Turfgrass Stress Management

By Andrew Turnbull

Satisfying golfers is difficult at the best of times, but a change in the climate could make life that much more complicated for turf managers in the near future. Higher temperatures may become the norm over the next decades and turf managers will need to have a deeper understanding of how turf grasses grow so that good environmental stress management techniques can be practiced.

Weather data and growing conditions

Before we investigate the plant science, let us examine turfgrass growing conditions during the summer of 2006.

Here in the UK we have the most turf friendly growing climate in the world, enabling turf managers to grow good playing surfaces without having to think too much beyond basic and sensible turf management practices such as reasonable mowing heights, regular topdressing, aeration, correct feeding etc. However, this luxury position may change in the near future. According to the UK Meteorological Office "Preliminary temperature figures for 2006 ... show the mean surface air temperature has continued to demonstrate a warming climate, both around the globe and especially here in the UK." Air temperatures reached up to 36°C in the UK, common to many parts of the world such as mid and southern Europe and the USA but not experienced by many UK based turf managers.

Percentage Growth Potential

Grasses belong to the plant family Poaceae, and the grasses we use in this country belong to the sub-family Festucoideae. This sub-family are also termed cool-season grasses as their optimum growth occurs at air temperatures of 20°C (68°F) and soil temperatures of 18°C (66°F). At temperatures above or below this optimum, grass growth will be below its best due to the slow speed of the plant's internal functions, mainly photosynthesis. Actual growth of grasses through the year can be measured against the optimum growth rate and calculated as a percentage of the potential maximum growth rate at 20°C. The formula used was developed by the PACE Turfgrass Institute and is called the Turfgrass Growth Model. The variance in the equation below is set to 10 for cool season turfgrasses and 12 for warm season turfgrasses.

$$100 \times e^{\left(\frac{1}{2}\left(\frac{\text{average temperature} - \text{optimum growth temperature}}{\text{variance}}\right)^{2}\right)}$$

Source: PACE Turfgrass Research Institute
www.paceturf.org

To illustrate this, examine the following table which shows the average temperature over a 30 year period, 1971 to 2001, for a weather station situated to the north of Birmingham.

Month	Ave temp ^{0}C	Ave temp ^{0}F	30 year % Growth Potential
Jan	6.90	44.42	**6.20**
Feb	7.20	44.96	**7.04**
Mar	9.80	49.64	**18.54**
Apr	12.10	53.78	**36.38**
May	15.80	60.44	**75.14**
Jun	18.60	65.48	**96.87**
Jul	21.30	70.34	**97.30**
Aug	21.10	69.98	**98.06**
Sep	17.90	64.22	**93.11**
Oct	13.90	57.02	**54.73**
Nov	9.70	49.46	**17.93**
Dec	7.60	45.68	**8.28**
Average	13.49	56.29	**50.35**

Source: *www.metoffice.co.uk*
Chart 1: 30 year average monthly temperatures at Sutton Bonnington 1971 – 2001

The percentage growth potential of cool season grasses, on average, only reach their full growth during June to September. This can also be illustrated in the graph below:

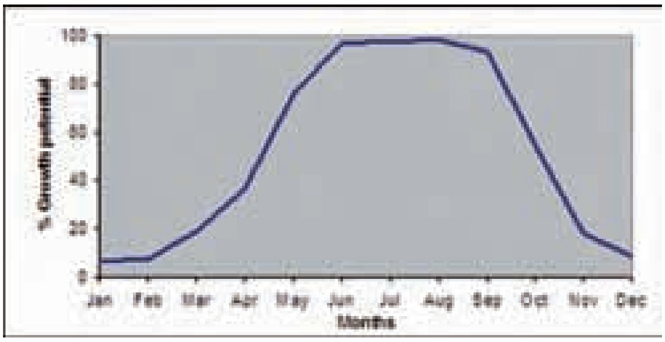

Figure 1: 30 year average % Growth Potential for cool season grasses in the north Midlands region of England

Compare this data (above right) with the average temperatures and the percentage potential growth for this past summer:

Month	Ave temp ⁰C	Ave temp ⁰F	% Growth Potential during 2006	% Growth Potential 30 yr ave
Jan	6.3	43.34	**4.78**	6.20
Feb	6.2	43.16	**4.57**	7.04
Mar	7.9	46.22	**9.33**	18.54
Apr	12.2	53.96	**37.32**	36.38
May	16.3	61.34	**80.11**	75.14
Jun	21.1	69.98	**98.06**	96.87
Jul	25.6	78.08	**60.17**	97.30
Aug	20	68.00	**100.00**	98.06
Sep	20.7	69.26	**99.21**	93.11
Oct	15.7	60.26	**74.12**	54.73
Nov	11.1	51.98	**27.71**	17.93

Source: www.metoffice.co.uk
Chart 2: 30 year average monthly temperatures at Sutton Bonnington Jan – Nov 2006

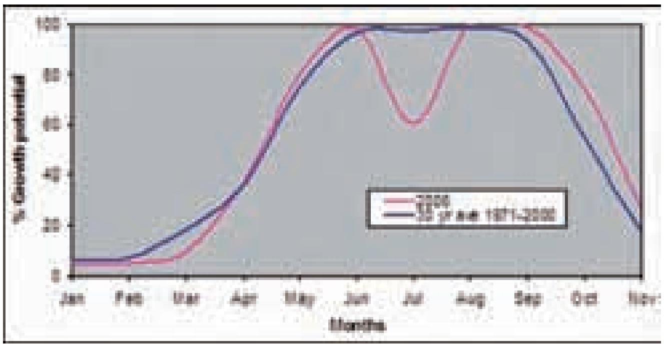

Figure 2: Comparison of the 30 year average and 2006 % Growth Potential for cool season grasses in the north Midlands region of England

OTHER AREAS OF THE UK
Below we can see how other parts of the UK fared.

Comparisons of 30 year average and 2006 % Growth Potential for various areas of the UK.

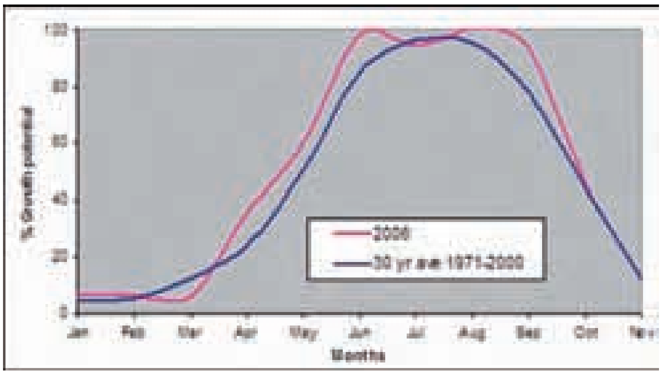

Figure 3: Leuchars – East coast of Scotland

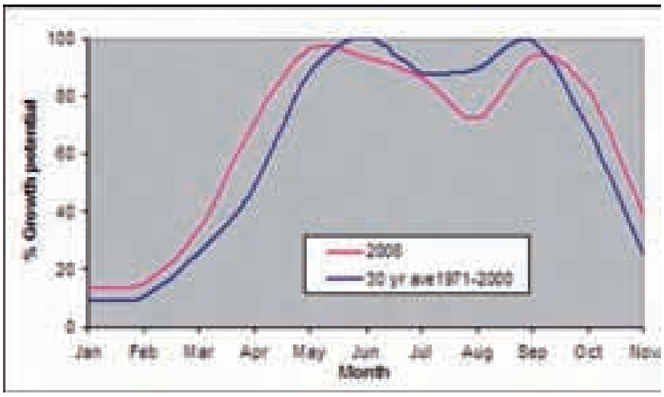

Figure 4: Greenwich – South east London

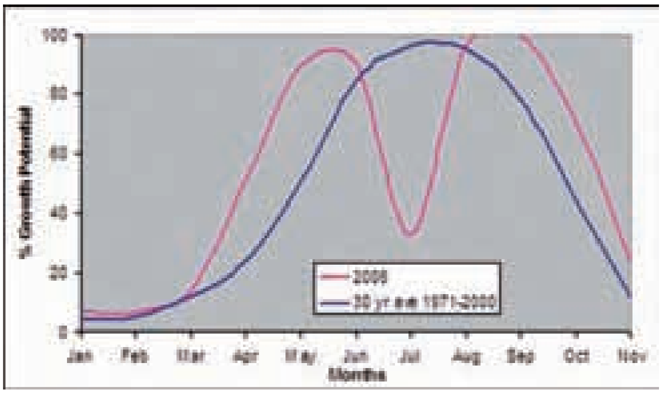

Figure 5: Cambridge – East England

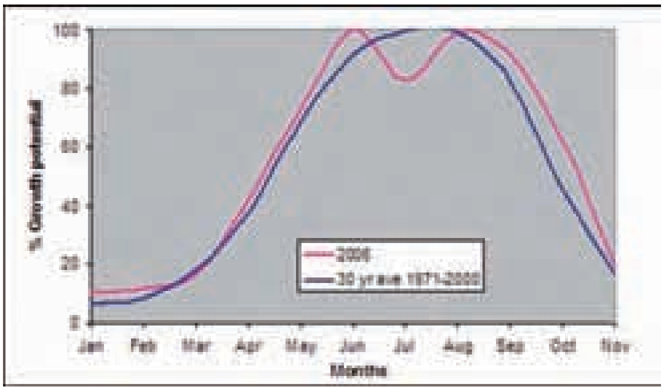

Figure 6: Armagh – Northern Ireland

Most areas suffered a dip in growth potential during the period when the quality of presentation would normally be at its best, i.e. June through to mid-August. Although some areas of the UK experience a dip in turf quality due to heat stress during most summers, as we can see from the above charts, most areas suffered restricted growth during July and August.

Some areas experienced an earlier than usual peak growth, then a dip, then another rise in growth during a period when normally grass growth would be slowing, i.e. a longer growing season.

So, what has caused this reduction in grass growth and playing surface quality?

Carbohydrate Metabolism

To manage healthy areas of turf that are able to withstand the effects of increasing use, the turf manager needs to understand plant energy relationships and carbohydrate partitioning. Carbohydrates, or sugars, control turfgrass growth, quality, resistance to environmental stresses and pests and are manufactured by plants in the leaves through a process called photosynthesis. In cool-season grasses the carbohydrates produced are mainly fructose and glucose and are important in cold hardiness. The carbohydrates are moved from the leaves to other areas of the plant when required and are used to make proteins and plant tissue. Unused carbohydrates are stored in roots and shoot stems until required during periods when the plant is under severe environmental stress.

Summary of Photosynthesis

Photosynthesis is the process in which carbon dioxide (CO_2) & water (H_2O) are converted into carbohydrates (food) in the presence of light energy and chlorophyll.

Reaction:

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2$$

Photosynthesis takes place in the chloroplasts of plant cells and consists of *Light-Dependent* and *Light-Independent* reactions. The Light-Dependent reaction converts light energy into ATP and $NADPH_2$, molecules used by the plant to energise reactions that convert carbon dioxide and water into sugars (carbohydrates). During light-dependant reactions water is split and oxygen is given off.

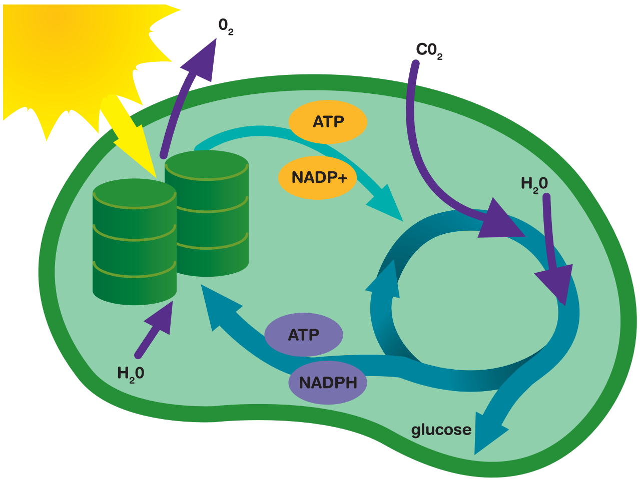

Illustration 10: Photosynthesis in the plant cells.
Source: *www.biologycorner.com*

Light-Independent reactions (the Calvin Cycle) incorporate CO_2 into sugar, the basic food source for all organisms, using the energy molecules ATP and $NADPH_2$ developed in the light-dependant reaction to drive the reactions.

Importance of Stomata

The CO_2 needed for photosynthesis enters a leaf via microscopic pores called stomata. During the day, when stomata are open, CO_2 enters the leaf through stomata and an enzyme, called Ribulose 1,5 bisphosphate carboxylase (Rubisco), fixes the carbon and combines it with Ribulose–1, 5–bisphosphate (RuBP), a five carbon molecule produced in the Calvin cycle.

C_3 Photosynthetic Cycle

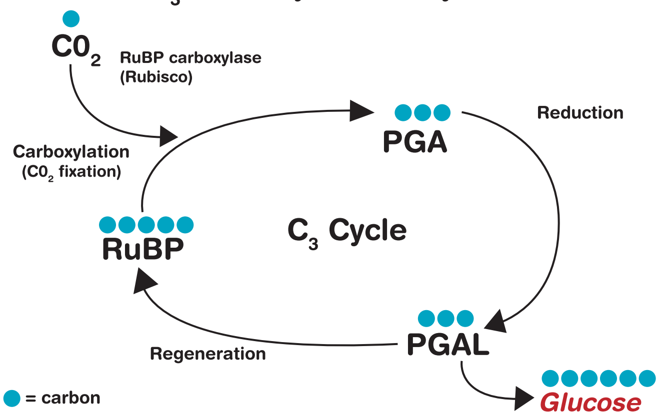

Illustration 11: The C3 photosynthetic cycle *Summer Stress*, Joe Vargas. Used by kind permission

In this pathway, the first product formed is a six carbon compound that breaks into two three carbon molecules called 3–phospohoglyceric acids, hence the term C–3 plants to describe cool season grasses and plants.

$$\underset{\text{Ribulose – 1, 5 – bisphosphate}}{6CO_2 + \text{RuBP (5 – carbon)} + 6H_2O} \xrightarrow{\text{Rubisco}} \underset{\text{3 – phosphoglyceric acid}}{\text{2 PGA (3 – carbon)}}$$

Stomata are also the main avenues of transpiration, the evaporation of water from leaves, and are the means by which grass plants keep cool during high temperatures. In hot and dry conditions, grass plants reduce water loss by closing the stomata. This action also reduces the amount of CO_2 entering the plant and O_2 is retained in the leaf thereby reducing photosynthetic yield. Under these conditions, CO_2 concentrations in the air spaces within the leaf begin to decrease and the concentration of oxygen released from photosynthesis begins to increase.

Photorespiration

Rubisco has a site that CO_2 binds onto, but Rubisco cannot distinguish between CO_2 and O_2. In the high concentration levels of oxygen produced within a plant when the stomata close, oxygen competes with carbon dioxide for the site of reaction in RuBP, which leads to a process called *photorespiration* and the efficiency of photosynthesis is reduced.

Photorespiration

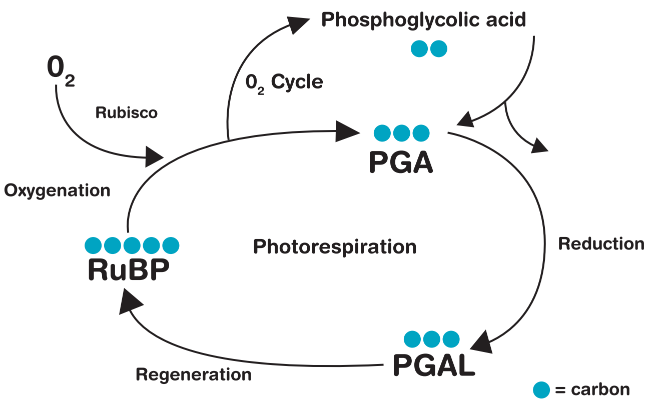

Illustration 12: Photorespiration: Summer Stress, Joe Vargus Used by kind permission

The oxidation process breaks down RuBP to CO_2, which is released as free CO_2. It is a wasteful process resulting in loss of CO_2 from cells that are simultaneously fixing CO_2 in the photosynthesis process.

$$O_2 + \text{RuBP} \xrightarrow{\text{Rubisco}} \text{PGA} + 2\text{P} - \text{glycolate}$$

$$2\text{P} - \text{glycolate} + O_2 \longrightarrow \text{PGA} + CO_2$$

Unlike normal cellular respiration, photorespiration generates no ATP and no carbohydrate. It is considered to be wasteful, since photorespiration drains away as much as 50% of the carbon fixed by the Calvin cycle. Photorespiration can be likened to a car stuck in the mud; the engine is working and the wheels are spinning, but the car is not moving.

So, in the summer the grass plants keep on growing in the warm environment but once temperatures reach about 30°C the plant cannot produce enough carbohydrates to keep up with the amount being used, and plant growth and vigour is disrupted. The leaves making the limited carbohydrates keep the carbohydrates for themselves and other parts of the plant suffer, especially the roots.

TURF MANAGEMENT SOLUTIONS

1. During non-stress periods

Carbohydrate reserves, built up during periods when the plant manufactures more carbohydrates than it can use in respiration, are essential to get through periods of high temperature stress. Peak production of carbohydrates are during the spring and autumn. If the plants reserves are depleted, the roots will begin to recede, picking up less nutrients and water. The plant will also not be able to grow rapidly and recover from wear or pest stresses. The best defense against this process is to have an ample carbohydrate reserve in your plants. This can be done by using cultural practices that promote a healthy plant without excessive growth, *before environmental conditions induce stress in turfgrass physiological functions*.

Nutrition:

Nitrogen fertilisation increases net photosynthesis and growth of leaf foliage in grasses but reduces root growth and stored carbohydrates. Turf could be weakened if excessive nitrogen fertiliser is applied in an attempt to fill in thin areas. Depletion of carbohydrate reserves can be hastened by nitrogen fertilisation. Therefore, high levels of nitrogen fertilisation should be avoided in the middle of summer. Instead, fertilise adequately in spring to build up reserves before temperature and moisture stress affect the plant, and in late summer and autumn to build up reserves before the winter, with very small amounts in the middle of summer. This may be against the “never apply nitrogen after August” mind set, but turf managers need to adapt management practices to take into account our changing climate.

Organic matter control

A small amount of surface thatch is beneficial in protecting the surface from damage from golf balls and foot traffic. However, it can also prevent aeration, i.e. the exchange of atmospheric air and soil carbon dioxide produced by roots and soil organisms. To avoid stress to the turf plant thatch control should be carried out in the spring and late summer.

Growth regulators

Research has shown mixed results on the effects of plant growth regulators (PGR) on carbohydrate partitioning. There are possibilities that they can have a positive effect of helping the plant redirect energy into root production, and some may also damage plant tissue and reduce rooting. They also may make the turf more susceptible to drought stress by reducing root growth. There is not enough published research to support a definitive conclusion on the effects of heat stress on PGR treated turf. However, anecdotal evidence suggests that some forward looking turf managers seem to have obtained some good drought resistance when using trinexapac-ethyl for *Poa anua* control.

2. Cultural practices during hot periods

Irrigation

Heat and water stress are the causes of photorespiration. Syringing during high temperature periods cools the leaf surface and is the most productive activity that can be carried out, but should not be overdone. Too much applied water will flood the surface layers of the turf leading to the loss of aeration pore space. This surface water will heat up and increase the oxygen demand of soil organisms and roots, leading to low oxygen levels in the rootzone and a decrease in turf growth and quality.

Mowing height

Reduced mowing heights, an increasingly common practice on many golf courses, also reduces the root mass of the grass plant. The plant puts energy into producing leaf tissue at the expense of root tissue. Raising mowing heights during heat stress periods enables the plant keep more root mass and draw in more moisture, leading to cooler internal plant temperatures.

Aeration

Aeration is commonly used to describe operations such as slitting, spiking and verti-draining. Aeration is actually the exchange of soil gases with atmospheric gasses, and takes place between the soil/atmosphere interface *and* through the grass leaves. To enable aeration to take place, surface pricking during the summer punches through the organic matter at the sward surface and enables atmospheric and soil air exchange. The use of equipment such as a sorrell roller, and air or water injection equipment leaves very little surface disruption and can have a significant effect on turf health in the summer.

Conclusions

With the prevailing message of managing turfgrass species with minimal inputs of water and nutrients, turf managers need to understand how to help the plant manufacture and store carbohydrates before stress conditions arrive during the summer period. Without this understanding it is debatable whether the message of "sustainable greenkeeping" has itself a more than short shelf life.

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