Understanding Turfgrass Roots — Part 2

While water uptake is critical, nutrient absorption, hormonal balance and proper treatment also play major roles in the health of turfgrass roots

By Richard J. Hull

Editors' note: In Turfgrass Trends for October, Dr. Hull presented Part 1 of his Back to Basics information on turfgrass roots, which discussed root development and function, growth patterns, root structure, system operation and water uptake. This article finishes his discussion.

Nutrient absorption

The routes described above for water uptake by roots are the ones that nutrient ions must also take. Since nutrients are dissolved in soil water, they are carried along with water into the apoplasm of plant roots. The apoplastic barriers created by the endodermis and exodermis also effectively block the radial transport of nutrient ions into the stele and throughout the plant.

Ions differ from water in that they carry a positive (cation) or negative (anion) charge and cannot cross the plasma membrane into the symplast via aquaporins.

However, they can cross the plasma membrane and become concentrated within the symplasm via specific transporters energized by electrochemical gradients created across the plasma membrane through the consumption of ATP.

The mechanisms of nutrient uptake by roots was described in an earlier article (Hull, 1995) and will not be repeated here. It is only important to know that nutrient uptake requires the use of metabolic energy by root cells and that nutrients do not enter roots passively along with water.

The membrane transporters that couple the expenditure of energy with nutrient ion uptake into root cells have a high affinity for nutrient ions and this permits the concentration of nutrients within the roots to attain levels much greater than that present in soil water.

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This mining the soil for essential nutrients constitutes one of the primary roles played by plants in the overall drama of life. All animal life depends on the minerals concentrated within plants for their source of such nutrients.

Nutrient ion absorption by roots is selective. Those ions essential for plant growth (potassium, nitrate, magnesium, sulfate, zinc, etc.) each enter root cells via their own membrane transporter.

Other less useful or even toxic ions (sodium, aluminum, selenium, etc.) are not accommodated by specific ion transporters and thus, do not enter roots readily.

Because some nutrient elements can be toxic at concentrations only slightly higher than what would be beneficial (boron, manganese, copper, etc.), their cellular levels must be tightly regulated. Specific ion transporters are responsible for maintaining optimum ion concentrations.

Nutrient ions absorbed into the proto-

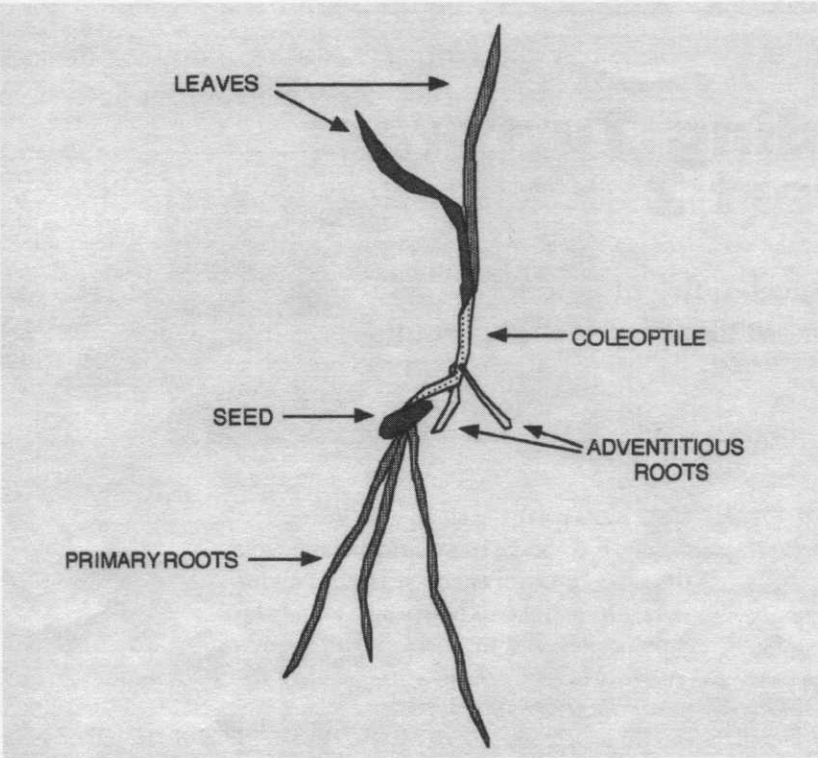

Fig. 1. Primary and adventitious roots developing from a turfgrass seedling.

plasts of epidermal and cortical cells can be transported via the symplast into cells of the stele by means of cytoplasmic streaming, diffusion and the flow of water through roots powered by transpiration.

Once in the stele, nutrients ions are again transported across cell membranes into the apoplast. Here they are carried to the shoots in large xylem vessels via transpirational flow eventually to be reabsorbed by living cells of stems and leaves.

Transpiration, of course, only occurs during the daylight hours so during the night, nutrient ions transported into xylem vessels of the roots are not carried to the shoots but rather become concentrated within the vessels.

This high solute concentration attracts water into xylem vessels creating substantial root pressure that sometimes causes guttation droplets to form on leaf tips visible during early morning. The suberized cell walls of the endodermis prevents ions and water concentrated in the xylem from back-flowing to the soil through the apoplast.

Thus, water and nutrients absorbed by roots are usually retained and loss to the soil normally occurs when cells die or sustain injury.

The energy required by roots is delivered from the leaves in the form of simple sugars (sucrose mostly) via interconnected living tube-like cells called sieve tubes. These, along with companion cells and other miscellaneous cells, make up the phloem that normally is located in the angles between xylem poles (Fig. 2).

Sugars released from the sieve tubes move via the symplasm to all living cells of the root. Releases of organic substances from root cells to the soil is normally a controlled process.

Mucilage is released by root cap cells for root lubrication and cells in the absorptive region of roots will excrete organic solutes during times of nutrient (especially phosphorus) deficiencies (Marschner, 1995).

The influence of morphological characteristics of turfgrass roots on nutrient uptake has received little attention. However, a recent study reported by our group (Sullivan et al., 2000) has demonstrated differences in the weight, length, surface area and diameter of roots (Fig. 4) among six cultivars of Kentucky bluegrass.

Below-ground organs were segregated into fine roots, adventitious roots and rhizomes (Fig. 5). Adventitious roots in this case, were those emerging from upper nodes of the crowns and plant stems and comprised only a small portion of the total root system all of which was technically adventitious, primary roots having been removed earlier.

These root characteristics were correlated with entire plant nitrate uptake. The six cultivars differed in their rates of nitrate uptake and these differences were positively influenced by weight, total length and

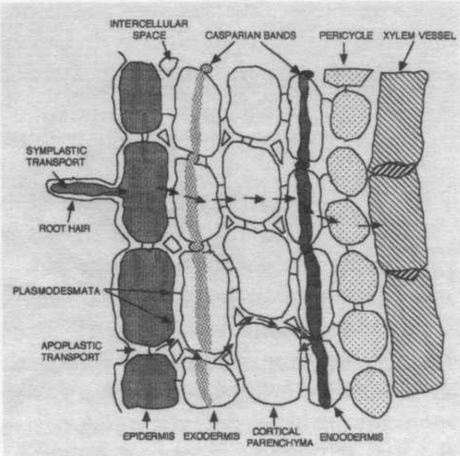

Fig. 3 Diagram of root (longitudinal view) showing apoplastic and symplastic transport routes.

surface area of fibrous and adventitious roots. Root diameter was negatively correlated with nitrate uptake indicating that total nutrient absorption was mostly a function of fine roots.

Of course in Kentucky bluegrasses, most of the root system is composed of fine roots. Nitrate absorption was negatively correlated with rhizome weight, length and surface area but the relationship was not simple. There appeared to be an optimum amount of rhizome production that resulted in the greatest nutrient uptake.

This is due to the increased number of new plants produced at rhizome nodes. These plants generate fibrous root systems that invade fresh soil and absorb nutrients.

However, excess rhizome growth constitutes a heavy demand for photosynthetic energy produced by the shoots and this energy is drawn away from root growth resulting in fewer roots and less nitrate uptake.

Thus, the finest turfgrass roots appear to be most responsible for nutrient recovery from the soil and rhizomes make a positive contribution only to the extent that they add to the number of functioning roots.

Hormonal balance

Beside their obvious roles in water and nutrient acquisition, roots also participate in the coordinated growth of plants and in their response to stress conditions. Roots and shoots mutually depend on the contributions of the other.

Roots cannot grow or function without the energy provided by the photosynthetic production of the shoots. Also, shoot growth is limited by the supply of nutrients and water provided by the roots.

It is important that the growth of roots and shoots be coordinated so that the growth of one is not always limited by the performance of the other. If plant growth were controlled by such a balance of limiting factors, one system, roots or shoots, would always be operating at full capacity while the other was limited by inadequate resources delivered to it.

This would make it difficult for the roots to grow and accumulate reserves if all their energy were being expended to supply water and nutrients to meet the demands of shoots. The same would hold for shoots if their productivity was devoted exclusively to meet the needs of roots.

To coordinate the activities of these two mutually dependent plant systems so each can grow and provide for its present and future needs, plants have evolved a hormonal control system.

The action of ABA allows a plant to conserve its resources during stress, making them available for growth to resume when conditions become favorable.

There are many hormones involved in growth coordination but for simplicity, I will concentrate on the two that appear to be most involved: cytokinins and abscisic acid (ABA).

Cytokinins are derivatives of the purine adenine and they promote cell division and thereby growth. Cytokinins are synthesized in the roots and are carried in the xylem to the shoots where they counteract the inhibiting effects of the hormone auxin. Auxin is made in the shoot apex and moves down the stem inhibiting the growth of axilary buds causing the phenomenon known as apical dominance.

Cytokinins block the inhibitory action of auxin allowing lateral buds to grow and produce branches.

Because cytokinins are derived from the roots, it is the basal shoot buds that are most stimulated to grow. This is why grass stems rarely branch and tillers and rhizomes or stolons emerge from the basal buds of the crown (Hull, 2000).

If root growth is inhibited by stressful soil conditions or roots are damaged by disease or insects, the supply of cytokinins to the shoot is interrupted and shoot growth is inhibited. This is why a stem cutting rarely exhibits any growth until it has initiated adventitious roots.

This control of shoot growth works in the plant's best interest. If roots are injured or inhibited, shoot growth ceases making its photosynthetic products available to regenerate roots and reestablish the supply of water and nutrients for the shoot.

If shoots continued to grow when roots were hurting, there would be little energy available to restore the roots, the shoots would eventually suffer from lack of water or nutrients and the plant likely would die.

Abscisic acid (ABA) is an inhibiting hormone. It normally retards growth, induces dormancy in buds, causes stomates to close and generally induces a plant to become inactive. ABA synthesis can occur in any plant organ and is often promoted by stress conditions.

The action of ABA allows a plant to conserve its resources during stress, making them available for growth to resume when conditions become favorable. The role of ABA in root function is well illustrated by the phenomenon of early drought response (Davies and Zhang, 1991).

When a plant begins to experience a lack of water this is first perceived by the shallow roots. These roots become stressed for water and begin to synthesize ABA which is transported to the shoots. This occurs before the shoots have suffered any loss of water potential since deeper roots are providing all the water required by the plant.

However, the delivery of ABA to the shoot causes stomates to close in the leaves dramatically reducing transpiration and slowing the rate of water loss. ABA also

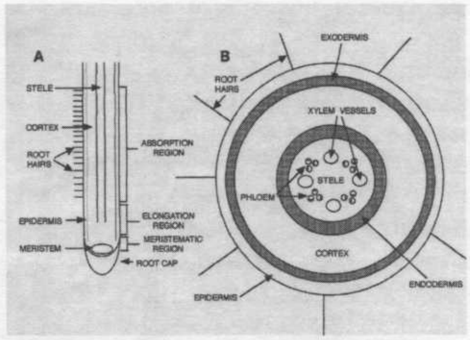

Fig. 2. Grass root structure.
A. Longitudinal diagram through a young root showing developmental regions.
B. Cross section of a grass root through the absorption (root hair) region showing tissue types.

inhibits shoot growth, greatly reducing the use of photosynthetic products by the shoot.

This makes more photosynthate available to support root growth which occurs not in the drought stressed shallow roots but rather the deep roots that have adequate water and can respond to additional supplies of energy.

In this way, the first roots to experience drought stress use ABA as a signal molecule informing the plant to reduce its water use and allocate more of its energy to growing deep roots. This permits plants to respond to drying conditions in a timely manner and alter their growth pattern so as to avoid general drought injury.

Understanding this plant response mechanism has permitted turf managers to schedule irrigation for optimum water use efficiency.

Getting optimum root growth from turfgrass

Understanding turfgrass roots, their structure and function, can constitute information useful to the turf manager for growing more vigorous and stress tolerant grass. It might be helpful to link management practices with the basic requirements for good root growth.

1. Roots need space. To respond to environmental signals and prepare for stressful conditions, a turfgrass root system needs a sufficiently large soil volume so it can adjust its growth pattern and better utilize available resources. Implicit with this requirement is a growing medium that is conducive to root growth. In short, it must be well aerated, of suitable structure, have the capacity to hold an abundance of available water and be lacking in toxic substances.

A reasonable cation exchange capacity to insure nutrient retention would also be good. Thus, a good blend of sand and silt along with 4-6% organic matter, a pH of 5.5 to 6.5 and favorable particle structure to permit gas exchange should be provided.

A well designed sand/peat green should supply these conditions but a growth medium based on native soil may need to be amended to become optimum.

The root zone must be sufficiently large to accommodate stress induced changes in root system architecture. The depth should be such (1 to 1.5 ft.) that drought stimulated downward root extension can occur. If these soil conditions change over time, management practices should insure they are brought back to optimum levels.

Aeration will help maintain good soil structure, insure good aeration and incorporate organic matter to greater depths. It might be good to remember that root turnover is the best source of soil organic matter.

Thus, conditions that favor deep root growth will also help maintain a favorable organic content and a suitable water holding capacity. Scheduling irrigation so as to permit turf to suffer mild drought stress before supplying water will encourage deep rooting.

2. *Roots need energy*. Roots are not photosynthetic. Therefore, they depend absolutely on photosynthetic energy captured by the shoots. It is good to consider that the amount of photosynthetic energy available to a plant depends on its leaf surface, the duration of light and, in cool-season grasses, the extent by which production is decreased by heat stimulated photorespiration.

Sound turf management should encourage photosynthetic production and minimize whatever detracts from it. Mowing at the greatest height consistent with the use requirements of turf is a good guide. Increased mowing height during the hottest summer months will partly compensate for increased photorespiration.

Selecting grasses with leaf angles that will retain more leaf surface even if subjected to close mowing will also help maintain favorable energy relations. Limit durations of deep shade. Cool shade is attractive and refreshing during hot summer days but turf needs light.

Long durations of full sunlight are not essential and may even be harmful if excess heating and drought occur. Thin trees to provide moderate or broken shade. This will help the trees and improve air circulation while insuring sufficient light energy for the turf.

3. *Roots compete for energy*. During the heat of summer, the turf manager should be aware that roots are not the only sink for the photosynthetic product of leaves. Actually, roots of cool-season turfgrasses are normally not very strong sinks during the hot months often receiving less than 5% of total photosynthate (Hull, 1996).

If shoot growth is stimulated during summer, the roots experience even greater competition for available energy and their growth decreases and mortality likely will increase. Nitrogen fertilization should be avoided during the hottest summer months. Its metabolism will consume energy and it will invariably stimulate shoot growth that will compete with roots for limited available energy.

If turf needs a green-up, try an iron application with a little nitrogen. That will stimulate chlorophyll synthesis and might even improve the plant's energy status.

4. *Heat is the enemy of roots*. Heat is especially hard on roots of cool-season turfgrasses (Huang, 2000). If soil temperatures exceed 70 -75° F, roots decline rapidly. This is probably due to less available energy translocated from the shoots but whatever the cause, root heating should be avoided.

Again, a higher mowing height will provide more turf mass to insulate the soil better. Irrigate during the evening or at night. That will cool the soil and allow time for energy transport to roots, slow root respiration and permit some recovery. Partial shade during the heat of afternoon will also reduce the heat load on turf.

Maintaining adequate water so transpiration can cool the grass is critical during the hot season. Equipping putting greens with forced internal ventilation has the potential of keeping turf roots several degrees cooler. Equipment designed to draw excess water through the turf by applying a subsurface vacuum can be useful for providing root system ventilation. With some modification, the system can be run in reverse and force cooled air up through the turf.

This technology offers considerable promise for easing the management of greens in hot locations. Less ambitious efforts involving the installation of fans can improve air circulation and this will increase transpiration and cool the grass.

There are many ways turf management practices can be modified to favor good root growth and reduce summer decline. If a manager understands the structure and function of the turf root system, many desirable cultural modifications that would encourage good root conditions will become evident. This article is submitted with that hope.

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BUILD EXPECTATIONS

By Curt Harler

The recent uproar over the "unexpectedly" high test scores since California banned bilingual education is not about speaking Spanish or Vietnamese in the classroom. The lesson here – and it applies to turfgrass managers and the rest of us -- is about expectations.

For those of you not familiar, in June 1998 California voters overwhelmingly passed Proposition 227 which banned bilingual education in the state's schools. Everyone from President Clinton to local school teachers predicted disaster for non-English speaking students.

The children surprised everyone. The opposite happened. Their math scores went up 14 points. Reading (in English) scores jumped nine points. What happened?

Two things were at work here. First, it seems that those in charge had very low expectations of a group of normal kids. We've all seen it happen – the guy who was always raking leaves in the background turns out to have unexpected talent as a mechanic. Or the quiet one who didn't say six words all summer turns out to be a whiz handling the job-scheduler on the computer. By next season he's in the front office working with PCs.

It's just a reminder that we should give everyone a chance to shine. There likely is hidden talent on your team. But it requires taking time to find out just what a person's aspirations are. Many workers, especially newer ones, are simply too shy to speak up. Seek all of your employees out informally, perhaps on a lunch break, and find out what their goals are. Some will have none. But others will surprise you.

The second factor at work is acceptance. No one – student, summer help, supervisor – likes to be branded as different. It is both distracting and humiliating. Whether in school or on the golf course, it interferes with getting the job done.

Expect the most from people. True, you'll occasionally be disappointed; but for the most part you'll be pleasantly surprised. And your workers will be delighted.

In Future Issues

- The value of clippings
- Primo update
- Surfactant applications
- Phosphorus runoff update
- Snow mold
- Grasses we love--Part 2