The Importance of Organic Matter Dynamics

How research uncovered the primary cause of secondary problems.

BY CHRIS HARTWIGER

Through the research of Dr. Bob Carrow (University of Georgia) and others, the true cause of summer bentgrass decline has been identified primarily as physiological complications, not pathological.

A great deal of time, effort, and money is spent building putting greens that feature the most advanced construction methods and superior turfgrass varieties and provide excellent playing conditions. Keeping them in top condition is a process that must begin from the day the greens are established.

A putting green rootzone undergoes dynamic changes as plants and root systems grow, mature, and die. The debris or organic matter created in this cycle is deposited in the upper portion of the rootzone. This process of organic matter accumulation, referred to as organic matter dynamics, has a major impact on the soil physical properties of the rootzone. Appropriately managing this cycle will lay the foundation for healthy turfgrass, and failure to do so can lead to many secondary problems. This article will examine research conducted to better understand organic matter dynamics and the role core aeration and sand topdressing play in managing organic matter buildup and preventing secondary problems.

HISTORY

Some readers may be wondering why there is a need to research the relationship between organic matter dynamics and core aeration. Haven't history and field observations demonstrated the benefits of keeping turfgrass areas well aerated? After all, aeration has progressed from greenkeepers with pitch forks to Tom Mascaro's first mechanical aerator in the mid-1940s to today's high-tech machines (Labbance, 2004). Was it not common in the 1960s through the 1980s to aerate the putting greens twice per year with ½" to ⅝" hollow tines and fill the holes with approximately 15 to 20 cu. ft. of sand with each application (Carrow, 2004)? The answer to both questions is a resounding "yes," but several trends in the 1990s brought forth a need to further study organic matter dynamics and its relationship with aeration and topdressing.

The 1990s produced many innovations for putting greens, including improved turfgrass varieties, more sophisticated aeration equipment, more effective fungicides, and superior mowing equipment. As superintendents continued to improve the playing quality of putting greens, pressure mounted to minimize the disruption caused by aeration. It was common for superintendents to meet this demand by reducing hollow tine size, aerating less frequently, or skipping aeration altogether. Disruption to putting surfaces may have decreased in the short term, but in the longer run, summer performance problems were common, particularly in the southern zone of bentgrass adaptation. Many of these problems were blamed on a complex of diseases referred to as "summer bentgrass decline." Experts concluded that if poor summer performance was due to disease, then the answer to solving this issue must be using the right combination of fungicides. Could it be that turfgrass managers and researchers were overlooking something?

During the early 1990s, Dr. Bob Carrow of the University of Georgia hypothesized that many of the problems on high-sand bentgrass/*Poa annua* putting greens, including summer bentgrass decline, were not caused by diseases but were due to changes in soil physical conditions in the surface zone related to organic matter dynamics (Carrow, 2004). Further, Dr. Carrow believed either too much organic matter accumulation or a rapid death of surface roots could result in reduced infiltration, a higher water content, and a decrease in both the total quantity of oxygen in this zone and movement of oxygen within this zone (Carrow, 1998). A research review conducted by Dr. Carrow failed to uncover any previous research on measuring soil oxygen levels in putting green rootzones. A research idea was born.

ORGANIC MATTER DYNAMICS

Major changes take place in the upper rootzone within the first 24 months after establishment. When seeds germinate, the new turfgrass plants begin to develop a prolific root mass that often extends to the bottom of a 12" rootzone. The beginnings of a layer with higher organic matter can be seen in the top of the soil profile. This layer helps to act as a pad or cushion and offers improvements in wear tolerance compared to the original sand rootzone. As time passes, the organic layer becomes thicker and is mixed with topdressing sand. The rate of development of organic matter is influenced by many factors, including temperature, fertility levels, pH, water quality, and many more. Root depth begins to decrease over time as the development of organic matter impedes oxygen flow into the rootzone.

The initial amount of organic matter (usually peat) in a sand-based rootzone generally is between 0 and 2% by weight, and organic matter content increases most rapidly within the first 24 months through the deposition of fresh organic matter. This initial amount of organic matter is chosen because it offers a good balance between air-filled and water-filled pores. Murphy and McCoy have reported in separate studies that as organic matter content in a sand mix begins to increase above 4 to 5% by weight, the percent of larger soil pores decreases due to plugging with organic matter (Murphy, 1993; McCoy, 1992). Water-filled porosity increases greatly at the expense of air-filled pores.

Insufficient oxygen is common when these levels are exceeded. What started out as a rootzone structure with sand particles bridging together and creating a good balance of air- and water-filled pores has evolved into a rootzone characterized by sand particles "floating" in organic matter.

DR. CARROW'S RESEARCH

Dr. Carrow hypothesized that high organic matter has the potential to cause two major problems on sand-based putting greens. First, the accumulation of organic matter greater than 4 to 5% by weight often causes oxygen content to decrease, saturated hydraulic conductivity (SHC) to decrease, and water content to increase (O'Brien and Hartwiger, 2003). When this primary problem occurs, there is a much higher likelihood that a host of secondary problems, including disease, wet wilt, black layer, soft surfaces, scalping, limited rooting, and more frequent high-temperature injury, will appear.

The second problem is a rapid change in the "nature" of the organic matter from structured OM in the form of live roots to an unstructured form in dead roots. The dead roots swell with water as they begin to decompose, and this can plug macropores (air-filled pores), causing low oxygen levels in the rootzone. Dr. Carrow believed this to be a common problem during the summer months, particularly in the Southeast, where high temperatures and excess rain may extend for long periods of time.

The balance between microbial decomposition of fresh organic matter and deposition of additional organic matter usually is adequate to prevent excessive sealing during the summer months when root systems die back. However, when unusually hot, wet conditions persist, root death can be rapid and extensive. Air-filled pores become plugged, infiltration slows, and the remaining roots become stressed from a lack of oxygen. These remaining roots cannot take up enough water for transpirational cooling because of low oxygen. Microbial demand for oxygen is high, root demand for oxygen is high, and there just is not enough oxygen available. The plants do not die from a lack of live roots. They die from direct high-temperature kill as internal mechanisms force stomatal closure. This can be seen by a yellowing of the turf and death over a 24- to 72-hour period (Carrow, TERO).

As organic matter content increases above 4% by weight, the more likely it is that a massive root dieback from hot, humid weather will occur. This scenario is perceived to be the number-one cause of summer bentgrass decline, which is now considered to be a physiological problem rather than a disease problem. Research by Huang et al and Carrow confirmed the adverse effects of high temperature and low soil oxygen, with Carrow documenting that soil oxygen levels fell below the range of 20 to 40 mg O_2 cm^2 min^{-1} (Huang, 1998; Carrow, 2004).

With the support of USGA funding, Dr. Carrow embarked on a five-year project beginning in 1996 that included, but was not limited to, the following goals:

1. Determine the effectiveness of hollow-tine core aeration and a variety of less-disruptive water-injection or solid-tine treatments on saturated hydraulic conductivity (SHC), soil oxygen levels, and organic matter levels in the summer months during the period when bentgrass roots typically die back.

2. Determine the effectiveness of selected fall/spring cultivation on bentgrass root maintenance and viability, SHC, and soil oxygen status during spring and fall root development periods (Carrow, USGA Research Summary).

Through Dr. Carrow's research, we learned that the surface zone in a sand-based putting green, where most roots grow and the majority of fresh organic matter is deposited, controls the SHC for the rootzone. When organic matter exceeds 3.5 to 4.5% by weight, macroporosity declines substantially.

Core aeration was the only treatment that reduced the amount of organic matter in the surface zone compared to the control. All treatments, including one hollow-tine core aeration treatment in the spring followed by filling aeration holes with sand, did not keep organic matter levels below 4.5% by weight.

Most cultivation treatments (hollow tine, solid tine, and water injection) that create at least a ¼" hole can dramatically and immediately enhance SHC. Non-disruptive cultivation with holes at least ¼" in diameter will result in a period of improved SHC for approximately three weeks.

The prolific growth of roots during periods of optimum temperatures (soil 55- 65°F, air 60-75°F) can also plug macropores and reduce SHC and soil oxygen levels. Non-disruptive cultivation increases SHC and soil oxygen levels during this important period.

When hollow-tine core aeration is conducted with holes filled by topdressing, the duration of improved SHC is usually five to eight weeks for ½" to ⅝" diameter holes on high-sand greens (Carrow, 2004).

RESEARCH YOU CAN USE

Dr. Carrow's study confirmed his hypothesis that reduced oxygen levels caused by the accumulation of organic matter in the surface zone is the primary cause of many secondary problems experienced in sand-based bentgrass putting greens. Outlined below are examples of how you might be able to use this information:

When organic matter percentages exceed 4-5% by weight, saturated hydraulic conductivity and soil oxygen levels can be compromised. A poor root system and numerous secondary problems may not be far behind.

Core aeration followed by sand topdressing to fill the aeration holes is effective in increasing SHC, increasing soil oxygen levels, and reducing percent organic matter in the zone of organic matter accumulation. In the summer months when bentgrass root dieback is common, use water injection or solid-tine cultivation every 21 days to keep SHC and oxygen levels as high as possible.

Non-disruptive cultivation performed every 21 days during periods of optimum root growth will increase root growth if soil oxygen levels have been limited by plugging of macropores with live roots.

Have an accredited soil testing lab determine the concentration of organic matter in the upper portion of the rootzone. Numerous scientists have confirmed that once organic matter levels increase above 3.5% to 4.5% by weight, the number of macropores decreases below desirable levels. Putting greens with organic matter levels above 4.5% by weight are at much higher risk of severe and rapid turf decline from low soil oxygen levels in the summer months and shallow rooting throughout the entire year. Strive to keep organic matter levels below this level using core aeration and sand topdressing (Carrow, 2004).

CONCLUSION

No one has ever claimed that excellent putting surfaces happen by accident. History has shown that aeration works, and recent research has quantified its benefits on sand-based putting greens. The best putting greens over the long run will be those with the fewest limiting factors. Turfgrass research does not have much meaning unless people take advantage of the discoveries it provides. It is now up to each golf course to use common sense and communication to develop a cultivation program that works toward meeting golfer expectations, not against them. The information is available, it's free, and it works. The rest is up to you.

REFERENCES

Carrow, R. N. 2004. Surface organic matter in bentgrass greens. *USGA Green Section Record* 42(1):11-15.

Carrow, R. N. 1998. Organic matter dynamics in the surface zone of a USGA green: practices to alleviate problems. *USGA 1998 Turfgrass and Environmental Research Summary.* USGA, Far Hills, N.J.

Huang, B., L. Liu, and J. D. Fry. 1998. Effects of high temperature and poor soil aeration on root growth and viability of creeping bentgrass. *Crop Sci.* 38(6):1618-1622.

Labbance, B. 2004. The hole story. *Golf Course Management.* 72(1). http://www.gcsaa.org/gcm/-2004/jan04/01hole.asp.

McCoy, E. L. 1992. Quantitative physical assessment of organic materials used in sports turf rootzone mixes. *Agron. J.* 84:375-381.

Murphy, J. W., T.R.O. Field, and M. J. Hickey. 1993. Age development in sand-based turf. *International Turfgrass Society Research Journal.* 7:464-468.

O'Brien, P., and C. Hartwiger. 2003. Aeration and topdressing for the 21st century. *USGA Green Section Record.* 41(2):1-7.

CHRIS HARTWIGER *is a USGA Green Section agronomist in the Southeast Region.*