A Seething Foundry; Energy Production and Utilization

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Perspective

The Golf Symposium held in November highlighted the lack of understanding of the causes and solutions to winter injury in the turfgrass research community. The multi-causal phenomenon involves all aspects of turfgrass physiology and metabolism, but most importantly it raises the question of how the turfgrass plant responds to environmental stress—in this case low-temperature and freezing.

Plant stress physiology has been an area of active research since scientific principles have been used in turfgrass research to elucidate specific responses to drought, disease, traffic, etc. We have learned that the healthy plant is more capable of withstanding stress. Yet, maintaining healthy plants remains a challenge. And maintaining healthy plants demands an understanding of how the plant produces energy and uses it for growth.

This spring my wife Barbara will begin her first semester as a Horticulture major at the UW-Madison. Barbara enjoys the beauty and the art of flowers, trees, shrubs, and grasses. She looks out over a landscape and sees a place of beautiful serenity. I view the same landscape and discern unceasing turmoil, as Daniel Hillel states in "Out of the Earth"—***a seething foundry*** *in which matter and energy are in constant flux.* Light hits the plants, heat is exchanged, water moves through pores and changes phases, and the leaves absorb CO_2 and synthesize it with other products to form the primary components of life. While the soil is the heart of the system, the plants (in our world, the turfgrasses) are the soul.

Energy Production

Cool-season grasses, like all other green plants, are capable of capturing energy from sunlight and combining it with Carbon (from CO_2), Hydrogen (from water) and Oxygen (from CO_2) to form an initial source of energy, a 3-carbon molecule (4-carbon in warm season grasses).Three carbon molecules then undergo conversion to a 6-carbon molecule—glucose or 5-carbon molecule—fructose.

Carbohydrates, such as glucose and fructose, can be utilized as basic structural components of the grass plant. Structures such as cell walls and membranes, xylem, phloem, etc. Also, photosynthetically derived carbohydrates are utilized by the plant to provide energy through respiration. These compounds are referred to as nonstructural carbohydrates or carbohydrate reserves. Respiration is the alteration of these reserves that releases energy to support growth. For example, stopping at the fuel pump and filling your car with fuel is comparable to the plant producing glucose and fructose through photosynthesis; the explosion that occurs in the engine, forces the piston, and ultimately moves the wheels is similar to the utilization of glucose and fructose during respiration. The result is the car moves, or in the case of plants, growth occurs.

Young turfgrass leaves produce energy in excess of their needs. This energy is immediately available for other plant parts, or can be stored for later use—similar to having a spare fuel tank for those long trips. Corn and potatoes store these reserves by building long chains of glucose molecules—starch. The cool-season grasses store their reserves as long chains of glucose and fructose molecules—fructans. These reserves are considered the energy currency (or fuel) of plant growth.

Energy Utilization

The elegance of our turfgrass energy system lies in its simplicity. Established turf utilizes most of the energy produced to generate leaves, tillers, and roots. Complex reproductive biology is virtually eliminated from the system, as a result of mowing, except for an occasional seed germinating. Interestingly,annual bluegrass management adds this dimension which subtly complicates the energy dynamics. Still, the elaborate responses to stress, interaction between plants and microorganisms, and water and nutrient acquisition and cycling, reveal the system's complexity.

Plant growth and maintenance are purchased with the energy of carbohydrates obtained from recent products of photosynthesis or from reserves. The amount of reserve is often used as an indicator of the health of the turfgrass plant. Energy accumulation is greatest during periods of high light intensities and minimal shoot growth—generally late summer-early fall. Energy utilization (depletion) is greatest during periods of rapid shoot growth—generally the mid-to-late spring. For example, our car engines get more miles to a gallon of fuel on a highway, leaving our reserve tank untouched (accumulation). However, stop and go around town depletes our fuel more quickly and, as a result, we draw on the reserve tank sooner (depletion).

Environmental and cultural factors (stress) conducive to high growth rates deplete energy reserves more rapidly. If reserve energy levels are allowed to deplete, plants are less likely to tolerate stress and recover from injury (disease), regardless of fertility or irrigation practices.

Summer on our putting greens provides one example of the impact of low energy reserves. Fertilized and irrigated greens actively producing shoots because of daily mowing, burn energy reserves rapidly through respiration. Similar to your car carrying a heavy load uphill. You must push the accelerator further down just to remain at constant speed. Also, your primary fuel tank is empty, now you are depleting your energy reserve.

For your grass plants this stress period burns all available energy, immediate and reserve, to replace leaves. Little energy remains for other plant parts, especially roots. We refer to this as sink priority. Leaves being the source of energy and sinks where energy is sent. Except, energy is in such high demand by leaves, and because their closest to the source, they take priority over other energy sinks, such as roots. Root growth virtually stops, and is possibly lost under these conditions. Taken with the fact that annual bluegrass already is stressed under typical summer growing conditions and it is easy to see our challenges. However, strictly from an energy perspective, in our car example, you can't push the accelerator any further, the car with (a heavy load) won't climb the hill, so you start to roll back down.

Low-Temperature Stress

In my symposium presentation I raised the importance of energy reserves, in the form of fructans, as an avenue of enhanced winter survival. As mentioned earlier, the plant experiences periods of high energy production and low energy utilization—notably late summer-early fall. For annual bluegrass, its biology as a winter annual suggests that it germinates from seed to overwinter in the vegetative state, resuming growth again in the early spring.

Increasing fructan levels has been shown with several crops to significantly enhance winter survival from freezing and low-temperature pathogens, such as the snow molds. However, there are several studies where there is no relationship between winter survival and fructan content. If new annual bluegrass plants are germinating, as indicated earlier, most of the energy produced might be going to create new leaves, not for storage. Additionally, many of us struggle deciding if we should manage the annual bluegrass or deter its growth. Existing plants, of the perennial type, possibly benefit from some type of fall fertility. To what extent is still not known.

Summary

The energy dynamics (production and utilization) must be understood if we ever become less reliant on energy intensive inputs such as synthetic fertilizers, water, and pesticides. Managing our "simple" closely-mowed turf system will continue to pose new challenges as consumer expectations continue to rise. Proper timing and amounts of fertilization and irrigation should be implemented to maximize energy production, always leaving some for a "rainy day".

Specifically regarding winter injury, we are beginning experiments to understand the relationship between reserves (fructans) and winter survival. We need to get more annual bluegrass from around the state to investigate any differential responses and compare them to creeping bentgrass. Also, possibly other grasses possess energy mechanisms for enhanced winter survival. I believe that understanding turfgrass energy relations is the heart of the soul of our seething foundry...