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IN THIS ISSUE

Understanding and Minimizing Drought Stress

James B Beard

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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Feature Article

Syringing and Hand Watering Greens in Summer for Drought, Disease and Hydrophobic Soils

Peter H. Dernoeden

Many regions of the United States are experiencing a severe drought. **Perhaps the only good attribute of dry weather is that disease pressure generally is less severe. This is particularly true for foliar diseases including brown patch (*Rhizoctonia solani*) and Pythium blight (*Pythium* spp.). Conversely, root diseases that are initiated in the autumn or spring when soil moisture is more plentiful (such as take-all [*Gaeumannomyces graminis* var. *avenae*]) become more destructive as rising temperatures coincide with dry conditions.** Similarly, **fairy rings and localized dry spots are more severe and destructive during hot and dry periods.** In the case of the latter two maladies, keeping soil moist is the most practical approach to reducing the potential for turf loss. Deep and infrequent irrigation is generally recommended for improving stress tolerance, to promote rooting, and for reducing potential algae, moss, black layer and many disease problems. Syringing and hand watering (also known as manual watering), however, are essential cultural practices for managing golf and bowling green areas prone to wilt as well as localized dry spots and fairy rings. Syringing and hand watering are very different practices and the nature of these differences will now be discussed.

Syringing. Turf under drought stress develops a bluish-purple color and is subjected to foot printing. This common stress of greens is alleviated during daytime hours by syringing. **The purpose of syringing is to alleviate wilt and or/ high temperature stress without creating or exacerbating an existing wet soil or thatch condition on hot summer days.** Greens are most often syringed to alleviate wilt rather than to abate high temperature stress in the canopy. Syringing involves applying a thin film of water on leaves without delivering so much water that the underlying thatch, mat and soil become wet. The evaporation of water cools leaves, allowing stomates (i.e., pores on the leaf surface) to open. Assuming adequate soil moisture, the opening of stomates induces the natural movement of water from soil into roots, through the plant via the transpiration stream, and water vapor emerges from stomates thereby cooling the plant. The wilting of turf in the presence of adequate soil moisture is referred to as "wet wilt" and generally occurs on windy days when relative humidity is low. In drier soils, syringing allows turf to survive that day or until morning when appropriate (i.e, deep) irrigation programs can be scheduled. **During periods of high temperature and low relative humidity, and particularly on windy days, syringing may be required three or more times daily.** The critical periods generally are between 11 a.m. (11:00 hours) and 4 p.m.(16:00 hours). Syringing, however, is less effective during periods of high humidity when water cannot evaporate. Regardless, it is prudent to lightly syringe wilting greens during periods of high humidity. Greens, however, should not be syringed repeatedly until all of the water has evaporated and the leaves are dry. **Syringing is best performed by hand, however, if this is impractical the overhead irrigation system can be used.** Generally, a full rotation of the irrigation heads (1-2 minutes) is enough to supply a light film of water to the canopy. For hand syringing, the nozzle should be kept horizontal (i.e., not directed downward) and the operation should take less than three minutes to cover an average sized green. In many situations it only may be necessary to syringe localized wilted areas (i.e., "hot spots") rather than the entire surface of greens. It is important not to wet the thatch, mat, and underlying soil during periods of high temperature stress. Excessive water in the thatch, mat, and soil on hot and sunny days can lead to supraoptimal (i.e., high) temperature stress around stems and roots, which may cause yellowing, loss of vigor, and possibly scald.

Hand Watering. The advantage of hand watering is that it allows the manager to place water where it is needed without overwatering areas that contain sufficient soil moisture. Hand watering involves applying enough water to re-wet dry soil areas to root zone depth. These areas normally occur in chronic "hot spots" such as mounds, high spots, south facing slopes, or in collars at the interface between the sand rootzone and adjacent native soil. This is normally accomplished by applying light and frequent applications of water. **Water is applied using a shower-head nozzle in a back-and-forth pattern until the turf surface begins to appear "glassy".** It is important not to "fire hose" the area causing water to run-off and puddle in low areas. Once an area has become glassy, the applicator should move onto another area of the green to allow water in the glassy areas to completely penetrate the turf canopy. Applying repeated, small amounts of water will eventually provide sufficient hydraulic head to move water out of the thatch and into the underlying soil. **Do not just wet the thatch, but instead probe the soil frequently to ensure that the rootzone also becomes sufficiently hydrated.** By just wetting the thatch, the turf becomes prone to scalping and creates an environment that promotes supraoptimal heating, algae, moss, disease, and other problems. The ability of a given rootzone soil to be wetted will depend on its physical properties (i.e., texture, compaction, infiltration and percolation rates, and organic matter levels). Turf grown on sand-based rootzones generally requires more frequent hand watering than native soil (i.e., push-up). It is best to hand water in the evening as air temperature are falling, however, this may be impractical. The next best time for hand watering is early in the morning prior to mowing so that excess water has time to drain before the heat-of-the-day.

Where soils are rendered hydrophobic by fairy rings and localized dry spots, the affected areas will require spiking to create openings for water to move into the soil. For localized

Feature Article

Drought and Climate Change Accentuate Insect Problems in Irrigated Turf

Daniel A. Potter

Drought conditions were especially severe during the first half of 2002 along the entire Atlantic coast from Florida north to Maine, from the Gulf states across Texas, and in the Plains, Southwest, and Rocky Mountain states. Non-irrigated lawns, golf roughs, and surrounding fields and pastures have been brown or dormant for much of the summer. **Such conditions often magnify insect problems on irrigated lawns and golf courses.** Winged adults of many pest insects concentrate their egg-laying in moist areas. Some, especially ones with mobile immature stages (e.g., armyworms, mole crickets), may emigrate from dry border areas to feed on lush turf.

Soil moisture is the most important factor determining the distribution and abundance of turf insects. Consider white grubs, the larvae of masked chafers, Japanese beetles, European chafer, black turfgrass ataenius, and other species. All of these beetles lay eggs in moist soil, typically 1 to 2 in. deep (2.5–5 cm) under turf. Small and oval when first laid, the eggs swell by absorbing water from surrounding soil, hatching in 2 to 3 weeks. Eggs won't survive if soil moisture is below about 10%. The tiny, newly-hatched grubs also are unlikely to survive in very dry soils.

Not surprisingly, adult behavior is affected by rainfall and irrigation. If drought occurs during the weeks before adults normally appear, the newly-mature beetles may remain underground until rain softens the ground. The first heavy downpour triggers intense flight, mating, and egg-laying activity. **Some species (e.g., Japanese beetle) may fly a half mile (0.8 km) or more in search of suitable egg-laying sites. My research has shown that egg-laden females are attracted to irrigated lawns and golf turf, particularly when surrounding areas are dry.** I have seen 6-fold increases in grub densities in irrigated lawns compared to adjacent dormant ones. On golf courses where fairways and tees are protected by preventive insecticides, this often translates into the highest grub densities being in moist green and tee banks, and irrigated rough. Mole crickets display similar behavior on southern golf courses, seeking more moist turf areas when overall conditions are dry.

Drought also tends to concentrate surface-feeding pests in irrigated turf. In Kentucky, drought-related watering restrictions in recent summers were followed by increased damage to fairways and putting greens from the bluegrass webworm (*Parapediasia teterella*), a ubiquitous species that normally is more abundant in higher-mowed lawns and roughs. Like most turf caterpillars, it completes several generations per growing season. By late summer, non-irrigated roughs and nearby residential turf had become so dry that they were unsuitable as larval food, and the moths focused their egg-laying on whatever green turf they could find. Larval populations became increasingly concentrated on fairways, tees, and putting greens. Cutworms probably behave similarly.

Recent plague-like outbreaks of armyworms (*Pseudaletia unipuncta*) on cool-season lawns, golf courses, and athletic fields also seem to be climate-related. **Armyworms normally favor corn and small grains, but larvae may migrate *en masse* from parched pastures or agricultural fields into adjacent moist turf.** Annual infestations originate from moths that are carried north on frontal systems and deposited in downdrafts associated with storms. **In 1999–2001, armyworm arrivals coincided with severe spring droughts affecting portions of the Midwest and Northeast. Corn had not yet germinated because the soils were so dry. The moths evidently sought an alternative for egg-laying, and the resulting larval populations wreaked havoc on turf.**

Drought can aggravate outbreaks of some pests by suppressing naturally-occurring insect pathogens, especially nematodes and fungi. Hairy chinch bugs, for example, thrive in hot dry conditions, whereas a lethal fungus, *Beauveria*, often suppresses their populations when rainfall is abundant. **Drought-stressed turf is less able to tolerate and recover from damage from root-feeders or other insects.**

Insects are cold-blooded so their growth rate is temperature-dependent. **Inordinately warm weather may allow pests with multiple broods (e.g., turf caterpillars, chinch bugs, ants) to complete extra generation(s) and reach higher densities by the end of a growing season.** A prolonged autumn allows grubs to feed and grow longer before hibernating, likely enhancing their overwintering survival.

Turf managers should keep an especially close watch on irrigated areas, where insect pests tend to concentrate, when surrounding non-irrigated areas become very dry.

Syringing and Hand Watering Greens

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dry spots, most water repellency occurs in the top 1 to 2 inches (2.5-5.0 cm) of soil, but the problem can be as deep as 6 inches (15 cm) (Karnok and Tucker, 2002). Hence, **wetting agents often are required to assist with water penetration through the hydrophobic zone of repellency. The same is true for alleviating drought damage caused by fairy rings.** Powered water injection devices also are useful for wetting hydrophobic soils. For more information on managing localized dry spots and fairy rings see **TurFax** articles published in 1999 and 2002, respectively.

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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.

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Research Summary

Competitive Ability of Creeping Bentgrass Cultivars Against Annual Bluegrass

This investigation assessed the relative competitive ability of 6 and 7-old turfs of thirteen creeping bentgrass (*Agrostis stoloniferous*) cultivars to annual bluegrass (*Poa annua*) under a closely mowed putting green cultural regime of 1/8 inch (3.2 mm). Competitive ability was assessed by transplanting 108 mm diameter, mature turf monostands of annual bluegrass into the creeping bentgrass turfs. The relative competitive ability of the 13 cultivars segregated into four distinct groups. **Ranking best was Penn G-2 with no lateral annual bluegrass invasion during a full growing season in each of two years. In the second grouping, in order from lowest to highest were Penn G-6, Seaside II and Penn A-1, ranging from 3.9 to 8.7% annual bluegrass.** In the third group were Southshore, Penn G-1, SR 1020, Putter, Cobra, and Penneagle ranging from 20.1 to 36% annual bluegrass. The largest annual bluegrass lateral encroachment occurred in Providence, PennLinks and Penncross ranging from 37.3 to 58.4%. **Basically those creeping bentgrass cultivars with shoot densities above 2,000 per square decimeter usually exhibited the most vegetative competitiveness in suppressing the lateral invasion of annual bluegrass in mature polystands.**

Comments. More recently Dr. Karl Danneberger reported similar creeping bentgrass cultivar rankings in an Ohio study. These findings suggest that significant cultural control of annual bluegrass can be accomplished on closely mowed putting greens by the selection of certain creeping bentgrass cultivars that can sustain very high shoot densities under extraordinarily close mowing regimes.

Source. The Comparative Competitive Ability to Thirteen *Agrostis stolonifera* Cultivars to *Poa annua*. by J.B Beard, P. Croce, M. Mocioni, A. De Luca, and M. Volterrani. International Turfgrass Society Research Journal 9:828-831. 2001.

Ask Dr. Beard

Q. *Am faced with a strong possibility that there will not be sufficient water to irrigate the fairways and roughs this summer. Would an application of gibberellin prove beneficial?*

A. The answer is no. In fact, it would prove negative. The primary shoot response to a gibberellin application is increased vertical leaf growth which results in greater leaf area and a higher evapotranspiration rate. In addition, there typically is a reduction in shoot density which will cause a decrease in the resistance to outward water vapor diffusion that also will increase the evapotranspiration rate. Finally, a gibberellin application typically will result in reduced root growth, which means a more limited capability to absorb water from a large portion of the soil profile. Actually, an application of a plant growth regulator effective in reducing the vertical leaf extension rate of grasses will lower the leaf area available for evapotranspiration and thus would be beneficial in terms of water conservation. Investigations have shown that flurprimidol can reduce the water use requirement in the order of 10 to 30%, depending on the turfgrass species.

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