TURFAX™

of the International Sports Turf Institute, Inc.

Volume 10, No. 3

May-June 2002

The International Newsletter about Current Developments in Turfgrass

Understanding and Minimizing Drought Stress

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Drought is a period of dryness. Drought stress is a result of an extended time without precipitation, combined with the lack of an irrigation capability and a high evapotranspiration (ET) rate. The severity of soil drought is affected by the duration without rain, the evaporative power of the air, and the water retention characteristics of the soil. The frequency with which a soil drought occurs is greater in the arid and semi-arid climatic regions. Droughts are most likely to occur during the midsummer period, although the actual timing of occurrence and frequency are not predictable.

Drought resistance is a general term encompassing a range of mechanisms whereby plants withstand periods of dry weather. There are three primary components of drought resistance in turfgrass: (a) dehydration avoidance, (b) dehydration tolerance, and (c) escape

Dehydration avoidance is the ability of the plant to avoid tissue damaging water deficits even while growing in a drought environment favoring the development of water stress. In this case a positive water balance is maintained within the plant by excluding the water stress usually via enhanced rooting and/or a reduced evapotranspiration rate. **In contrast, dehydration tolerance is the ability of a plant to endure low tissue water deficits caused by drought**. In this case the plant possesses mechanisms to prevent or minimize tissue damage even though a negative tissue water balance exists. Drought escape involves the completion of an entire life cycle, or critical portions thereof, during drought-free periods in an otherwise drought-dominated environment.

The turfgrass manager has a number of options available to prepare a turf for drought stress. Included are:

- Select drought resistant species and cultivars.
- Optimize turfgrass dehydration tolerance.
- Maximize rainfall effectiveness.
- Maximize water absorption by roots.

Select Drought Resisant Species and Cultivars

Turfgrass species vary greatly in their relative resistance to drought stress (*Table 1*). If one knows prior to establishment that the turf area will not be irrigated or that the capability to irrigate will be limited, it usually is advisable to select drought resistant turfgrass species and cultivars.

Most C4, warm-season turfgrasses have considerably better drought resistance than for the C3, cool-season species. Note that species with a low shoot evapotranspiration rate and deep, extensive root system will have good dehydration avoidance which is a key component of drought resistance as it shortens the duration of internal tissue water deficits. There are significant differences in drought resistance among turfgrasses not only in shoot recovery but also in leaf firing. There is an opposite relationship between leaf firing and shoot recovery for each species and cultivar. This means that those turfgrasses which turn yellow or brown earlier tend to have poorer post-drought stress shoot recovery, in other words, poor drought resistance.

Studies of inherent dehydration tolerance have revealed surprising differentials among warm-season turfgrass species. Texas Common St. Augustinegrass, which ranks only good in both dehydration avoidance and drought resistance, had quite

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high dehydration tolerance. In contrast, bermudagrass which is superior in dehydration avoidance and drought resistance ranks significantly lower than St. Augustinegrass in dehydration tolerance. Similar mechanistic investigations need to be pursued with the cool-season turfgrasses.

There is a morphological component of dehydration tolerance as it relates to the water stress dormancy capability in perennial grasses. Bahiagrass has a very early, distinct dormancy capability. Also, perennial turfgrasses with secondary lateral stem development generally exhibit better drought resistance. **Of particular importance in dormancy survival are those species characterized by strong rhizome development.**

Table 1. The comparative drought resistance of the 35 turfgrasses**, when grown in their respective climatic regions of adaptation and their preferred cultural regime.

Relative Ranking	**Turfgrass Species**	
	Cool-season	**Warm-season**
superior		dactylon bermudagrass* (*Cynodon dactylon*) hybrid bermudagrass* (*Cynodon hybrid*) seashore paspalum (*Paspalum vaginatum*) American beachgrass (*Ammophilia breviligulata*)
excellent		kikuyugrass (*Pennisetum clandestinum*) zoysiagrasses (*Zoysia* spp.) American buffalograss (*Buchloe dactyloides*) bahiagrass (*Paspalum notatum*)
good	crested wheatgrass (*Agropyrum cristatum*)	blue gramagrass (*Bouteloua gracilis*) St. Augustinegrass* (*Stenotaphrum secundatum*) centipedegrass (*Eremochloa ophiuroides*) tropical carpetgrass (*Axonopus compressus*)
medium	tall fescue (*Festuca arundinacea*) crested dog's tailgrass (*Cynosarus cristatus*) Canada bluegrass (*Poa compressa*) wood bluegrass (*Poa nemoralis*) sheep fescue (*Festuca ovina*) crested hairgrass (*Koeleria cristata*) perennial ryegrass (*Lolium perenne*) Kentucky bluegrass (*Poa pratensis*)	common carpetgrass (*Axonopus fissifolius*)
fair	creeping bentgrass (*Agrostis stolonifera*) hard fescue (*Festuca trachyphylla*) Chewing's fescue (*Festuca rubra* var. *commutata*) creeping red fescues (*Festuca rubra*) redtop (*Agrostis gigantea*)	
poor	meadow fescue (*Festuca pratensis*) colonial bentgrass (*Agrostis capillaris*) turf timothygrass (*Phleum bertolonii*) creeping bluegrass (*Poa annua* var. *reptans*) annual bluegrass (*Poa annua* var. *annua*)	
very-poor	annual ryegrass (*Lolium multiflorum*) rough bluegrass (*Poa trivialis*) supina bluegrass (*Poa supina*)	

* Significant variability has been demonstrated among cultivars within the species.

** Based on the most widely used cultivars of each species.

Stomatal density has been shown to have minimal association with the evapotranspiration rate under well-watered conditions. **In contrast, the stomatal and epidermal resistances to evapotranspiration become more significant with the onset of significant internal plant water deficits. Key factors are the rates of stomatal closure and epidermal wax formation. In studies with warm-season turfgrasses, the bermudagrasses, bahiagrass, and zoysiagrass had the capability to close their stomata quite quickly upon the onset of a significant internal water deficit;** whereas the stomata of St. Augustinegrass, centipedegrass, and seashore paspalum remained open 3 to 4 times longer. In terms of cuticular resistance, certain perennial grass species, that normally have moderate wax formation possess the capability to form a substantial wax layer rather rapidly following the onset of tissue water deficits. **Bermudagrass exhibits extensive and rapid wax formation that covers the stomata.** In contrast, St. Augustinegrass, centipedegrass, and seashore paspalum have limited wax formation capabilities that do not extend over the stomata.

Turfgrass Cultivar Diversity in Drought Resistance. There also are significant differences in drought resistance among cultivars within certain species. For example, **Penncross is far more drought resistant than most other creeping bentgrass cultivars**. There are very significant variations among both St. Augustinegrass and bermudagrass cultivars. Most St. Augustinegrass cultivars have good drought resistance. However, **Floratam and Floralawn exhibit superior drought resistance. The bermudagrass cultivars have superior drought resistance, especially FloraTeX™, Ormond, Sonesta, Midiron, and Santa Ana.** Tifway and Tufcote have somewhat less drought resistance, but still are much better than the zoysiagrasses, American buffalograss, centipedegrass, and carpetgrass. Most zoysiagrass cultivars show similar comparative drought resistance.

Optimize Dehyderation Tolerance

The inherent internal physiological hardiness of turfgrasses to water stress may be affected by the cultural practices employed. **Slow growing tissues possessing a small cell size and a high carbohydrate content are more dehydration tolerant.** Thus, cultural practices that avoid excessive shoot growth stimulation will result in increased dehydration tolerance. Factors that enhance dehydration hardiness include:

- Moderate to low nitrogen nutritional rate.
- Adequate potassium level.
- Moderate to low intensity of irrigation.
- Full sunlight conditions.

The same cultural practices also maximize turfgrass hardiness to heat stress, which is frequently associated with summer drought stress. **Note that a brown, dormant turf possessing a healthy crown and/or lateral stem system is not dead.** Rather, such a turf possesses the recuperative potential to initiate new growth after the occurrence of the first significant rainfall. Dormant bermudagrasses and Kentucky bluegrasses are capable of initiating of full green turf in 14 days under favorable temperatures.

Maximize Rainfall Effectiveness

Typically, some rainfall occurs during the winter and spring period prior to the onset of a drought. Thus, it is important to maximize the amount of available water that enters the soil rather than being lost by surface runoff. **Turf cultivation, especially coring, may be utilized to enhance surface soil conditions that are receptive for maximum soil water infiltration and percolation.** Such an approach is particularly helpful on sloping areas where water loss by runoff is greatest. **Vertical french drains, 4 to 6 inches (100-200 mm) wide by 6 to 30 inches (150-740 mm) deep, that are filled with pea gravel (6.4-20.3 mm) are especially effective on slopes.** These techniques of water harvesting will become more important in the future.

Maximize Water Absorbtion by Roots

The maximum rooting depth and distribution, plus normal root hair development, will enable turfs to absorb moisture from a greater portion of the soil profile, thereby being more drought resistant due to the better dehydration avoidance. Thus, selecting deep rooted species and cultivars is important. Relative interspecies rooting comparisons during the midsummer heat-drought stress period are shown in *Table 2*. These rooting depths range from 8 feet (2.4 m) to as shallow as less than 12 inches (30 cm), with the latter depth being common for most cool-season turfgrasses. Note that bermudagrass can achieve rooting depths of up to 8 feet (2.4 cm) under mowed conditions. In contrast, zoysiagrass has more shallow rooting. Comparable intraspecies variations in rooting also occur within certain turfgrass species.

There are both environmental and cultural factors that can be manipulated to ensure as deep a root system as possible. The potentially unfavorable rooting conditions are summarized as follows:

Unfavorable Soil Environmental Factors:

- **Unfavorable Temperatures**-Root growth of cool-season turfgrasses is favored by soil temperatures of 50 to 60F (10-16C). Soil temperatures above 77F (25C) cause the cessation of root initiation from cool-season turfgrasses, plus the loss of existing roots by increased maturation or aging. In contrast, root growth of warm-season turfgrasses is favored by soil temperatures of 75 to 85F (24-30C).
- **Unfavorable Soil pH**-Root growth is seriously restricted and root functions limited at soil pH's below 5.6 and above 7.4. Chemical soil tests at 1- to 3-year intervals should be utilized to monitor the soil pH.
- **Soil Compaction**-Compaction problems are associated

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with an increased soil density which results in impaired soil, air, and water movement. Existing soil compaction problems can be partially alleviated by coring in multiple directions to a depth of at least 3 inches (7.6 cm).

- **Soil Waterlogging**-Waterlogging fills the soil pores with water which causes problems due to the elimination of adequate oxygen levels needed for root growth and general turfgrass health. Also, anaerobic conditions formed in waterlogged soils can produce gases and related compounds that are toxic to grass roots. One or a combination of conditions can produce a soil waterlogging problem, including: (a) improper surface drainage, (b) improper subsurface drainage, (c) excessive irrigation, (d) excessive rainfall, and/or (e) soil layering.
- **Hydrophobic Soils**-This problem involves an organic coating on the soil particles that causes them to repel water. It is particularly common on sandy soils and may be associated with soil fungi activity. It is best prevented or corrected by the application of an effective wetting agent, which should be watered-in immediately after application.
- **Saline and Sodic Soils**-High soil salinity levels cause a reduction in turfgrass rooting that is expressed through increased proneness to wilt. The development of a salinity problem is best prevented by applications of water at a rate greater than the evapotranspiration rate in order to leach the salts downward through the soil profile. Sodic soils are best corrected by the application of sulfur or gypsum, preferably by soil incorporation, followed by

Table 2. The comparative mid-summer rooting depths of 24 turfgrasses**, when grown in their respective climatic regions of adaptation and their preferred cultural regime.

	Turfgrass Species	
Relative Ranking	**Cool-season**	**Warm-season**
superior		bermudagrasses* (*Cynodon* spp.) kikuyugrass (*Pennisetum clandestinum*)
excellent		St. Augustinegrass (*Stenotaphrum secundatum*) seashore paspalum (*Paspalum vaginatum*)
good		bahiagrass (*Paspalum notatum*) crested wheatgrass (*Agropyrum cristatum*) zoysiagrasses (*Zoysia* spp.)
medium	tall fescue (*Festuca arundinacea*)	common carpetgrass (*Axonopus fissifolius*) centipedegrass (*Eremochloa ophiuroides*) American buffalograss (*Buchloe dactyloides*) tropical carpetgrass (*Axonopus compressus*)
fair	creeping bentgrass (*Agrostis stolonifera*) hard fescue (*Festuca trachyphylla*) blue fescue (*Festuca ovina* var. *glauca*) perennial ryegrass (*Lolium perenne*) sheep fescue (*Festuca ovina*) Chewing's fescue (*Festuca rubra* var. *commutata*) creeping red fescues (*Festuca rubra*)	
poor	Canada bluegrass (*Poa compressa*) Kentucky bluegrass (*Poa pratensis*)	
very-poor	wood bluegrass (*Poa nemoralis*) rough bluegrass (*Poa trivialis*) supina bluegrass (*Poa supina*) creeping bluegrass (*Poa annua* var. *reptans*) annual bluegrass (*Poa annua* var. *annua*)	

* Significant variability has been demonstrated among cultivars within the species.

** Based on the most widely used cultivars of each species

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JB Comments

Turfgrasses Versus Trees and Shrubs in Water Conserving Landscapes

There are certain adversary groups that continue to be active in promoting the reduction of turfgrass areas within urban landscapes and the replacement of the areas with trees and shrubs as a means of water conservation. **Statements have been published such as "all turfgrasses are higher water users than trees and shrubs." This is totally false.** Actually, the major grasslands of the world are located in the semi-arid climatic regions, whereas the major forests of the world are located in the high rainfall areas.

Just what is our current state of knowledge backed by sound scientific data concerning these issues of proper plant use for water conservation within the urban landscape?

- Very few of the many hundreds of tree and shrub species available have actually been quantitatively assessed for their water use rates.
- In contrast, a major portion of the turfgrass species have been assessed for water use rates.
- The few comparative water use studies that are available prove that the commonly used trees and shrubs are much higher water users than turfgrasses, especially when soil moisture is available. This is based on the sound scientific premise that the rate of water use increases with leaf area.
- Much confusion has arisen from the "low water use plant lists." It has been incorrectly assumed that those plants capable of surviving in arid regions are in fact low water users. However, the physiological mechanisms controlling the water use rate and drought resistance are entirely different, and are in no way directly correlated across plant species.
- For unirrigated sites, detailed studies have been conducted on drought resistance and dehydration avoidance of many turfgrass species and cultivars. Results have shown that a number of warm-season turfgrass cultivars can survive 158 days in a sand root zone without irrigation under the hot summer conditions in College Station, Texas.
- Comparative studies of drought resistance among tree and shrub species are lacking.
- It should be recognized that when turfed areas are irrigated the adjacent trees and shrubs also are being irrigated as a result of the multitude of shallow roots that concentrate under the irrigated area.
- There are numerous turfgrasses capable of ceasing growth, entering dormancy, and losing chlorophyll during summer drought stress, that readily recover once rainfall occurs. Why assume that turfgrasses must be green throughout the summer season? Many trees drop their leaves during drought stress, or during the winter period, with only brown bark remaining. What then is wrong with a tan to golden brown turf during droughts, if one chooses not to irrigate?
- There is no valid basis for water conservation legislation requiring the extensive use of trees and shrubs, in lieu of turfed areas. Rather the sound strategy based on good science is the use of appropriate low water use turfgrasses, trees, and shrubs for moderate to low irrigated landscapes and to select appropriate drought resistant turfgrasses, trees, and shrubs for nonirrigated areas.
- In most situations it is the "human" factor that wastes water through improper irrigation practices and landscape designs.

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downward leaching of the sodium after displacement from the clay particles.

- **Insect, Nematode, and Disease Injury**-There are pests which feed actively on grass root systems causing serious damage. White grubs can be particularly damaging. The appropriate pesticide should be applied to control the target pest when a serious problem starts to develop.
- **Toxic Herbicides**-A number of preemergent herbicides have a degree of toxicity to turfgrass roots. These effects may not be evident in terms of aboveground shoot growth under normal growing conditions; but can become quite striking during water stress periods when the lack of a root system restricts water absorption.

Unfavorable Cultural Factors:

- **Close Cutting Height**-As the cutting height is lowered, the depth and extent of rooting is restricted proportionally due to a decrease in leaf area available for photosynthesis.
- **Excessive Nitrogen Fertility**-Excessive nitrogen applications that force leaf growth cause the reserve carbohydrates to be drawn from the roots and may results in die-back of the root system of C3, cool-season turfgrasses. Thus, an individual nitrogen application should not exceed 1 lb N/1,000 sq. ft. (0.5 kg are^{-1}) as a water soluble carrier or its equivalent rate as a controlled-release carrier. High quality putting green turfs are maintained at a lower rate, usually not exceeding 0.3 lb N/1,000 sq. ft. (0.15 kg are^{-1}) of a water soluble nitrogen carrier or equivalent as a controller-release carrier.
- **Deficiencies of Potassium or Iron**-These two nutrients can have a striking effect in enhancing root growth and should be maintained at high available soil levels. Chemical soil tests conducted at 1- to 3-year intervals should be used to establish proper base levels of both nutrients. Also, additional potassium should be applied at a rate that is 50 to 75% of the nitrogen rate used.
- **Excessive Thatch Accumulation**-A thatch problem causes a high percentage of the roots to be concentrated in the thatch layer, thus limiting the zone from which water uptake occurs.