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

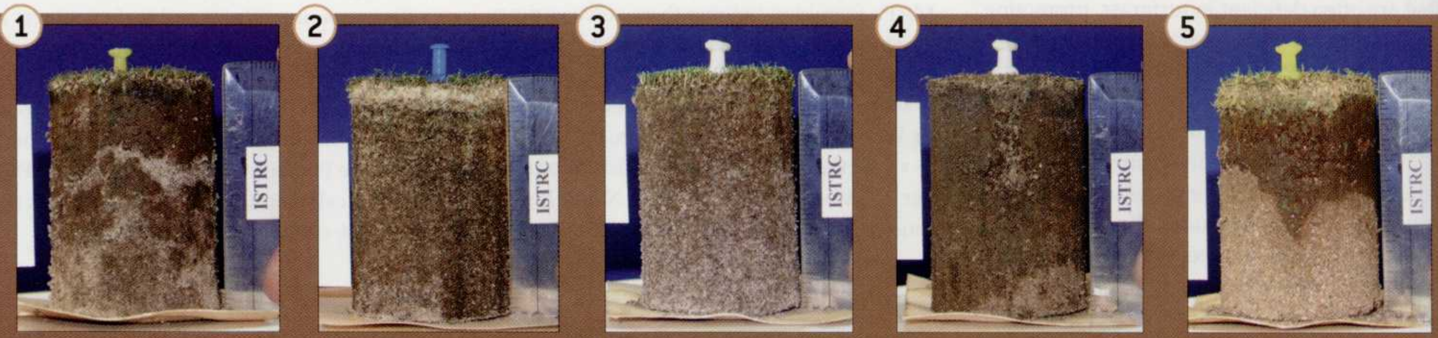
Tine size	1.25" x 1.25" centers	1.5" x 1.5" centers	2.0" x 2.0" centers	2.5" x 2.5" centers	5" x 5" centers
¼" hollow tines	3.14%	2.18%	1.23%	0.79%	
3/8" hollow tines	7.07%	4.91%	2.76%	1.77%	
½" hollow tines	12.57%	8.73%	4.91%	3.14%	
5/8" hollow tines		13.64%	7.67%	4.91%	
5/8" hollow vertidrain					1.23%
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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