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TURFGRASS TRENDS

THE SCIENCE OF TURFGRASS

The Origin of Turfgrass

How grasses came to life — and still live

By Richard J. Hull

Turfgrass is an important part of the landscape throughout the world. Golf is a popular activity in tropical, semitropical and temperate regions. This is true because turfgrasses exist that are well-adapted to both hot and cold climates. But as every superintendent knows, no one grass performs well under both of these conditions.

Turfgrasses come in two flavors: cool-season grasses that grow well when temperatures are in the 65 to 75 degree Fahrenheit range, and warm-season grasses that grow best between 80 and 95 degrees F. Cool-season grasses can be killed by prolonged high temperatures, but they go dormant and survive when temperatures are well below freezing. By comparison, warm-season grasses go dormant when temperatures drop into the low 40s to 30-degree range but generally do not survive being frozen. In Southern states, green turf can be enjoyed during the winter months when dormant warm-season grasses are overseeded by cool-season grasses.

In the North, cool-season turf is green in winter only if grown on heated soil or if the dormant turf is painted green. Grasses seem unable to compete with crabgrass during July and August yet hold their own against these invaders during late spring and early fall. These observations are symptomatic of fundamental differences between cool- and warm-season grasses. What happens to cool-season turfgrasses when they become less vigorous during hot weather? Conversely, why do warm-season grasses appear to be indifferent to elevated temperatures but can't tolerate the cold?

Photosynthesis is the problem

When looking for the reason why the growth and survival of a grass responds to an environmental variable, in this case temperature, it is often useful to observe the impact of that variable on basic physiological processes. For a plant's growth and survival, there's nothing much more basic than photosynthesis. If you measure the rates of net photosynthesis (the rate of carbon dioxide (CO_2) fixation) as temperature increases, you will find the photosynthetic rate increases steadily for a warm-season grass until the temperature approaches or exceeds 100 degrees.

When you make the same observation using a cool-season grass, you'll observe an increase in CO_2 fixation as temperatures reach 70 degrees but a progressive decline in CO_2 fixation at higher temperatures. This means that at high temperatures, warm-season grasses have more energy and resources available to support their growth than cool-season grasses.

This doesn't fully explain the differences in heat tolerance among grasses but only suggests that photosynthetic CO_2 fixation may be the heat-sensitive process. To further understand why photosynthesis is inhibited by high temperatures in some plants, but not so inhibited in others, it may be useful to consider the findings of paleoecologists.

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The tees, fairways and greens of this Southern golf course are overseeded with a cool-season grass. Its warm-season bermudagrass borders are dormant and brown.

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Their research will take us to the origins of photosynthesis — back to the early Precambrian Era and the beginning of life, about 3.5 billion years ago when the Earth was only 1 billion years old.By that time, the earth had acquired much of its water, and life is thought to have evolved near thermal vents in the deepest parts of these primordial seas. Single-cell, bacteria-like organisms were likely the earliest life forms, deriving their energy to synthesize carbon compounds and reproduce by oxidizing reduced sulfur and other chemicals present in seawater. Their primitive respiration involved an electron flow based on oxidizing hydrogen sulfide (H_2S) and reducing nitrogen oxides, metals and what little oxygen might be present.

This occurred in the darkness of oceanic depths but apparently it didn't take long for sunlight at the ocean's surface to be used to drive the chemistry by which electrons from sulfur compounds reduce CO_2 to form carbohydrates (CH_2O) required by living cells.

For light to serve as a source of energy, a photon-capturing pigment was needed and chlorophyll evolved to serve that function. In time, the availability of reduced S-compounds became limiting and cells evolved the means to use water as the reductant (electron source) for reducing (fixing) CO_2.

A byproduct of this reaction was free oxygen (O_2) that initially was present in the atmosphere and oceans at very low concentrations but gradually increased as photosynthetic organisms (cyanobacteria) became abundant throughout the oceans. Over the following 2.5 billion years, the atmospheric O_2 concentration increased from only a trace (less than 1 percent) to near the present 21 percent. As O_2 became more abundant, it emerged as the dominant terminal electron acceptor (oxidant) for respiratory metabolism until virtually all plants and animals became dependent upon this gas (oxidative respiration).

The O_2 released into the oceans and atmosphere by microbial photosynthesis was initially consumed by the oxidation of metals dissolved in oceanic waters and exposed at the surface of rocks. As these metals became oxidized, O_2 accumulated in the atmosphere, where it reacted with hydrogen (H_2) that was formed when solar ultraviolet (UV) radiation was absorbed by water molecules splitting them to H_2 and O_2. Hydrogen, being extremely light, would be lost to space unless there was sufficient O_2 present for it to recombine and again form water. As atmospheric O_2 concentrations increased, ever more H_2 was recaptured, preventing the massive loss of water.

In addition, O_2 also interacted with UV radiation forming the triatomic molecule ozone (O_3) that accumulated in the upper atmosphere and effectively absorbed most UV radiation shielding the Earth's surface from its destructive effects. It was the formation of an O_3 layer that made the colonization of land by plants and animals possible. Because water absorbs the energy of UV radiation, it shielded life in the oceans, allowing marine life to evolve and flourish there long before an O_3 layer had formed. However, because the O_2 from which O_3 was produced is a product of photosynthesis, life has transformed the Earth.

In photosynthesis, light isn't used directly to reduce CO_2 and make simple sugars. Rather, high-energy intermediate compounds are formed through photochemical reactions and these energize and donate electrons to the carbon of CO_2 (four electrons per carbon). This reduction of CO_2 occurs in a complex biochemical pathway known as the Calvin Cycle, named after Melvin Calvin, who was awarded the 1961 Nobel Prize in chemistry. The primary step in the Calvin Cycle is the reaction that chemically binds CO_2 to the five-carbon sugar ribulose bisphosphate (RuBP). The catalyst for that reaction is an enzyme that bears the name ribulose bisphos-

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New turf varieties address many common turf issues, offering more resistance to disease, drought and pests. Bear in mind, the fundamental physiological needs of turf do not change dramatically, but it is important to recognize that species and varieties of turf require the need for best management practices for the selected species. Recognizing the limiting factor of turf, regardless of the varietal benefits, is essential in providing optimal growth and performance. Consistently maintained nutrition and environmental management is still the most important step in growing strong, healthy turf. Learn more at www.Floratine.com.

phate carboxylase/oxygenase — or RubisCO. The complete reaction involves the binding of CO_2 to RuBP (carboxylase), forming an unstable six-carbon intermediate that then splits to form two molecules of the three-carbon acid: phosphoglyceric acid.

The two three-carbon acids (PGA) pass through the Calvin Cycle, where the carbon from CO_2 is reduced to the level of a carbohydrate and a RuBP is regenerated to accept another CO_2 and keep the cycle going. Because the first chemical products of CO_2 fixation via the Calvin Cycle are two PGAs, this pathway is referred to as C-3 photosynthesis and plants that fix CO_2 in this way are C-3 plants.

When RubisCO emerged, there was very little O_2 in the atmosphere or in the seas. But as we outlined above, its concentration increased dramatically over the 2 billion years that followed. High O_2 levels represented a potential problem for RubisCO because the site on the enzyme that binds CO_2 will also bind O_2. When this occurs, the enzyme functions as an oxygenase and produces, from RuBP, one molecule each of PGA and a two-carbon acid phosphoglycolate. The PGA enters the Calvin Cycle but P-glycolate enters a different pathway that consumes an O_2 and liberates a CO_2, effectively nullifying any net CO_2 fixation. Because this pathway utilizes O_2, releases CO_2 and only occurs in the light, it is often called photorespiration.

RubisCO has a stronger affinity for CO_2 than it has for O_2 and as long as plant life was confined to the seas, it functioned efficiently. This is because seawater contains abundant carbonate and bicarbonate that are in equilibrium with dissolved CO_2. As CO_2 in sea water is consumed by photosynthesis, it's replaced by bicarbonate and carbonate so a constant supply of CO_2 is always maintained.

However, when plants colonized the land, their photosynthetic organs (stems and leaves) were no longer surrounded by water. Land plants had to obtain their CO_2 directly from the atmosphere. Initially this was not a problem because the Earth's atmosphere contained abundant CO_2. During the Cambrian biological explosion of 500 million years ago, atmospheric CO_2 concentrations averaged 0.5 percent or 5,000 parts per million (ppm). That's 14 times the 360 ppm CO_2 in today's atmosphere. With so much CO_2 available, the greater affinity of CO_2 over O_2 for the RubisCO binding sites insured that the enzyme's carboxylase function (CO_2 fixation) would dominate over its oxygenase activity (photorespiration).

As vascular plants spread over the continents during the Devonian and Carboniferous Periods and vast amounts of carbon as plant debris were buried in sediments, atmospheric CO_2 levels declined. By the beginning of the Permian Period (300 million years ago, CO_2 concentrations were less than 1000 ppm and, while they rebounded during the 200 million years that followed, CO_2 levels periodically dropped below the 300 ppm level during the Cenozoic Era (65 million years ago to the present).

When ambient CO_2 concentrations in the atmosphere are between 250 and 350 ppm, the concentration of CO_2 dissolved in the sap of photosynthetic leaf cells is less than 10 micromolar (less than 0.44 ppm). At that CO_2 concentration, the CO_2 fixing activity of RubisCO is less than 50 percent of its maximum rate and, as the temperature increases, the CO_2 levels drop even further (gasses are less soluble in water as its temperature increases). Thus, when leaf temperatures approach 90 to 95 degrees Fahrenheit, their photosynthetic rate is reduced by about 75 percent. Under these conditions, photosynthesis will barely equal respiration and a plant cannot survive that way for long.

If our story ended here, turfgrasses probably would be found only in the temperate zone where summer temperatures rarely exceed 90 degrees and then only for short intervals. No turfgrasses would survive in the warm humid or warm arid zones and only with difficulty in the transition zone. How the warm-season grasses solved the high temperature problem will be the subject of this story's continuation in a future issue.

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