Understanding, Assessing, and Managing Shade Stress Problems

John Sorochan
University of Tennessee
sorochan@utk.edu

Turfgrass & Shade

Light

Light Components

What is PAR?

Light = Photosynthetically Active Radiation

PAR = Photosynthetically Active Radiation

CO₂ + H₂O → (CH₂O)ₙ + O₂ + H₂O

Photosynthesis

Light Energy

• Light quality
  - Wavelengths (measured in nanometers, nm)
  - Go from very short (cosmic or x rays) to long (radio waves)
  - Visible light from 380 to 700 nm (PAR within)

• Light quantity
  - Particles (photons) - Energy
  - Most important in photosynthesis
  - The shorter the wavelength, the more energy
Action Spectrum of Photosynthesis

Light Spectrum

- < 380 nm; can cause mutations, used by breeders
- 380 – 700 nm visible light used for Pn
  - Violet and blue; short sturdy growth
  - Green; reflected light
  - Yellow and red; enhance shoot elongation
- > 700 Infrared
  - Seed germination and responses; flowering

Light Intensity (Quantity) Measurements

μmol m⁻² sec⁻¹: 1 x 10⁻⁶ or 0.000001 mol m⁻² s⁻¹
- Full sun: 2,000 μmol m⁻² s⁻¹
- Measure with a spectroradiometer
- Average sunny day will total 60 mol PAR
  - All is meaningless without time factor;
  - must get Total Irradiance Dose (TID)
  - ie. Number of mols PAR/day

Light Intensity (quantity) Variations

- Season (summer greatest)
- Latitude (decrease with increase in latitude)
- Time of Day (greatest at Mid-day)
- Atmospheric Screening
- Topography – south vs. north slopes
- Shade!

Low Light Quantity

- Effects:
  - Reduced photosynthesis results in low energy levels
  - Poor recovery from damage
  - Poor density
  - Poor stress tolerance

Diurnal Variation of Sunlight
Annual Variation of Sunlight

Proportion of Each Wavelength available in full sun and shade

Light Quality in Shade

Reduced Light Quality

- Delicate leaves damage easily
- High succulence leads to cell disruption under traffic
- Low red light causes rapid vertical shoot growth
  - Loss of root growth, stem growth, and energy for general metabolism
Where is Turfgrass shade a problem?

- Golfplatz Hittfeld
- Home Lawns
- Sports stadiums

Shade = Limited Light
New Meaning of "Portable Field"

Gelredome (Arnhem, Holland)

Estimated that 20 - 25% of managed turfgrass is under shade stress – Beard, 1973

Houston Astrodome: Built 1965

Surface: Tifway 419 Bermudagrass (1965); Astroturf (1966 – closed 2002)
Shade effects on turfgrass

Morphological Changes

<table>
<thead>
<tr>
<th>Full Sun Turf</th>
<th>Shaded Turf</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Leaf Thickness</td>
<td>• Leaf Thickness</td>
</tr>
<tr>
<td>• Plant Height / elongation</td>
<td>• Plant Height / elongation</td>
</tr>
<tr>
<td>• Density</td>
<td>• Density</td>
</tr>
<tr>
<td>• Tillering</td>
<td>• Tillering</td>
</tr>
<tr>
<td>• Growth Habit</td>
<td>• Growth Habit</td>
</tr>
<tr>
<td>• Root/Shoot Ratio</td>
<td>• Root/Shoot Ratio</td>
</tr>
</tbody>
</table>

Physiological Changes

- Lower Carbohydrate Reserves
- Reduced Transpiration
- Lower Respiration (can exceed Pn)
- More Succulent
- Reduced Cuticle Thickness

Environmental Changes under Shade

- Relative Humidity: Increased
- Air Movement: Restricted
- Temperature: Moderated
- Competition from Tree Roots

Thin, Delicate Leaves

- Effects:
  - Leaves damage easily

- Management:
  - Restrict traffic
  - Closely monitor disease activity

Increased Succulence

- Effects:
  - Cell disruption under pressure

- Management:
  - Restrict traffic
  - Reduce N fertilizer
  - Irrigate only as necessary
Rapid Vertical Growth

- Effects:
  - Most plant resources are allocated to rapid shoot growth limiting the resources available for root growth, stem growth, and other forms of metabolism.
Cultural Practices that Can HELP Improve Shaded Turf

- Irrigate only as needed
- Avoid Excess Nitrogen
- Increase Mowing Height

Managing Turf in Shade

Mowing Height on Golf Course Greens

- In Full Sun:
  - Prostrate growth
  - High density
  - Green Speed:
  - Fast

- In Shade:
  - Upright growth
  - Poor density
  - Green Speed:
  - Faster

Shade Research

Golfplatz Hittfeld

Shade tolerance of turfgrasses

- High: Fine fescue / Supina bluegrass
  - Colonial bentgrass / Rough bluegrass
  - Tall fescue
  - Creeping bentgrass
  - Kentucky bluegrass
  - Perennial ryegrass

- Low: St. Augustine
  - Zoysiagrass
  - Centipede grass
  - Carpetgrass
  - Bahiagrass
  - Bermudagrass

Effect of species on Pn in reduced light conditions (3.5 mols PAR day⁻¹) Nov. 1996

Turfgrass Selection

Shade tolerance of turfgrasses

Annual Variation of Sunlight

Data: O.J. Noer Facility, WI, USA 2005

Cool-season grass limits
- ~30% Min

Warm-season grass limits
- ~15% Min

~55% Min
- ~28% Min
Mowing and Traffic

- The recommended cutting height for grass growing in the shade is slightly higher than the recommended height of the same grass growing in full sun.

- If possible, limit the amount of traffic on heavily shaded grass as it is slow to recover from physical damage.
  - Increased mowing height helps protect the plant’s growing point by leaving more leaf tissue.

Increasing Photosynthetic Potential

<table>
<thead>
<tr>
<th>Mowing Height</th>
<th>Photosynthetic Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>13% ↑</td>
</tr>
<tr>
<td>Medium</td>
<td>25% ↑</td>
</tr>
<tr>
<td>High</td>
<td>28% ↑</td>
</tr>
</tbody>
</table>

*Courtesy Dr. Greg Bell, Ok State*

Fertilizing

- Turf grown in the shade requires fewer nutrients than turf grown in full sun.

- Apply about half the typical rate than for turf in full sun.

- Higher rates of fertilizer will weaken the turf or go unused by the plants.

Fertilizing Timing

- The best time to apply fertilizer is when the plant most needs the nutrients.

- For turf, there are three opportunities
  - Late spring, late summer, and late fall.

- To extend the availability of the nutrients use a fertilizer that has 25-50% of the nitrogen listed as slow release.
Results of Normal N Fertilization in Shade

Normal Nitrogen
No Nitrogen

Courtesy Dr. Greg Bell, Ok State

Objectives

- Best species
- Best management program
  - PGRs
  - Nitrogen type


Nitrogen Response of Turf Quality in Shade Depends on Turf Species (Verona, WI, 2001)

Different N Responses Among Grass Types

- Bentgrass better uptake through leaves?
- Kentucky bluegrass had 2X root mass
  - Slower root turnover
  - More efficient partitioning of carbohydrates?
- Supina may be heat-sensitive
  - Affect rooting or N metabolism?

Kentucky bluegrass

Granular N  Foliar N

Irrigation

- Water as needed....

ONGOING DEBATE:
- "Light and Frequent" vs "Deep and Infrequent"?
How Much Irrigation?

• More shade = Less water
  – Full sun: 100% ET 3x weekly?
  – 80% shade: 40% ET 1x weekly?

Measuring Soil Moisture

Irrigation

• Consider the Environment
  – Cool canopy temperatures
  – Restricted air circulation
  – Poor Evaporation
  – Reduced photosynthesis
  – Slower metabolism
  – Reduced transpiration
• Tree Root Competition

Diseases

• Even if sunlight is sufficient for growth, shaded turf may still die or be weakened by one of several diseases.
  – Powdery Mildew and Pink Snowmold most common
• Shade moderates temperature extremes, reduces wind movement, and increases relative humidity.
• Shade also increases the length of time leaf surfaces remain wet from dew, rain, or irrigation.

Diseases

• Microdochium patch
  (pink snow mold)
• Powdery mildew
• Leafspot
• Rust
• Brown patch
Turfgrass Boundary Layer

Research has shown that turfgrasses, especially those with marginal shade tolerance naturally, may maintain better quality in shade when treated with PGRs.

- Type II PGRs (especially Primo Maxx)
- Bluegrasses (Supima bluegrass)
- Creeping bentgrass
- Zoysiagrass

Plant Growth Regulators

- PGRs work by slowing leaf elongation, which leaves more food/carbs. available for root growth.

Remedies - growth regulator

Atkinson et al., 2011

Zeon zoysiagrass in Singapore National Stadium
Effect of PGRs on Pn in reduced light conditions (3.5 mols PAR day⁻¹) Nov. 1996

Frequency of Primo Applications Effect on Shaded Turf Quality (Verona, WI, 2001)

Comparing HPS and LED Lighting Systems

- Lights
  - HPS (High Pressure Sodium)
  - LED
  - No light (93% shade)
  - Full sun
- Turf
  - Bermudagrass
  - Kentucky bluegrass
**SGL Bermudagrass Study**

- **% Green Cover**
  - LED
  - High Pressure Sodium
  - Control
  - Full Sun

- **Turfgrass Rooting**
  - LED
  - High Pressure Sodium
  - Control
  - Full Sun

**Summary**

- High pressure sodium lights provided the same amount of green cover as full sun plots.
- A rooting reduction in shaded treatments was found.
- Shade increased the internode length.

---

**Kentucky Bluegrass Study**

- **Dark Green Color Index**
  - LED
  - High Pressure Sodium
  - Control
  - Full Sun

- **Turfgrass Quality**
  - LED
  - High Pressure Sodium
  - Control
  - Full Sun

**End of Study Color Differences**
Soil Temperature

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Temperature °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPS</td>
<td>12</td>
</tr>
<tr>
<td>Control</td>
<td>8</td>
</tr>
<tr>
<td>Full Sun</td>
<td>8</td>
</tr>
</tbody>
</table>

Soil Water Content

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Soil Water Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPS</td>
<td>5</td>
</tr>
<tr>
<td>Control</td>
<td>10</td>
</tr>
<tr>
<td>Full Sun</td>
<td>20</td>
</tr>
</tbody>
</table>

Summary

- Dark green color for HPS lights were the same as full sun plots
- LED had lower quality than all other treatments
- HPS had an increase in soil temperature of 4 degree C from the control
- HPS had the lowest soil water content and needed the greatest amount of supplemental irrigation

Summary of Managing Turf in Shade

- Limit traffic and monitor disease closely
- Apply PGR’s if the expense is justified
- Use maximum mowing height
- Limit nitrogen fertilization
- Apply sufficient but minimal irrigation
- Remove obstacles to air movement
- Root prune high value areas
- Be flexible, mulch is an alternative

Summary of Managing Turf in Shade

- Management:
  - Reduce N fertilizer
  - Mow infrequently
  - Apply growth regulators
    - Cell elongation inhibitors not cell division inhibitors
    - Trinexapac-ethyl (Primo)
    - Paclobutrazol (Trimmit)
  - Communication!

Taking Control of Shade

Measuring and Communicating Shade Issues

Remedies - selective pruning
### Remedies

Thunder

Lightning

### Shade on Sports Turf

### Total irradiation using a foot-candle or lux meter

- Useful to measure light at turf canopy
- May give erroneous values relative to plant productivity
- Typically, about 50% of total irradiance is PAR irradiance

### Mapping Shade Patterns

Light meters vs. PAR meters

- The human eye is more sensitive to yellow light
- Standard light meters measure total irradiation and report as total lumens and lux (foot-candles)
- Plants respond more to blue and red light
- PAR meters focus on the wavelengths important for plant physiology and growth
Hand-held Light Meter

Measure PAR in micromoles m⁻² s⁻¹

```
50 75 25
150 750 150
450 350 750
```

“m” x 3600 = mols m⁻² day⁻¹

Watchdog Data Loggers

- Multiple versions
- 2 or more sensor ports – $230-430
- Quantum light sensor – Measures PAR – $230

Measuring the Light of Day

<table>
<thead>
<tr>
<th>Time</th>
<th>RH (%)</th>
<th>Temperature (°F)</th>
<th>PAR Shade (µmol/m²/s)</th>
<th>PAR Full Sun (µmol/m²/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5:00</td>
<td>98.7</td>
<td>58.7</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>6:00</td>
<td>98.5</td>
<td>58.7</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>7:00</td>
<td>100</td>
<td>58</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>8:00</td>
<td>100</td>
<td>58.7</td>
<td>67</td>
<td>750</td>
</tr>
<tr>
<td>9:00</td>
<td>100</td>
<td>58.7</td>
<td>95</td>
<td>1033</td>
</tr>
<tr>
<td>10:00</td>
<td>96.2</td>
<td>58.7</td>
<td>139</td>
<td>1640</td>
</tr>
<tr>
<td>11:00</td>
<td>96.2</td>
<td>58</td>
<td>26</td>
<td>326</td>
</tr>
<tr>
<td>12:00</td>
<td>88.5</td>
<td>58.6</td>
<td>105</td>
<td>1359</td>
</tr>
<tr>
<td>13:00</td>
<td>98.7</td>
<td>57.3</td>
<td>328</td>
<td>1359</td>
</tr>
<tr>
<td>14:00</td>
<td>98.5</td>
<td>58</td>
<td>290</td>
<td>1640</td>
</tr>
<tr>
<td>15:00</td>
<td>89</td>
<td>59.4</td>
<td>317</td>
<td>1359</td>
</tr>
<tr>
<td>16:00</td>
<td>89</td>
<td>60.8</td>
<td>323</td>
<td>1359</td>
</tr>
<tr>
<td>17:00</td>
<td>85.9</td>
<td>58.7</td>
<td>140</td>
<td>780</td>
</tr>
<tr>
<td>18:00</td>
<td>85.6</td>
<td>57.3</td>
<td>87</td>
<td>675</td>
</tr>
<tr>
<td>19:00</td>
<td>85.4</td>
<td>55.2</td>
<td>55</td>
<td>111</td>
</tr>
<tr>
<td>20:00</td>
<td>98.7</td>
<td>59.7</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

Seeing the Light of Day

Sum = 8645486

Divide by 1,000,000

Equals

8.6 mol PAR/day

8.6/48=18% of full sun
Lighting Systems

Take-Home Points

• Light & Photosynthesis
• Types of Shade
• Effects of Shade on Turf
• Turf Management in Shade
• Shade Research
• Taking Control of Shade
• COMMUNICATION!

Thank You

John Sorochan
University of Tennessee
sorochan@utk.edu

http://www.turf.tennessee.edu