Volume 10, Number 1

TURFAX™

January–February 2002

of the International Sports Turf Institute, Inc.

The International Newsletter about Current Developments in Turfgrass

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Turfgrass Shade Adaptation

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The sun is the energy source that supports life on earth, including turfgrasses. The radiant energy is converted to chemical energy in green plants by photosynthesis. In the case of mowed turfgrasses, they are capable of absorbing and converting to chemical energy only 1 to 2% of the total incident solar radiation. Thus, a major portion of the incident radiant energy is absorbed and reradiated at longer wavelengths with the release of heat.

Shade. Studies in a number of states reveal that home owners rank shade as the number one problem in growing turfgrasses. It is estimated that between 20 and 25% of the lawn turfs in the United States are grown under some degree of tree or structural shade stress. Obviously, the problem becomes more severe in older residential areas as the trees grow and mature. Another shade stress aspect is an increase in the construction of tall, erect stadia and partially-roofed, fully-roofed, or retractable-roofed stadia, where turfgrasses are to be propagated.

Radiation Assessment. In the past, light intensity has been used when referring to plant requirements. However, **the more appropriate terminology for the receipt of radiation on the surface of the turfgrass canopy is irradiance,** which is defined as the radiant flux density or energy received on a specified surface and expressed in energy units of watts per square meter (Wm^{-2}). **A preferred, more specific term is photosynthetically active radiation (PAR),** which is the radiation in the photosynthetically active portion of the spectrum, from 400 to 700 mm. A typical PAR under direct sunlight is 400 Wm^{-2}.

Unfortunately, many architects involved in the construction of stadia where shade is a concern in turfgrass propagation fail to use the proper energy terms and measurements. They tend to use **illuminance,** which is the luminance flux per unit area on an intercepting surface at a given point. It is typically used in relation to quantifying lighting requirements for human activities, such as for recreational and sporting facilities, and especially where the event is televised. The standard unit of illumination flux is the **lumen.** To reemphasize, **it is incorrect to use illuminance in assessing the radiation energy requirements of turfgrasses in shaded environments.**

SHADE MICROENVIRONMENT

Shade alters the microenvironment in which turfgrasses must grow. **The most obvious change is a reduction in irradiance. However, a number of other important microenvironmental factors must also be considered in turfgrass shade ecology.** One of the few published comparative quantitative characterizations of the altered turf-level microenvironment under a tree monostand is shown in Table 1.

In addition to the direct blockage of incident solar radiation by the above tree canopy, there is also the reduction in radiant energy caused by **an alteration in light quality.** In the case of tree shade, there is selective screening of the blue and red wavelengths, with a higher per-

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centage of green wavelengths being reflected resulting in the visual perception by the eye of a green color.

There is typically **a restriction in wind movement** under a canopy of trees, especially if surrounded by a barrier of shrubs or other low-growing woody vegetation. A lack of air movement results in a stratification of higher temperatures and humidities adjacent to the turf canopy, thereby resulting in a more favorable microenvironment for certain disease-causing fungal pathogens.

Typically, the microenvironment under tree shade is characterized as having an **increased relative humidity,** especially adjacent to the turfgrass canopy. This results in a much more favorable microenvironment for fungal pathogen activity that causes increased disease problems.

Two positive dimensions of microenvironment alteration under tree shade include a **moderation in extremes of both diurnal and seasonal temperatures.** In addition, there may be **an increased carbon dioxide level.**

Finally, trees have a significant **negative impact due to root competition for water and nutrients from the soil.**

TURFGRASS RESPONSES TO SHADE

A low irradiance weakens the turfgrass due to reduced photosynthesis and carbohydrate reserves, and causes a decrease in the shoot density. A complete loss of turf occurs if the reduction in radiant energy is severe enough. However, the irradiance is sufficiently above the compensation point in many shade situations to permit maintenance of an acceptable turf. Several hours of full sunlight plus the diffuse radiation from leaf reflection and transmission are usually adequate for turfgrass growth under properly maintained individual trees. When trees are grouped, the resulting dense canopy is more likely to limit turfgrass quality and to increase the problems of turfgrass culture.

The more favorable microclimate for disease development and the lack of disease-resistant cultivars are key factors limiting the shade adaptation of certain cool-season turfgrass species. Pathogen activity in the shade is enhanced by longer dew persistence, higher atmospheric relative humidity, reduced wind movement, altered light quality, low evapotranspiration rate, and more succulent plant tissue. Adequate disease resistance is an important factor in the development of shade-adapted cool-season turfgrasses. Similar disease problems have also been observed with certain warm-season turfgrass species grown under shade. However, the disease problem is not nearly as critical as with the cool-season turfgrasses. **Adverse morphological responses under a shady environment are key factors in poor shade adaptation of certain warm-season turfgrasses.**

The ability to overcome disease problems contributes significantly to shade adaptation. Other factors that may contribute to shade adaptation of certain turfgrass species are: (a) a lower compensation point, respiration rate, and/or carbohydrate requirement, (b) lower nutrient and/or water requirements, (c) greater competitive ability for radiant energy and/or nutrients, and (d) a lower radiant energy requirement. The relative importance of these four dimensions has not been determined for most turfgrass species. **The survival of seedlings at low irradiance is greater in species, such as red fescue, that have an inherently slow rate of biomass accumulation. Also, the growth of red fescue is not influenced as much by reduced irradiance as for some other turfgrass species.** Plants grown at low irradiance have a lower compensation point and become light saturated at considerably lower irradiance than when grown in full sunlight. Evidently the photosynthetic apparatus of certain low-irradiance toler-

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Table 1. Comparisons of the microenvironments of an unirrigated creeping red fescue turf in full sunlight and intense tree shade at East Lansing, Michigan, on a mid-August day.

Environmental Factor	Sunlight	Shade*
irradiance at 12 noon (Wm^{-2}/cal cm^{-2} min^{-1})	1,117/1.6	104/0.15
total daily incident radiation (Wm^{-2}/cal cm^{-2} min^{-1})	460,000/659	26,500/38
average air temperature at 1 inch/25 mm (°F/°C)	74/23	62/17
average soil temperature at 6 inch/150 mm (°F/°C)	72/22	60/16
maximum air temperature at 1 inch/25 mm (°F/°C)	96/36	73/23
minimum air temperature at 1 inch/25 mm (°F/°C)	52/11	53/12
wind velocity at 2 inches/50 mm (mph/kmph)	4.0/2.5	0.0/0.0
relative humidity at 2 inch/50 mm (%)	45	68
atmospheric carbon dioxide at 1 inch/25 mm, 12 noon (ppm)	276	305
duration of dew persistence (hrs.)	0	12.5

* A stand of mature sugar maple (*Acer saccharum*) trees surrounded by a dense shrub barrier.

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ant turfgrasses can adjust more readily to a low irradiance so the available radiant energy is utilized more efficiently.

In certain climates, shading affords a more favorable microenvironment in which turfgrass species may persist. For example, Kentucky bluegrass grows and may persist under the shade in the cooler portions of warm-semiarid climates, but not in full sunlight. This is contrasted to the cooler climates where zoysiagrass grows in full sunlight, but not in shaded sites. The lower temperatures of shaded sites can favor or impair the adaptation of turfgrass species, depending on the temperature optimum of the species and the dominant climate of a region. A delay in low-temperature discoloration of warm-season turfgrasses typically occurs under a tree canopy due to the moderation of low temperatures and reduced irradiance that lowers the photo degradation of chlorophyll.

Tree shade creates a stressful environment for most turfgrasses in terms of growth, morphological, and anatomical responses. One of the more obvious effects results from the reduced irradiance levels in the shade. However, this component is not necessarily the primary limiting factor in shade adaptation of turfgrasses. Most likely, those turfgrass genotypes with the best shade adaptation will possess a combination of favorable physiological, morphological, and pathological resistance characteristics.

Cool-Season Turfgrasses. In terms of interspecies comparisons of shade adaptation of four major C_3, cool-season, perennial turfgrasses, it was found that disease was the principal limiting factor rather than a lack of irradiance. Kentucky bluegrass (*Poa pratensis*) is severely thinned by bipolaris leaf spot (*Bipolaris sorokiniana*), perennial ryegrass (*Lolium perenne*) is severely thinned by Helminthosporium diseases and snow molds, tall fescue (*Festuca arundinacea*) is severely thinned by typhula blights (*Typhula* species), and rough bluegrass (*Poa trivialis*) is severely thinned by take-all patch (*Gaeumannomyces* spp.) and bipolaris leaf spot. The only turfgrass species that sustained a reasonable turf cover in the shade environment was red fescue (*Festuca rubra*). Also, **a polystand of one or two turfgrass species with red fescue reduces the severity of disease on any one species in the polystand.** Subsequent research revealed that 18 Kentucky bluegrass cultivars, which exhibited no symptoms of bipolaris leaf spot (*Bipolaris sorokiniana*) and powdery mildew (*Erysiphe graminis*) injury in nearby full sunlight plots, were severely injured by these pathogens when grown under a tree shade environment. Similar responses to brown patch (*Rhizoctonia solani*) were found on 10 tall fescue cultivars.

Warm-Season Turfgrasses. A key limiting factor in sustaining adequate turf vegetation in the shade for a number of C_4, warm-season, perennial turfgrass species with an indeterminate growth characteristic is a morphological limitation. **Specifically, the initiation and/or growth of lateral stems is greatly restricted by the low irradiance.** In the case of the St. Augustinegrass (*Stenotaphrum secundatum*) cultivar Floratam, all lateral stem initiation ceases when placed in a shaded environment. Investigations with four bermudagrass (*Cynodon* spp.) genotypes revealed a drastic reduction in shoot density and restrictions in lateral stem development, but increased internode length. **The elongated lateral stems tended to grow more upright, and consequently were removed during the mowing process.** The

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Table 2. Comparative shade adaptation of 30* turfgrasses in their respective regions of adaptation.

Relative Comparison	Turfgrass	Relative Comparison	Turfgrass
excellent	fine-leaf fescues	medium	redtop
	wood bluegrass		meadow fescue
	St. Augustinegrass*		Canada bluegrass
	rough bluegrass		centipedegrass
	kikuyugrass		tropical carpetgrass
	creeping bluegrass		crested dog's-tailgrass*
	supina bluegrass	poor	common carpetgrass
good	tufted hairgrass		perennial ryegrass*
	annual bluegrass		seashore paspalum*
	creeping bentgrass		bahiagrass
	tall fescue	very-poor	annual ryegrass
	crested hairgrass		Kentucky bluegrass*
	colonial bentgrass		bermudagrasses*
	manila zoysiagrass		American buffalograss
	Japanese zoysiagrass		
	mascarene zoysiagrass		

* Varies among certain cultivars.

JB Comments

All-Encompassing "Ultradwarf" Terminology Confusing

There are a number of turfgrass specialists grouping the newer high-density hybrid bermudagrass (*Cynodon dactylon* x *C. transvaalensis*) cultivars that are tolerant of very-close mowing heights on putting greens as "ultradwarfs." Included in this grouping are Champion, FloraDwarf, MiniVerde, MS Supreme, and TifEagle. **In utilizing the "ultradwarf" terminology they also assume the five cultivars have similar growth habits and cultural requirements. Unfortunately, this is not the case and is leading to problems.** A more correct terminology would be **ultradense.**

In terms of growth habit, certain of these ultradense cultivars are full dwarfs, while others are vertical-dwarfs with normal to accelerated lateral stem development. An example of the former is FloraDwarf, while Champion and MS Supreme are examples of the latter vertical-dwarf characteristics. The reason that the type of growth habit needs to be described and understood is that it can strongly affect the cultural practices to be used.

In terms of specific cultural requirements the research information is limited at this point in time. **There is evidence that among these five ultradense cultivars the nitrogen requirement can range between 0.3 to 0.5 lb N/1,000 ft^2 (0.15–0.25 kg N/100 m^{-2}) per growing month, to as high as 2 lb N/1,000 ft^2 (1 kg N/100 m^{-2}) per growth month.** Obviously, a cultivar having a nitrogen requirement in the lower range will tend to develop a serious biomass/thatch problem if fertilized in the higher nitrogen range, whereas a cultivar requiring the high nitrogen level will perform unacceptably if fertilized in the lower nitrogen range.

There also is research indicating that certain of these five ultradense cultivars vary in their response to lowering of the cutting height from 0.2 to 0.1 or 3/16 to 1/10 inch (4.8 to 2.5 mm). There is an increased density for certain of these cultivars, while certain others will start to thin at cutting heights of 1/8 inch (3.2 mm) and below.

The same principles apply to the newer high-density creeping bentgrass (*Agrostis stolonifera*) cultivars that tolerate very-close mowing.

In summary, it is important to recognize that each of the ultradense cultivars has specific cultural requirements to maximize their performance. Thus, it is important to obtain clear information in writing from the developer/marketer of each individual cultivar as to the cultural requirements they recommend.

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better shade adaptation of FB 137 bermudagrass was associated with a very short internode length, which facilitated a better sustainable shoot density under shade stress.

TURFGRASS SPECIES SHADE ADAPTATION

Turfgrass shade adaptation is the relative ability of a turfgrass to persist and grow under a multiplicity of shade-related stresses. It does not involve a single factor, but a rather complex microenvironmental regime. The comparative shade adaptation of turfgrasses in their respective climatic adaptation regimes and optimum cultural practices are summarized in Table 2. There may also be variations in shade adaptation among cultivars within certain species.

Cool-Season Turfgrasses. The **fine-leaf fescues** (*Festuca* spp.) continue to be the preferred species for shaded environments in cool climates. **Rough bluegrass** is adapted to cool, wet shaded environments. The **bentgrasses** (*Agrostis* spp.) are satisfactory, especially if a preventive fungicide program is followed and the soil is moist. **Tall fescue** is adapted to shade in the warmer portions of cool-humid climates where freeze stress kill is not a problem.

Warm-Season Turfgrasses. The shade adaptation of **St. Augustinegrass** is excellent in warm climates, except for the Floratam cultivar, as is kikuyugrass (*Pennisetum clandestinum*). The zoysiagrasses (*Zoysia* spp.) have good shade adaptation, while the bermudagrasses have very-poor shade adaptation. Only a few bermudagrass cultivars, such as MS-Choice, show promise for use in shaded environments.

Root Zone Aspects. The comparative role of the root system in the competitive adaptation of various turfgrass species to tree roots has received little attention. One *in vitro* study has been published in which **tree roots significantly reduced the shoot growth of four cool-season turfgrass species even when water and nutrients were maintained at optimum levels.** It also was found that **Kentucky bluegrass was more severely affected by competition from tree roots than red fescue, rough bluegrass, and perennial ryegrass.**