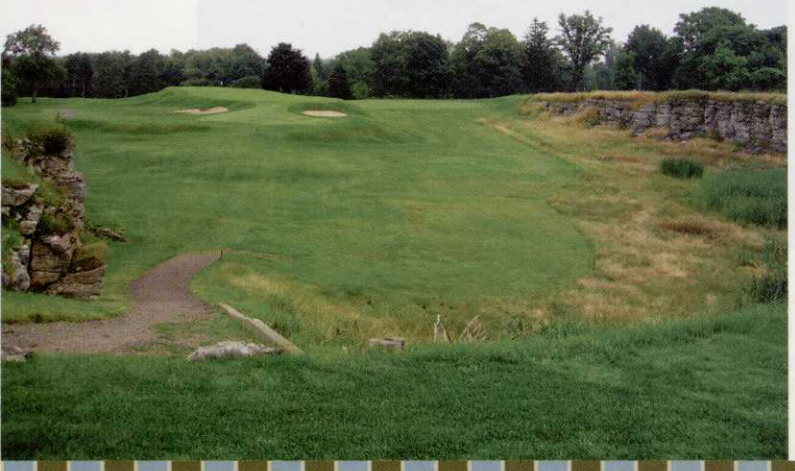

With the older greens at the Country Club of Buffalo, Jim Frank, CGCS, has adjusted the nutrition and aeration to the overall properties of the soil to match the turf's needs. Photo: the Country Club of Buffalo

BY STEVE AND SUZ TRUSTY

Fine-tuning turf

Superintendents adjust integrated plant management programs to improve conditions

Maintaining healthy turf at a certain expected level of conditioning requires much more than applying water, fertilizer and pesticides. Golf course superintendents increasingly adopt holistic approaches to turfgrass management. They combine basic turfgrass science with technological advancements and adapt cultural practices to weather conditions. Each golf course presents its own unique setting for that combination of science and art. Four superintendents share the adaptations they've made in their integrated plant management programs to improve course conditions.

BRING IT BACK

Hidden Valley Golf Course in Norco, Calif., overlooks the Corona Valley. The course design focuses on preserving the natural vegetation, dry streams and boulder outcroppings. Because the course was slotted for conversion into homes at one point, it received minimal care for three years.

In January of 2007, Iain Sturge was hired as golf course superintendent with the charge of returning the course to its former prime condition. Having served as an assistant superintendent seven years previously, Sturge realized it would be challenging, especially with a budget about 45 percent of the original $1.2-million budget.

The initial focus was to repair the pumping station and functionality to the irrigation system – 12 to 15 percent of the sprinkler heads weren't working. Resurrection of equipment to operational status came next followed by the turfgrass itself. The soil profile is about 90 percent dissolved granite, with some pockets of silty clay, which makes improvement difficult. Varietal competition added to the problem.

"When I arrived, the fairways ranged from 75 percent to 100 percent *Poa annua*," Sturge says. "We cut back on the water and allowed the *Poa* to die out with the heat. The course was originally 419 Bermudagrass, but a lot of common Bermuda was seeded in, so it's a mix now. We've pushed the Bermuda, lightly verticutting with hand rakes. We're topdressing only in the bare areas, using a 50/50 mix of composted cow manure and plaster sand, hand-raking it in. We'll skip overseeding with ryegrass to reduce stress on the Bermuda."

As for the greens, which are 75 percent *Poa* and 25 percent bentgrass, Sturge applies Primo and topdresses and verticuts them every two weeks.

Sturge, who has a small budget for chemicals, is fertilizing with urea, applying one-third of a pound of nitrogen every eight days.

"We're keeping the greens lean with very low nitrogen and lots of calcium," he says.

Sturge aerified the greens in May with standard five-eighths-inch coring, which disrupted play and lowered much-needed revenues. So, he used quadra-tining in October for much less impact on play.

"Next year, we're going to aerify with five-eighths-inch tines in July and again in August, rather than spring and fall," he says. "It's not the ideal time for the turf because temperatures can spike over 100 degrees for several consecutive days. But it's so hot, there's hardly any play, so we'll have little impact on the revenue flow.

We'll baby the turf through it and plan to deep-tine the following spring to compensate for it. We'll continue to adjust, steering toward a more conventional turf management program as we increase revenue."

SCALING BACK

Hillcrest Country Club in Long Grove, Ill., is an 18-hole private course northwest of Chicago. About a third of the course's soil profile is predominately black peat dredged from mid-course wetlands during conversion of part of that area to an irrigation pond. The remainder is silty loam, with the exception of the push-up greens. The greens, tees and fairways are a combination of *Poa annua* and bentgrass, and the roughs are a mix of bluegrass and ryegrass.

George Ott, CGCS, has eliminated early spring granular fertilization on greens, opting for a dormant application of slow-release organic fertilizer with at least half a pound of nitrogen, balanced with phosphorus and potassium.

"We generally apply it in early November, following a similar granular fertilization in September or early October," he says. "Our previous program was pushing too much top growth too early. Now we don't make another granular application until the end of May or the first part of June, depending on the weather."

Ott recently started matching the frequency

Iain Sturge, golf course superintendent at Hidden Valley Golf Course in California, has implemented an unconventional turfgrass program because of previous course neglect and a reduced budget. Photo: Hidden Valley Golf Course

of greens topdressing with turf growth.

"We watch the quantity of clippings the greensmowers are getting," he says. "As the baskets become fuller, we increase the frequency and might even topdress every week for a while. We used to topdress every three weeks all season long. The adjustment keeps our surfaces firm and maintains the faster green speed our golfers want."

Management implemented budget cuts in 2007, adapting to the regional market, but Ott anticipates a return to previous funding levels within the next year or two. He has cut his staff to 11 from 15 and is adjusting maintenance practices to reduce expenditures while striving to retain quality levels.

"Instead of two postemergent applications for broadleaf weed control, we made one application about two weeks later than the first application of previous years," he says. "It allowed more weeds to germinate, so there was a short period of visibility to our golfers, but the delay accomplished an effective eradication. It saved the costs of labor and herbicide for a second application."

Despite the budget reduction, a new irrigation system installation was completed in the spring of 2007. Now, the system has twice as many heads on the fairways, set in three rows rather than two, for better coverage control and greater efficiency.

"With the radio-operated system, we can turn on a single head for a quick syringe instead of sending an individual to hand water by hose, which allows us to allocate that crew time to other areas," Ott says.

MEETING TURF NEEDS

The Country Club of Buffalo in New York is on the site of a former stone quarry. Part of the course is built on the Onondaga Escarpment, the limestone shelf that extends from Ontario, Canada, to Syracuse, N.Y., and is responsible for the formation of Niagara Falls. Six of the greens lie below the escarpment, and 12 lie above it. The pH of the soil and natural water source are high. Turf on the greens, tees and fairways is a mix of *Poa annua* and bentgrass. The roughs are a mix of ryegrass, Kentucky bluegrass and *Poa*.

Jim Frank, CGCS, is in his 14th year as golf course superintendent, and when he started, the greens were still 100-percent native soil.

"It's been an opportunity and a continuing challenge for me to promote a competitive putting surface in today's world," Frank says. "We've used multiple drill-and-fill procedures over an extended period, incorporating sand to an eight- to 10-inch depth. We've worked through all the issues of layering and the variances of physical and chemical properties within the sand. Even when constructing a new green, the cation exchange and the nutritional inputs can vary significantly, so with our older greens we've needed to adjust the nutrition and aeration to the overall properties of the soil and try to match turf needs. The designer, Donald Ross, was a genius moving water off the greens, so we haven't needed to install additional drainage."

Weather conditions are a continual challenge.

Superintendent Iain Sturge has focused on reducing the *Poa* population on the course and improving the health and increasing the density of Bermudagrass. To help reduce stress on Bermudagrass, he won't overseed this winter. Photo: Hidden Valley Golf Course

Excessive rains as remnants of a hurricane might sweep through. Winter snows might start as early as October and continue into late spring with Lake Erie, the shallowest of the Great Lakes, freezing from shore to shore some years.

"Once September arrives, we need to aerify and verticut, and when it seems we've done enough, we do a little more," Frank says.

"The blizzard of October 12, 2006, that dumped two feet of snow and brought seven- to 14-day power outages hit our course hard," he adds. "We ended up removing more than 250 damaged trees. That turned into a good thing for our turf, creating additional air circulation and opening some areas to coverage by our irrigation system. Adjusting maintenance practices to the altered microclimates was a little thing compared to the benefits."

Frank only spot-aerifies greens in the spring, punching areas that have a tendency to dry out or wilt the quickest.

"I've added more verticutting to our program, just tickling the surface more often for grooming," he says. "I'm experimenting with subbing deeper verticutting for core aeration. There's less surface disruption and the results are surprisingly positive."

Another change is the use of a new greensmower with floating head technology.

"It's ironic, but we're mowing the greens lower, yet doing less damage and causing less stress," Frank says.

BETTER BALL ROLL

Located in the Willamette Valley of Portland, Ore., the state's top grass seed production area, Waverley Country Club was constructed in 1896. Its soil profile is silty loam with one small pocket of heavier clay.

"With our climatic conditions, we're growing *Poa annua* whether we want to or not," says golf course superintendent John Alexander, who has been at Waverley for 11 years. "We've decided to encourage it on the greens, tees and fairways. We have some in the rough, along with rye and some spots of fescue and bent."

With the amount of rain the area receives, drainage is always an issue at Waverley.

"Though some top-end clubs lightly topdress weekly, our budget only allows four to six applications of about a 16th of an inch each time," Alexander says. "We've found providing the plant with oxygen and keeping the soil drained is as beneficial as fertilizer.

Alexander and his staff core aerify the greens twice a year to maintain the firmness they want.

"We plan to core aerate the fairways twice, too, but if spring conditions preclude that, we'll compensate with a Vertidraining or a couple spikings," he says. "We're opting for more solid tining and spiking. The process is so nondisruptive with the rollers, the golfers hardly know we were there."

Summers are typically mild, with little rain from July through September, yet keeping the *Poa* healthy is a balancing act.

"We'll see afternoon stress and irrigate to about 80 percent of the ET rate, just enough to keep the *Poa* alive and get the playing surface we want," he says. "If we went to 100-percent ET replacement every night, we'd create too many soft spots. We'll have three to five crew members hand-watering dry patches most days."

Alexander uses wetting agents to keep the surface firm and water percolating during the frequent dry down and rewet cycles. He and his staff have started verticutting the greens weekly, reaching about one-sixteenth of an inch below the surface.

"We're not fighting grainy or thatch conditions with *Poa*, just creating better ball roll," he says.

Alexander also has adjusted his fertilization program, basically spoon-feeding the greens with a spray application every seven to 10 days. He also applies two granular applications a year in the fairways.

"We spray them every 14 days, putting down no more than 0.2 pound of nitrogen at any one application," he says. "We add Primo about every three weeks. It doesn't cut mowing frequency, but reduces clippings and improves the tightness of the turf for better ball roll." **GCI**

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