By Michael Vogt

Then was the summer of our discontent

Despite the use of respected spray and fertility programs, as well as what should've been efficient topdressing and cultivation programs, some of the best courses and superintendents suffered turf loss last season. Industry consultant Michael Vogt crunches the numbers to find out why.

ALL PHOTOS BY MICHAEL VOGT

The 2010 golf season wreaked havoc on greens surfaces from the eastern seaboard all the way to the Rockies in the United States and Canada. Granted, the sustained hot, humid conditions coupled with untimely downpours created an unsustainable environment for bentgrass and *Poa annua* turf maintained for golf greens. Some of the finest courses and superintendents succumbed to turf loss, with what would be considered bullet-proof spray and fertility programs along with topdressing and cultivation programs that followed the best known practices.

While these significant turf losses received a good deal of press, their actual causes or remedies will in all likelihood not be mentioned in the Wall Street Journal or your hometown newspaper. After the fact, diagnoses were made and the subject of the catastrophic turf failures became a forgotten memory. In my 30-plus years in the golf course maintenance business, I have not witnessed such a large-scale disaster with green turf loss.

No one can point to any one physiological or pathological process that devastated green conditions, but these are some of my observations in no particular order:

- Sustained low mowing heights throughout the summer put extra stress on turf;
- High organic matter in the top 3 inches of the root-zone held too much moisture;
- SBI (sterol biosynthesis inhibitors) - DMI (demethylation inhibitor) fungicide use;
- High temperature in the root-zone (> 90 F);
- Poor drainage and gas exchange on sand-based greens;
- Blue-green algae or cyanobacteria after some turf thinning;
- Winter damage – turf never recovered;
- Reduced maintenance budgets;
- Bacterial wilt;
- Fairy ring; and
- Sand and soil thermal properties.

This past summer, I attempted to discover several main causes for greens failure. One commonality was the unusually high temperature in the root-zone of thinning turf. Soil, soil with sand root-zones and some types of sands tended to have lower root-zone temperatures than most straight sand-based greens and fared better having increased rooting and more turgid green leaf tissue. Of course, total turf coverage was the best insulator from the sustained high ambient air temperature. After looking into high-percentage sand greens as opposed to soil greens, I launched a short survey. More severe turf loss was experienced on sand-based root-zone green construction than all others in both occurrence and severity.

My totally unscientific conclusion was that sand-based root-zones retained and transmitted heat more efficiently than the soil-based or soil/sand root-zone mix contributing to a more severe turf loss.

It is difficult to say something general about the soil thermal properties at any location because these are in a constant state of flux from change from angle of sun exposure, organic fraction and, most importantly, the entire water fraction in soil's capillaries. Air is a poor thermal conductor and reduces the effectiveness of the solid and liquid phases in the root-zone to conduct heat. While the solid phase of sand has the highest conductivity, it is the variability of soil moisture that largely determines its heat retention. As such, the green's root-zone moisture properties and root-zone thermal properties are very closely linked. It comes as no surprise that temperature variations are most extreme at the surface of the root-zone and these variations are transferred to sub-surface layers but at a highly reduced rate as depth increases.

Generally speaking, heat capacity indicates the ability of a substance to store heat energy; the greater its heat capacity, the more heat it can gain (or lose) per unit rise (or fall) in temperature. The heat capacity of dry soil is about 0.20 BTU per pound-per degree Fahrenheit of temperature change, which is only one-fifth the heat capacity of water. Therefore, moist or saturated root-zones have greater heat capacities, typically in the range of 0.23 to 0.25 BTU per pound-per degree Fahrenheit. Light, dry, sandy soils experience greater seasonal temperature swings than most wet soils.

This is because their lower heat capacity causes their temperature to rise or fall more than wet soils for a given amount of heat energy gained in the spring or lost in the fall. Thus, moisture-laden sandy soil or dry sand root-zones have the ability to conduct greater amounts of heat faster and in high moisture cases longer than soil type root-zones.

Creeping bentgrass root growth ceases at temperatures above 77 F, and most cool season turf plants are subjected to indirect heat stress above 86 F. Bentgrass root death occurs after five days of 90 F temperatures.

Left: Aerification remains the single most important cultural practice for a functional root-zone. Right: A dead green. High organic matter in upper three inches of root-zone caused turf to decline and die.

AGING GOLF GREENS

In the recently published research study by R.E. Gaussoin, Ph.D., University of Nebraska, aging sand greens is noted for the changes in physical properties. After the 10th year infiltration rate decreased 75 percent. In years one through eight, the decreases were the most significant. As infiltration rates decreased, so did large capillary space (critical for root gas exchange and root-zone temperature change). Also of note, total capillary space increased over the years, meaning that small capillary space was more inclined to hold additional water. The number one cultural practice to keep aging greens functioning properly, according to the research, is a sand topdressing program that closely matched the original root-zone, and on a regular basis to dilute organic matter accumulation and a timely cultivation program incorporating heavy topdressing.

WHAT KIND OF SAND?

Calcareous sand – which is composed primarily of calcium carbonate – is predominantly debris from once-living marine organisms. Plants and animals used calcium carbonate ($CaCO^3$) to form their skeletons and shells. When the organisms died, these pieces became part of the soil and sand.

Non-calcareous sand, in inland continental settings and non-tropical coastal settings, is silicon dioxide (SiO^2) usually in the form of quartz, which, because of its chemical inertness and considerable hardness, is the most common mineral sand resistant to weathering. Non-calcareous sands are not saturated with excessive calcium, making it easier to maintain a balanced fertility program.

The absence of excessive calcium leads to slower nitrogen breakdown which helps prevent disease in susceptible turf. Due to lower pH levels, applied nutrients are more available to the plant.

The physical properties of calcareous sand can be defined as any sand that contains at least 1 percent $CaC0^3$ by weight. These sands are easily obtained and often used for construction of golf course putting greens and other sand-based root zone media. However, their use is in question because of possilbe problems with their long-term stability. It is suspected that calcareous sands may break down, resulting in restricted or plugged pore space. The result could be poor drainage, restricted rooting due to root-zone saturation, and eventually thinning or turf death.

Laboratory experiments have been conducted using small PVC columns to simulate putting green profiles. The columns were filled with sands of varying calcite content.

Dilute acid was added to the columns on five day intervals, with water added on the days in between. The addition of acid simulates some of the reactions that occur following fertilization. Chemical properties of the drainage water were measured, as well as physical and chemical properties of the sand at the conclusion of the experiments. These studies confirmed that calcium carbonate does break down in response to acidification of the soil.

Unfortunately, the study needs to be continued to arrive at a solid conclusion regarding the fate of high-calcium sands. I would be interested in seeing a more complete study of these occurrences in the future.

GAS EXCHANGE IN THE ROOT-ZONE

A misleading fact is that the leaves of a turfgrass plant are the only portion of the plant that accumulates air and disposes carbon dioxide for transpiration. The roots are an important gas-exchange medium also. In fact, roots are the primary source of a grass plant's mechanism to capture oxygen. The roots gather oxygen from the soil matrix and release the carbon dioxide waste product into the soil. Carbon dioxide will gradually increase in the soil, and the oxygen content will decline, unless air circulation or soil permeability permits the release of carbon dioxide-rich soil gases with the atmosphere and the replenishment of the oxygen supply. Venting the root-zone with solid tines throughout the summer months helps balance the soil-gas ratio and evaporate moisture to cause a cooling effect to control high temperatures.

AERIFICATION, ORGANIC MATTER DILUTION AND GAS EXCHANGE

The golf maintenance industry has not found a superior cultural program to replace regular hollow core aerification. In an effort to increase play days this important cultural program has been neglected or reduced to increase rounds and revenue. Hollow core aerification relieves compaction, aerifies and removes organic material.

Historically, aerification relieves compaction and permits air to permeate into the root zone. With several hollow core aerifications annually it has been found to control and manage organic material build-up.

Organic material is removed with cored plugs. Removing organic material and filling the cavities with straight sand reduces the amount of organic material in the upper root zone. In addition, organic material gets diluted and migrates through sand-filled aerification cavities and dissipates into the lower root zone.

Green root-zones with high organic concentrations (>2.5 percent) will contaminate the sand-air macro pores and seal off these larger cavities. Organic concentrations in the upper three inches of the root-zone less than 2 percent generally do not have this sealing effect. Organic material continues to migrate through the sand with the percolating water, but the lesser amount of migrating organic material does not materially inhibit the cavity's air permeability.

It is a common phenomenon of hollow coring that the turf initially responds positively to the aerification. Unfortunately, the turf eventually returns to its original condition. On some greens the decline is rapid while slower on other greens. It is believed the phenomenon is explained by the organic sealing off the sand-filled cavities. The difference observed between turf systems is primarily attributable to differences in the upper root zones' organic content. While the cavities remain open, the turf thrives. Once the cavities are sealed off, the grass reverts to its former condition. As a common observation, it will take four to six hollow core aerification applications, with at least a 5/8-inch tine, before the observed positive changes to the turf will appear permanent. Some root zones require less applications, many root zones require more applications.

At minimum it is recommended that USGA-specification greens receive, on average, twice-annual aerification to merely maintain their physical condition. That is, twice-annual aerification is needed to merely remove the organic material deposited by the roots. This general rule, however, has its exceptions.

If twice-annual hollow core aerification applications are required with 5/8-inch tines or similar equipment to maintain a root system, an accelerated program is required to reduce the organic concentration. On grossly organically-affected root-zones the recommendation is an accelerated aerification program consisting of at least four aerification applications per year.

An accelerated aerification program is not intended to be permanent. In time, the greens will achieve optimal visual and physiologic properties which are capable of being maintained, due to the changes in the root-zone's physical properties, during periods of stress. It is possible to over-aerify a green; however,

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Hitting the Re-do button

The following are write-in responses to the question: "If you had a re-do button, what would you have changed for turf to better survive the summer of 2010?

- Mowing practices ranged from using smooth front rollers sooner, skipping mowing, raising heights of cut and rolling less and rolling in place of mowing.
- Add drainage
- Added more fans for air movement
- Better-timed fungicide
- Changed tournament scheduling
- Cooled my irrigation water
- Drainage in greens
- Drainage was the key, surface, sub-surface and air
- Flush greens more
- Go to smooth rollers sooner
- Had covers available
- Hand water
- Have roots checked for pythium infection
- I did all the rest of the items on the list
- If I had them, run sub-airs and fans
- Improve air circulation
- Improve winter drainage
- Increased watering
- Just not mowed at all
- Less mowing when wet
- Less verticutting
- Listen less to the members, do what is necessary playability be damned
- Managed wetting agents more carefully
- More fans
- More fans installed
- More hand watering and wetting agent use
- More roll, less cut
- Mowed less often
- Possible snow removal to reduce freeze thaw cycles from day to night.
- Push it harder with fertilizers in the spring and use more wetting agents in the spring when it was wet
- Put up more fans
- Raise height of cut earlier than I did.
- Raise it sooner
- Reduce applications of growth regulators
- Reduced rolling
- Reduced traffic on greens
- Remove tree canopies
- Shoveled all the snow
- Skip mowing greens on days of extreme heat
- Solid tine aerify
- Solid tine and then vent the same
- Stop growth regulator applications on greens sooner
- Switched to smooth rollers quicker, most importantly on cleanup mower
- Tree removal
- Used fans on pocketed greens
- Use different wetting agent
- Used more wetting agents
- Use impermeable covers
- Water a bit more. I was too conservative during the most extreme periods
- Watered more
- Tree removal
- Switch to solid rollers
- We aerified greens pretty aggressively on June 8-9 thinking we had plenty of time to recover. This year the heat hit early and never let up causing thin stressed turf by late June, with the whole rest of the summer to go. In hind sight, we would have been better served if we had not been so aggressive (heaving surface and tearing roots).

TURF MANAGEMENT

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the more common mistake is to reduce the number of annual applications too soon. Regular monitoring, consisting of at least annual testing, is essential to ensure the success of the program year after year. Eventually, the program will be modified to maintain the physical properties you have achieved.

WHAT CAUSED WHOLESALE TURF LOSS?

I have had conversations and have observed more devastation on golf greens than I care to talk about. I am by no means a scientist but I have been around golf turf for more than 30 years. What I have is evidence that nighttime temperatures never dropped in some cases below 80 F for extended periods, never allowing drier sand-based root-zones to cool.

Fans at green sites have a substantial benefit in aiding the cooling effect due to the evaporative effect on the turf canopy. Fans surrounding the putting surface are a distraction to the aesthetics. With the ongoing cost to operate, you'll soon discover over a period of several years a small fortune can be spent to keep bentgrass turf healthy with artificial wind. Why must greens be designed and built in depressions with large trees blocking natural sunlight and air circulation? Many superintendents responded in a write-in portion of the survey that increased air circulation would have improved turf conditions.

Older sand greens have problems with drainage and gas exchange. Whether from a high percentage of organic material in the upper portion of the root-zone, poor topdressing sand, not enough topdressing applications or perhaps a degradation of calcareous sand, the take away here is water and gas exchange in most cases were severely compromised. Second only to air circulation; superintendent's sited drainage was the limiting cause for healthy turf on greens they managed.

Organic material was the culprit in many situations. Superintendents are being placed under increased pressure to skip or curtail vital core aerification procedures and routine topdressing to increase playable days and in turn maximize revenues.

In normal, less stressful summers, the impact of accumulated organic material in the upper 3 inches of the root-zone was not a critical factor. In 2010, golf course turf roots cooked in the soupy, low-oxygen mess of thatch and organic matter.

High content or straight sand greens suffered significantly more because the physical ability of sand to transfer temperature is greater than soil on mostly push-up type greens. Even sand greens that have limited amounts of organic material to buffer temperatures were affected. Greens that have a soil component or had limited sand topdressing on top of soil base fared better, in my opinion, due the temperature buffering ability of the soil fraction if the green was well drained.

A sand green root-zone after multiple heavy topdressings.

WHAT NEXT?

There are some fundamental questions that need be asked:

• Could maintenance and construction methods be changed to regulate/moderate the temperature in the root-zone?

• In older sand greens, do calcareous sands cause a reduction of drainage and air exchange?

• Can new bentgrass varieties be bred to withstand higher root-zone temperatures?

• Could a soil fraction in the root-zone be incorporated to create an environment to increase decomposition of organic matter and perhaps buffer soul temperature?

• Is the sand size specification optimum to support drainage and gas exchange as the green ages?

• With just several minor changes during the last 50 years, can new research improve sand-based root-zone systems?

We all know, and the research bears it out, that the sand-based root-zone green begins to change dramatically with age, and the hanging water column (perched water table) system begins to be non-functional after the onset of organic material accumulation. The American Society of Golf Course Architects recommends replacing greens at an interval between 15-30 years. With aggressive and proper care I have witnessed sand-based as well as soil greens last more than 20 years and sustain great turf stands.

Sand-based root-zones are not for every golf course, the sand root-zone is very costly to build and maintain and the benefits of these greens diminish substantially if not cultivated and topdressed religiously. Less expensive sand/soil blends can be built and maintained for far less money and perform nearly as well.

The surveys point out that fundamentally, if not aggressively managed, the root-zone is the area that failed during the summer of 2010. And, expensive sand-based greens designed and built to enhance root-zone management have performed less than adequately, actually reducing water and gas exchange in the all important root-zone if not managed to a high level.

A new look needs to be taken to engineer and or manage a more stable root-zone that can sustain an environment for optimum root growth and function without the high cost and down-time of the current sand root-zones. **GCI**

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