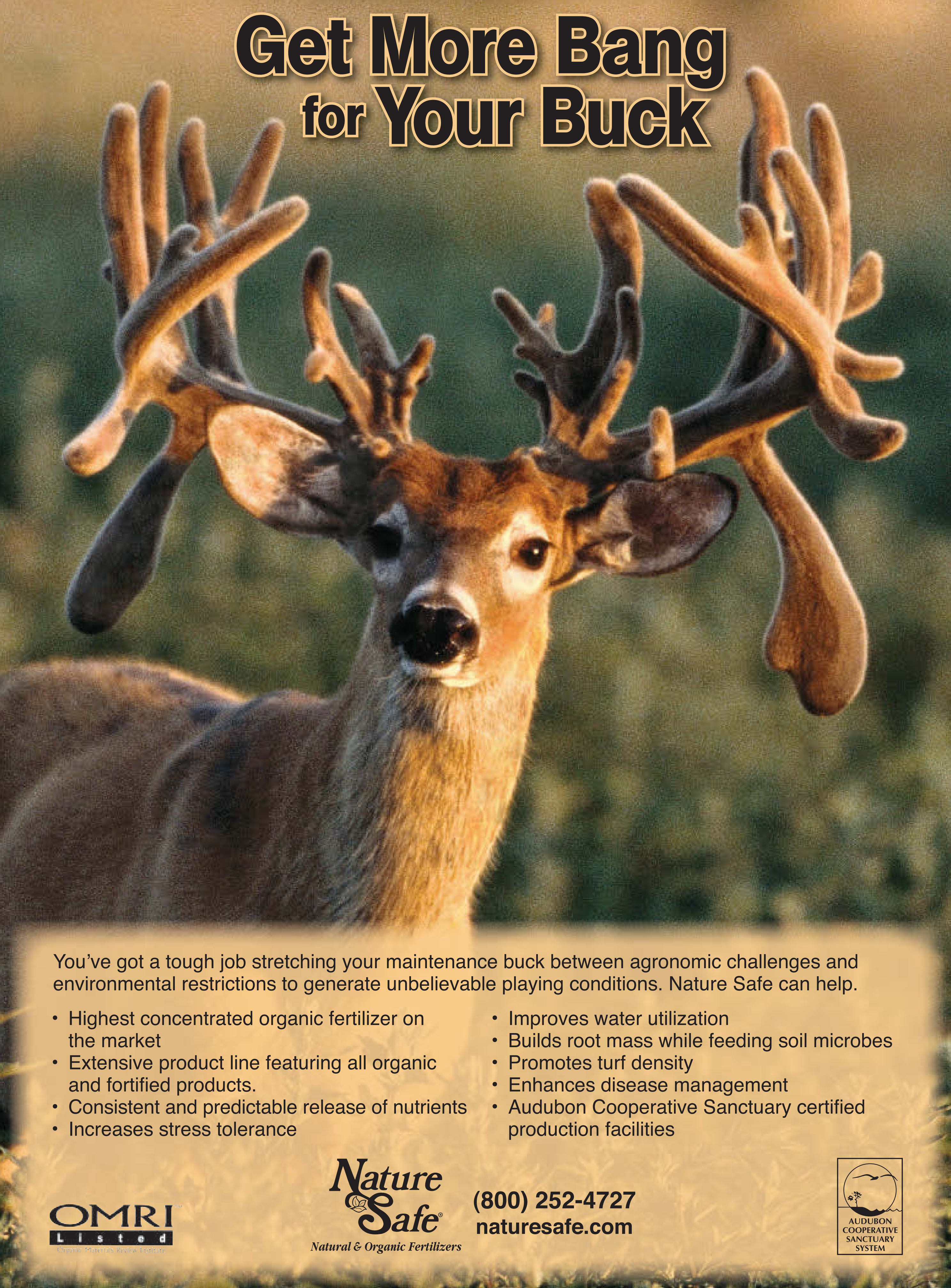

Get More Bang
for Your Buck
You've got a tough job stretching your maintenance buck between agronomic challenges and environmental restrictions to generate unbelievable playing conditions. Nature Safe can help.
• Highest concentrated organic fertilizer on the market
• Extensive product line featuring all organic and fortified products.
• Consistent and predictable release of nutrients
• Increases stress tolerance
• Improves water utilization
• Builds root mass while feeding soil microbes
• Promotes turf density
• Enhances disease management
• Audubon Cooperative Sanctuary certified production facilities
OMRI Listed
Nature Safe®
Natural & Organic Fertilizers
(800) 252-4727
naturesafe.com
AUDUBON COOPERATIVE SANCTUARY SYSTEM


OFFICIAL
GOLF COURSE
EQUIPMENT
SUPPLIER
Eliminate hydraulic leaks, Murphy's Law,
and "feedback" from the members.

Golfdom'S PRACTICAL RESEARCH DIGEST FOR TURF MANAGERS

TURFGRASS TRENDS

BENTGRASS MANAGEMENT

Effluent Increases Problems With Bentgrass in the Transition Zone

However, superintendents can take several approaches to handling these potential problems

By Danesha Seth-Carley, Tom Rufty, Dan Bowman, and Lane Tredway

In a previous article (February 2009, "Problems Surface with Effluent Use on Turf in the Southeast"), we began discussing effluent irrigation on golf courses in the southeastern U.S. transition zone. While providing an important irrigation water source, recycled water has recently been associated with a number of problems.

A main driver for the increase in effluent irrigation is the requirement by the Environmental Protection Agency and state regulatory agencies that effluent be dispersed on the landscape to protect surface water quality. This makes good sense, environmentally, as the turfgrass system is a natural filter for the pollutants present in effluent.

But one of the problems is excessive amounts of effluent are often being applied, flooding the soil, damaging the turfgrass and decreasing playability. Heavy, compacted soils and high rainfall in the region contribute to the risk of water overload. Permits for effluent disposal, often the result of negotiations between state regulators and engineers hired by developers, set application limits too high, which puts golf course superintendents in an impossible bind.

We now turn our discussion to another problem with effluent application on golf courses in the transition zone — the sensitivity of bentgrass putting greens. The transition zone is the Southern-most limit for growing bentgrass. With heat and humidity during summer months and the prevalence of fungal diseases, summer bentgrass decline often occurs even with a freshwater supply. Reports from golf courses indicate that effluent increases summer problems with bentgrass and may extend the problems outside of the summer period.

Why is bentgrass in the transition zone sensitive to effluent? The first problem a person thinks about with effluent irrigation in the Southwest is salt toxicity. Recycled water contains soluble salts, many of which are plant nutrients. However, with high evaporation rates in an arid climate, salts can cause leaf burning and accumulate in the rootzone. The situation is very different in the Southeastern transition zone.

Continued on page 54

IN THIS ISSUE

Continued from page 53

About 40 to 50 inches of rain is common and the rainfall is spread relatively evenly throughout the year. Even moderate rainfall can leach salts from the soil and keep salt levels below damaging thresholds. Also, our analyses of effluent generated by waste treatment plants in the Southeast indicate that the salt content is much lower than that found in the Southwest. Levels in the Southwest can range from 2 to 4 dS/m (a measure of the electrical conductivity of water defined as the salinity or salinity index), while they're generally about 0.3-0.7 dS/m in the transition zone. This difference reflects the naturally lower salt content of the water supply in the eastern United States.

It probably would be foolish to assume that effluent salt toxicity would never be a factor in the transition zone.

The abundant rainfall and relatively low salinity in the transition zone clearly create a lower risk of salt accumulation in the soil and a lower risk of salinity damage to turfgrasses in the Southeast. The potential for salinity problems is also diminished, of course, by the much lower evaporation rates in the humid environment. Nonetheless, it probably would be foolish to assume that effluent salt toxicity would never be a factor in the transition zone.

Extended summer droughts have occurred in four of the last eight years. Frequent, light irrigation with effluent coupled with high evapotranspiration during summer droughts could lead to salt accumulations in the upper root zone that could damage bentgrass.

Under normal rainfall conditions, the cause for the effluent irrigation problem with bentgrass in the transition zone probably lies in the ecology of the system and the involvement of several factors. Creeping bentgrass has been bred to produce a dense canopy, with rapid growth of new shoots and roots.

Salt accumulation in the upper root zone can cause bentgrass damage.

The production of biomass below ground and the large microbial population it supports leads to buildup of soil organic matter. Accumulation of organic matter creates the biggest management problem for bentgrass greens in any environment. As a general rule, when organic matter exceeds 3.5 percent to 5 percent by weight, it begins to clog soil macropores, restricting drainage and air exchange in the root zone (Adams, 1986, McCoy, 1992; Murphy et al., 1993).

Furthermore, in the heat of summer, organic matter near the soil surface is degraded to gel-like products that may seal pores and restrict gas exchange (Carrow, 2003).

The continuous use of effluent supplies significant amounts of several nutrients. Depending on the frequency of irrigation and the particular effluent source, as much as a 50 percent to 100 percent increase above the normal amount of nitrogen can be added to a bentgrass green.

In recent experiments, additions of this much extra nitrogen caused greater accumulation of organic matter in the upper soil horizon compared to normally fertilized turf. Additional nitrogen is also likely to stimulate microbial activity (Shi et al., 2007), which increases the possibility of sealing reactions at the soil surface.

The problem of too much soil organic matter leads to a cascade of reactions in the bentgrass system. Whether due to clogging of macropores or sealing at the soil surface, water retention increases and oxygen exchange into the root zone is restricted. As shown by two recent scientific papers, low oxygen conditions in the rootzone invariably result in the bentgrass plant producing roots higher in the soil profile, near the soil surface (Jiang and Wang, 2006; Seth-Carley et al., 2009).

Roots close to the surface are exposed to higher temperatures and greater likelihood of salt toxicity during droughts. Unhealthy roots lead to unhealthy shoots, i.e. summer bentgrass decline.

Numerous field observations also indicate that effluent use on bentgrass may result in greater susceptibility to pests.

Insects and fungal diseases are a continual problem in the Southeast, and pest problems are acute even with healthy plants. Depressed bentgrass health, coupled with the moist environment, creates the perfect storm for pest infestations (Dernoeden, 2002; Peterson et al., 2004).

Obviously, increased pest pressures lead to more pesticide applications and extra cost.

Handling the situation

Superintendents on courses using effluent water can take several approaches in handling the bentgrass sensitivity problem.

The best approach is to have separate delivery lines feeding irrigation heads for the greens. This allows irrigation of greens with fresh water and avoids mixing with effluent. The split systems are often installed on new golf courses where it's known in advance effluent will be used.

In many situations, a split system isn't an option. Established courses may have irrigation systems that aren't easily modified when effluent is introduced as a water source or new courses may have budget limitations. In those cases, superintendents' main management option is to flush effluent out of existing lines with non-effluent water, and then irrigate the greens.

Many courses use this approach, but flushing adds time to irrigation cycles and exacerbates water overloading on fairways. If effluent is the only water source for a course, superintendents are left with the unenviable approach of adding substantial amounts of effluent during dry periods to flush out salts from the soil horizon. This has the downside of loading the greens with nitrogen and other plant nutrients.

Although the use of effluent in the transition zone may create some problems, we must not lose sight of the important role golf courses can play as effluent dispersal sites.

Effluent is generated through the activities of man. Populations are growing in the Southeastern transition zone, so pressures for effluent dispersal continually increase. Golf courses are ideal sites to dispose of effluent with little threat to water quality.

If effluent problems can be handled effectively, golf course managers have an opportunity to make a major contribution towards environmental stewardship and sustainability.

A problem with effluent irrigation is that excessive amounts of effluent are often being applied, flooding the soil, damaging the turfgrass and decreasing playability.

Danesha Seth-Carley, Ph.D., is a senior researcher in the department of crop science at North Carolina State University. Her research centers on environmental stress effects on turfgrass species and the resulting susceptibility to soil-borne diseases. Tom Rufty is a professor in the departments of crop science and plant biology and co-director of the Center for Turfgrass Environmental Research and Education at N.C. State. Lane Tredway, Ph.D., is associate professor and a turfgrass extension specialist in the department of plant pathology at N.C. State. Dan Bowman is associate professor of crop science with research focus on the impact of turfgrass culture on environmental quality at N.C. State.

REFERENCES

Adams, W.A. 1986. Practical aspects of sportsfield drainage. Soil Use and Management 2:51-54.

Carrow, R.N. 2003. Surface organic matter in bentgrass greens. USGA Turfgrass and Environmental Research Online. 17:1-12.

Dernoeden, P.H. 2002. Stresses and maladies of creeping bentgrass. In: Creeping bentgrass management; Summer stresses, weeds and selected maladies, ed. P.H. Dernoeden, 21-78. John Wiley and Sons, Inc. Hoboken, N.J.

Jiang, Y., and Wang, K. 2006. Growth, physiological, and anatomical responses of creeping bentgrass cultivars to different depths of waterlogging. Crop Sci. 46:2460-2426.

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. ITSRJ 7:464-468.

Peterson, P., B. Martin, and J. Camberato. 2004. Rapid blight disease of cool-season grasses. Green Section Record. Sep-Oct:20-23.

Seth-Carley, D., S. Davis, D. Bowman, C. Peacock, L. Tredway, and T. Rufty. 2009. Effluent application to creeping bentgrass in the transition zone: Effluent analysis and potential negative effects from salinity and low oxygen. ITSRJ Vol 11. in press

Shi, W., D.C. Bowman, and T.W. Rufty. 2007. Soil microbial community composition and function in turfgrass ecosystems. Biodiversity and Bioavailability 1:72-77.

PHOTOS COURTESY: NORTH CAROLINA STATE

The Rise of Warm-Season Grasses

By Richard J. Hull

Turf can be maintained in hot climates for landscaping and recreational purposes primarily though the use of warm-season grasses. Unlike their cool-season cousins that fail to grow when temperatures exceed 85 degrees Fahrenheit, warm-season grasses can grow vigorously at temperatures approaching 100 degrees F (Beard 1973). Understanding the fundamental reasons behind this difference in heat tolerance among turfgrasses may enable the turf manager to achieve better turf performance.

In the first part of this series published in November, we traced the origin of the photosynthetic process that operates in cool-season turfgrasses and most plant species that grow in temperate climates. It was noted that photosynthesis evolved about 3.5 billion years ago in a world very different from the one we inhabit today. The biggest difference is the presence of 21 percent oxygen (O_2) in our atmosphere compared to less than 1 percent in that of the ancient world. That oxygen is the by-product of more than three billion years of photosynthesis — initially from bacteria but later mainly produced by algae and plants. The chemical reaction by which most carbon dioxide (CO_2) has been converted into organic matter is catalyzed by the enzyme ribulose bisphosphate carboxylase/oxygenase (aka RubisCO) that functions today pretty much as it did more than 3 billion years ago. In photosynthesis, this enzyme functions as a corboxylase when it assimilates CO_2 into the three-carbon phosphoglyceric acid (PGA).

Emergence of warm-season crabgrass in cool-season bluegrass during hot weather.

However, in the presence of O_2, RubisCO functions as an oxygenase binding with O_2 and initiating photorespiration that fixes no CO_2 and actually wastes energy. As atmospheric O_2 levels increased, photorespiration increased and began reducing photosynthetic efficiency until in our present atmosphere of 21 percent O_2 and 0.038 percent CO_2, net photosynthesis is generally inhibited by about 50 percent. At elevated temperatures, photosynthetic efficiency can be decreases by more than 75 percent, a rate insufficient to support plant growth. This is a major reason why cool-season turfgrasses fail to grow well in hot climates during the summer months.

C-4 photosynthesis

This photorespiratory erosion of photosynthesis has been a recurring problem for almost 50 million years. The principal evolutionary response to it has been an increased production of RubisCO. The strategy being: If low CO_2 and high O_2 concentrations make the carboxylase activity of RubisCO inefficient, let's just make more RubisCO. Today, RubisCO is by far the most abundant protein in the world, constituting more than 50 percent of the soluble protein in the leaves of most plants. While high RubisCO concentrations enabled photosynthesis to keep ahead of respiration, they were made and maintained at considerable cost in carbon and nitrogen resources. Growth rates were slowed during hot weather and plants were less able to reproduce and tolerate other environmental stresses.

A significant biochemical response to impaired photosynthesis due to photorespiration evolved about 20 million years ago (mya) in the early Miocene Epoch but really became prominent 10 to 8 mya when atmospheric CO_2 levels fell to below 250 parts per million (ppm). Known as C-4 photosynthesis because the first product of CO_2 fixation is a 4-carbon acid (oxaloacetate or malate), this adaptation was truly ingenious. The strategy is to capture CO_2 from its more abundant HCO_3^- form and use it to increase the CO_2 level within specific cells where RubisCO and the Calvin Cycle are concentrated. To do this, a specialized cellular arrangement within leaves is required. The CO_2 capturing cells (mesophyll cells) are grouped in a ring around a layer of CO_2-fixing cells (bundle sheath cells) that surround the vascular bundles (conducting xylem and phloem cells) of the leaf.

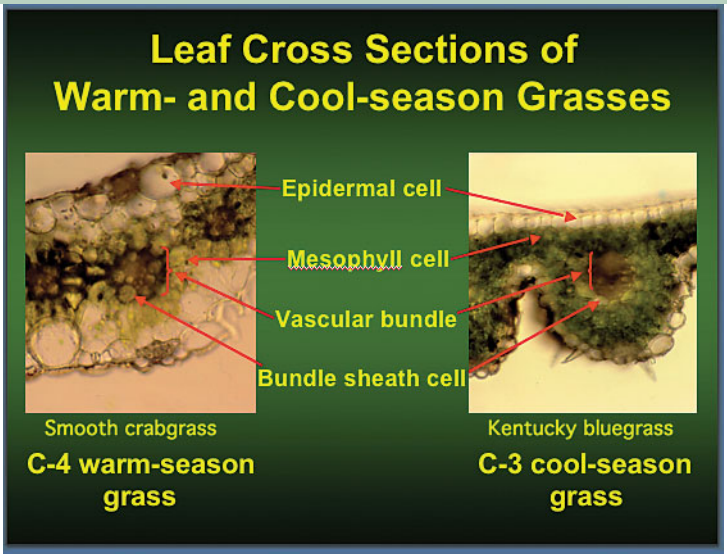
By comparison, leaves of cool-season (C-3) plants have more numerous and randomly organized mesophyll cells loosely arranged around the bundle sheath cells that enclose the vascular bundles, but here they generally lack chloroplasts.

In C-4 plants, atmospheric CO_2 diffuses into the leaves through open stomata, is dissolved on the wet surfaces of mesophyll cells and passes as CO_2 across a cell's plasma membrane into the cell. There it becomes hydrated to carbonic acid (H_2CO_3) and at the prevailing cytoplasmic pH of 7.0, it dissociates to bicarbonate (HCO_3- & H+).

The equilibrium between dissolved CO_2 and HCO_3- favors HCO_3- over CO_2 by a ratio of 50 to 1. Thus, even when CO_2 levels are very low, the HCO_3- concentrations within mesophyll cells are 50 times higher. There HCO_3- reacts directly with phosphoenolpyruvate (PEP), a three-carbon acid, forming the C-4 acid oxaloacetate (OAA). The enzyme PEP Carboxylase (PEPC) catalyzes this reaction. The PEPC enzyme has a high affinity for HCO_3- but does not react with O_2 so there is no O_2 competition with CO_2 for this enzyme and therefore, no photorespiration.

Oxaloacetate is next reduced to the chemically more stable C-4 acid, malate, that diffuses into adjacent bundle sheath cells via tubular protoplasmic connections (plasmodesmata) that traverse the intervening cell walls. In the bundle sheath cells, malate is decarboxylated to another C-3 acid, pyruvate, releasing CO_2. The pyruvate diffuses back into a mesophyll cell where it's converted to PEP and is ready to bind with another HCO3-, completing the C-4 cycle. Within the bundle sheath cells, CO_2 accumulates to levels higher than that in mesophyll cells. This is more than enough CO_2 to inhibit photorespiration and allow RubisCO to introduce CO_2 into the Calvin Cycle at peak efficiency. In warm-season grasses, the Calvin Cycle enzymes are not present in

PHOTO COURTESY: RICHARD HULL



Leaf anatomy of C-4 and C-3 grasses showing relationships between mesophyll and bundle sheath cells with a vascular bundle.

mesophyll cells but are contained exclusively within the chloroplasts of bundle sheath cells. Here, sugars made by the Calvin Cycle are in bundle sheath cells that are adjacent to vascular conducting cells (phloem), and can be efficiently exported from leaves to growing sites where they are needed.

Under hot conditions, when CO_2 levels in leaf cells are low and O_2 is high, C-4 photosynthesis supports a CO_2 fixation rate several times that of C-3 photosynthesis operating alone. However, at cooler temperatures when CO_2 concentrations in leaf cells are higher, C-4 photosynthesis is actually less efficient and supports a lower photosynthetic rate. Thus, C-4 photosynthesis provides a survival advantage only in those climates that routinely experience temperatures 85 degrees F and higher.

C-4 plants are also more efficient in their use of water. Because more CO_2 is photosynthetically reduced to sugars during each hour that stomata of C-4 leaves are open, those leaves will lose less water to transpiration for each gram of CO_2 fixed.

Studies reveal a water efficiency of 700 to 1,300 moles of water lost for each mole of CO_2 fixed in C-3 plants while C-4 plants lose only 400 to 600 moles of water per mole of CO_2 fixed. C-4 grasses also generally have a larger and deeper root system than C-3 grasses.

Continued on page 58

C-4 plants are also more efficient in their use of water.

Continued from page 57

Having evolved on numerous occasions over many years, it's not surprising there are variations in C-4 photosynthesis and even intermediate plants that exhibit greater photosynthetic efficiency but do not possess all the characteristics of a C-4 plant.

Heat tolerance in turfgrasses is not solely a function of being wended with C-4 photosynthesis. Elevated temperatures can cause other malfunctions in cool-season grasses where root sensitivity to heat can be especially troublesome. The lipid saturation level of cell membranes, the ability to detoxify O_2 free radicals, and the synthesis of heat-stable growth-promoting proteins all appear to play a role in making cool-season turfgrasses more heat tolerant.

However, there is ample evidence that C-4 photosynthesis does contribute to a plant's aggressiveness, especially in warm climates. C-4 plants comprise less than 4 percent of plant species but account for about 18 percent of the Earth's annual plant production.

Of the 18 plants designated as the world's worst weeds, 14 exhibit C-4 photosynthesis. Genetic research has not been successful in transferring C-4 photosynthesis into a C-3 plant. There is a lot involved in the C-4 syndrome and such a genetic feat may not be realistic. However, understanding what really distinguishes a warm-season from a cool-season turfgrass may be helpful in managing each to its fullest potential.

Hull is professor of plant sciences at the University of Rhode Island in Kingston, R.I.

REFERENCES

Beard, J.B. 1973. Turfgrass: Science and Culture, Prentice-Hall, Englewood Cliffs, NJ, Chapter 17.

Hull, R.J. 2009. The origin of turfgrasses: the rise of warm-season grasses. Golfdom – TurfGrass Trends: November, 2009.

Hull, R.J. and J.T. Bushoven. 2009. Does research offer answers to problems of summer decline? Golfdom – TurfGrass Trends: Jan. 66-70.

Ad Index

This index is provided as an additional service. The publisher does not assume any liability for errors or omissions.

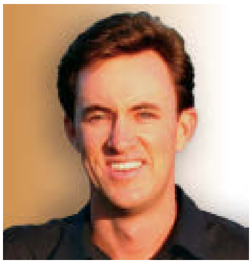
GOLFDOM (ISSN 1526-4270) is published monthly (12 issues per year) by Questex Media Group, LLC, 306 W Michigan Street, Suite 200, Duluth, MN 55802. Corporate office: 275 Grove St., Suite 2-130, Newton, MA 02466. Accounting, Advertising, Production and Circulation offices: 306 W. Michigan St., Suite 200 Duluth, MN 55802-1610. **Subscription rates:** One year $43 (U.S. and possessions), $65 (Canada and Mexico) and $98 (all other countries). Air expedited service is available in countries outside the U.S. and Canada for an additional $75 per year. Current issue single copies (prepaid only) $5 (U.S. and possessions), $7 (Canada and Mexico) and $8 (all other countries). Back issues (if available, prepaid only) $10 (U.S. and possessions), $14 (Canada and Mexico) and $16 (all other countries); add $6.50 per order shipping and handling for both current and back issue purchases. Periodicals postage paid at Duluth MN 55806 and additional mailing offices.

POSTMASTER: Please send address changes to *Golfdom*, P.O. Box 1268, Skokie, IL 60076-8268. Canadian G.S.T. Number: 840033278RT0001, Publications Mail Agreement number 40017597. Printed in the U.S.A.

Show Stoppers

WHEN IN SAN DIEGO FOR THE GOLF INDUSTRY SHOW, FIND THE TIME TO VISIT THESE FAMOUS LOCAL PLACES. YOU GOTTA TRY THE FISH TACOS!

BY GEOFF SHACKELFORD



I don't need to remind most of you that America's ninth largest city is a stupendous place to visit. The last Golf Industry Show in San Diego held in 2004 (known then as the Golf Course Superintendents Association of America International Golf Course Conference and Show) proved to be a monster hit thanks to idyllic weather and the joy of strolling around downtown's then-emerging Gaslight District. Five years later, the major construction is mostly finished. Barring an El Nino-fueled weather fiasco, Feb. 8-12 should be a stellar week for this year's GIS.

While you can have a great time just amusing yourself around the convention center area with countless restaurants, shops and pubs, there's more worth exploring if you have time and, in all but one case, access to a car.

Here's what I'm talking about:

Petco Park tour: It's no Fenway Park, but as far as modern ballparks go, Petco is a gem. The home of the San Diego Padres is located just across the street from the convention center. The architecture exudes an interesting blend of modern polish, sandstone and flashes of quirky retro, highlighted by the historic Western Metal Supply Co. building hovering over left field. Tours include visits to the press box, warning track, bullpen, dugout and the luxury box level, with promises of top-of-the-park views of the Coronado Bridge, downtown and the border with Mexico.

Off-season tours are available Tuesday through Friday at 10:30 a.m. and 12:30 p.m., with an additional 2:30 p.m. tour on weekends. Price is $9 for adults, $6 for seniors and $5 for children under 12.

One of the all-time great breakfasts: To partake in this, you must drive to the Hillcrest area just north of downtown where the world-renowned Hash House A-Go-Go (619-298-4646) serves up massive, delicious portions of pancakes, eggs, omelets and, of course, the house hash tossed with crispy potatoes and topped with two eggs. Pancakes include blueberry pecan and blackberry granola, while the griddled French toast dipped in banana-cinnamon cream and topped off by pecan maple syrup will make you want to make a second home in San Diego. Warning: There are lines on weekends. And double warning: Lunch and dinner meals are great, too.

Torrey Pines paragliding: This isn't everyone's cup of tea, mind you, but if there's enough wind, a nice dollop of courage and $150 in your wallet, the Tandem Flight program offers 20-25 minutes of paragliding over the cliffs of La Jolla with a highly trained instructor. You'll get killer views of Torrey Pines's fourth hole and the California coastline. The first-come-first-serve flights usually run from noon to 3 p.m. Just call 858-452-9858 in the morning to see if they're operating that day. All ages welcome and spectators can wait at the Cliffhanger Café. Cameras aren't allowed, but for an extra $15 they'll take photos of you.

Torrey Pines golf shop: It's easy to pull in to now-historic Torrey Pines, home to the epic 2008 U.S. Open. Convenient 30-minute parking spots are offered and usually open if you just want to pop into the golf shop or walk over to the 18th green and see the par-5 that yielded Tiger Woods' epic final hole birdie. Also, for fans of unique architecture, a walk around the lodge at Torrey Pines is a must.

And now for fish tacos: If you're heading back to the convention center, stop off at Bluewater Seafood (619-497-0914) near the airport and easily accessible from Interstate 5. Featured on Food Network, all the food is stellar, but there's simply no excuse for passing on the fish tacos. At $3.95 a taco or $7.95 for two, you'll get huge portions of fresh swordfish, mahi mahi or shrimp with great sauce and cabbage. Tortillas come from the nearby El Indio, another great spot for cheap and tasty Mexican food.

Follow Shack, Golfdom's contributing editor, at www.geoffshackelford.com or via Twitter.com/GeoffShackelford.