Summer Stress and Pre-Stress Conditioning

Continue to learn

The essence of turfgrass management is to provide a quality golf course surface throughout the playing or growing season. In most instances a specific period or time exists where management of a golf course green or fairway is difficult. This period often revolves around an environmental stress period defined primarily by temperature but often in conjunction with a moisture stress.

The combination of high soil temperature and saturated soil conditions resulted in a rapid loss of turf.

Identifying the stress period is the centrepiece for developing a pre-stress conditioning management programme. The 'beginning of the season' should be thought of as occurring after the stress period, and the 'end of the season' is when the turf is under stress. Management practices need to be considered in the context of how they might influence, positively or negatively, turf growth during the stress period. In other words, what are the practices that we will implement prior to the stress period that will enhance survival once the stress period arrives?

By definition, stress subjects the turfgrass plant to a hardship. Each stress induces a strain or injury, which results from direct or indirect physical or metabolic alterations. A temperature stress occurs when plants are exposed to temperatures above or below their optimum range.

TEMPERATURE STRESS

The optimum range for cool season turfgrass shoot growth is 15-24°C and 10-18°C for root growth. In contrast, the optimum temperature for warm season turfgrass shoot growth is 27-35°C and 24-29°C for root growth. Outside these ranges the turfgrass is under some degree of strain or injury.

The three major temperature stresses are freeze stress, which occurs at temperatures at or below 0°C; chilling stress, which occurs at temperatures below 12°C but above freezing; and heat stress, which occurs above the optimum for growth, and is typically lethal above 45°C. Freeze and chilling stress are primarily concerns on warm season turfgrasses. Freeze stress however can occur to annual meadowgrass (Poa annua) and to a lesser extent perennial ryegrass (Lolium perenne L.). Heat stress most commonly is a concern on cool season grasses and is greatly affected by the temperature and the duration of the stress.

HIGH TEMPERATURE STRESS

Elevated temperatures have a physiological and morphological impact on cool season turfgrasses. Creeping bentgrass studies have found that increasing temperatures above the optimum reduced net photosynthetic rates, decreased leaf chlorophyll content, increased respiration, and reduced carbohydrate content turfgrass growth (Ref 8). The visual impact to the turf quality caused by these changes is a reduction in growth, and a decline in turf density. In addition, under high temperatures, traffic or wear stress is more evident due to the fact the turf cannot recover quickly.

At supraoptimal temperatures beyond what we would consider chronic (37 to 40°C) protein denaturation or unfolding can occur causing death or severe injury to the plant (5). In this case a special group of proteins, called heat shock proteins, play a role as 'chaperones' that help prevent the unfolding of proteins once they are exposed to high temperatures (5). These proteins may also help explain genetic differences in heat tolerance among cultivars of creeping bentgrass (12).

Soil temperature is considered more detrimental to turfgrass growth than air temperatures (15). As described previously the optimum soil temperature range for cool season turfgrass growth is narrow, 10-18°C. However root growth can occur below the optimum until soil temperatures reach freezing (0°C). Conversely, increasing soil temperatures above the optimum can cause root growth to decline and death to occur (9). A temperature threshold for root decline and death occurs once average soil temperatures rise above 21°C. The total root loss can exceed 50%.

A high soil temperature in conjunction with a high soil moisture content level can cause a more rapid turf loss than soil temperature alone. Soils that have poor internal drainage, and are compacted, become oxygen deficient upon saturation. The lack of oxygen causes a rapid decrease in root respiration, contributing to rapid root loss. Under these conditions, root loss can occur in a matter of hours.

IDENTIFYING THE HIGH TEMPERATURE STRESS PERIOD

Radiant energy (sunshine) is the major contributor to leaf temperature. Under sunny, clear days, no wind, and adequate soil moisture levels where transpiration rates are not limiting, the canopy temperature is often 7 to 10°C warmer than the ambient air temperature (4). For example, if the ambient air temperature were 32°C the canopy temperature would be approximately 41°C.

If a cloud were to pass in front of the sun the canopy temperature would drop 5 to 8°C. Thus, on cloudy days under the same conditions of no wind, and adequate soil moisture, the canopy temperature would be similar to the ambient air temperature.

A slight breeze (~8kph) across the turf canopy can reduce the temperature 4 to 7°C under sunny clear conditions. In shaded or restricted areas, where little air movement occurs, promoting air movement through cutting or trimming trees or installing fans can help reduce the canopy temperatures and thus reduce the potential for canopy temperature build-up.

In the above situations, moisture levels were not limiting. However, if the turfgrass plants cannot meet the transpirational needs, leaf temperatures can raise 11°C or higher beyond the ambient air temperature. Localised dry spots often have canopy temperatures of 49°C due to the lack of moisture present to the turfgrass plants (3).

As previously mentioned, average daily soil temperatures above 21°C can result in significant root loss. For onsite measuring of soil temperatures, many of the new irrigation systems come with weather stations that have the capability for measuring and recording soil temperatures. Soil temperatures can also be measured with a relatively inexpensive soil temperature probe placed on a nursery or practice green to a 5cm depth. Reading the soil temperature between 11 and 12 noon will provide a rough measure for the average daily soil temperature.

By Karl Danneberger and David Gardner, Professors of Turfgrass Science, Department of Horticulture and Crop Science, The Ohio State University, Columbus, USA

Heat stress normally manifests itself in association with under stresses like increased susceptibility to moisture stress, and increased susceptibility to pests.

Once average daily soil temperatures remain above 21°C that creeping bentgrass and/or Poa annua green or turf is under temperature stress. In a recent study, the combination of syringing and fans not only reduced canopy temperatures, as mentioned above, but also reduced soil temperatures (2,7). Although, decreasing soil temperatures from supraoptimal conditions by a few degrees may enhance shoot/root rations (16), root growth does not increase until soil temperatures are optimum for root growth.

PRE-STRESS CONDITIONING FOR SUMMER STRESS

Developing a hardy plant that can sustain prolonged periods of summer stress is the goal of pre-stress conditioning. Obviously, a criterion for pre-stress conditioning is knowing when the stress period occurs, as described above. Pre-stress conditioning practices should focus on enhancing the health of the turf including improving its growing environment (1).

Pre-stress conditioning practices include providing adequate soil aeration and surface organic matter management through coring, topdressing and vertical mowing. Correct fertilisation programmes and mowing heights would also be practiced to enhance turfgrass growth going into the stress period. However, a couple of specific practices that enhance the condition of the turfgrass plant prior to stress are irrigation and the use of exogenous plant hormones/growth regulators.

MOISTURE STRESS AS A PRE-STRESS CONDITIONER

Prior to summer high temperature stress, plants undergoing moisture stress like annual bluegrass, perennial bluegrass, and Kentucky bluegrass are more heat tolerant than those not exposed to moisture stress (14). Drought pre-conditioned plants tend to accumulate ion solutes, specifically potassium, at higher levels during periods of high temperature stress compared to non-drought stress plants (10).

The higher ion concentration allows for a relative higher osmotic adjustment potential during summer stress. In addition, a deeper more extensive root system develops prior to the period of high temperature stress (10). When irrigation is needed, deep infrequent irrigation is the most desirable for hardening turfgrass plants off for the summer.

PLANT REGULATORS AND HORMONES PRE-STRESS CONDITIONERS

Plant regulators are a small group of hormones that in small amounts can affect membrane functions, enzyme activity, and gene expression in plants. Cytokinin is one of the plant hormones that plays an important role and it can promote axillary bud growth by overriding auxin affects.

Thus, this interaction with auxin is a means of balancing shoot/root ratios. Cytokinin is also important in retarding leaf senescence or yellowing during periods of high temperatures. It probably plays a roll through stimulating RNA and protein synthesis and delaying degradation of chlorophyll.

Research has found that applications of cytokinin to the root system (cytokinins are synthesized in the root tips and transported via xylem) alleviated leaf senescence and improved turf quality (13). Further research has found that cytokinin containing seaweed and humic acid extracts increased plant cytokinin levels possibly leading to improved drought tolerance (17).

Along these lines certain classes of fungicides exhibit cytokinin-like properties in preventing leaf senescence (11). In the late 1970's and 1980's it was postulated that one of the reasons Poa annua fairways survived summer stress was that fungicides used to control anthracnose also acted as a leaf anti-senescence agent by inducing cytokinin-like affects. In this case, fungicide applications were applied preventatively prior to the summer stress period.

Trinexapac-ethyl (Primo), a plant growth regulator, increases levels of zeatin riboside, one of the more prevalent and bioactive cytokinins (6). The increased plant levels potentially could increase the heat and drought tolerance of the turf. To get the desired effect multiple applications need to be initiated prior to the stress period.

CONCLUSION

As the intensity of turfgrass management increases, the susceptibility of the turf to environmental stresses increases. Managing turf successfully during stress periods depends increasingly on the condition of the plant going into the stress. Our understanding of how and why pre-stress conditioning factors may help is still in the early stages. However, it is clear that under intensive management, these factors will play a greater role.

Reference:

1. Carrow, R.N. (Jan/Feb 2004,). Surface organic matter in bentgrass greens. USGA Green Section Record. Retrieved April 14, 2005 from www.usga.org/turf/green_section_record/2004/jan_feb/surface.html
2. Danneberger, T.K. & Gardner, D. (2004, June). Syringing can dramatically affect canopy temperatures. Turfgrass Trends. Retrieved April 29, 2005 from www.turfgrasstrends.com/turfgrasstrends/article/articleDetail.jsp?id=99488&pageID=2
3. Danneberger, T.K. & White, S. (1988, Feb). Treating localized dry spots. Golf Course Management 56, 6-10.
4. Danneberger, T.K. & Yan, J. (Aug 27, 2003). Does the water temperature affect syringing? Superintendents Korner TurfNotes. Retrieved April 7, 2004, from http://hcs.osu.edu/sk
5. DiMascio, J.A., Sweeney, P.M., Danneberger, T.K., & Kamalay, J.C. (1994). Analysis of heat shock response in perennial ryegrass using maize heat shock protein clones. Crop Science 34, 798-804.
6. Ervin, E.H. & Zhang, X. (May 2004). Primo changes plant hormone levels that prompt beneficial side effects for healthy turf. TurfgrassTrends. Retrieved April 15, 2005 from www.turfgrasstrends.com/turfgrasstrends/content/printContentPopup.jsp?id=92965
7. Guertal, E.A., van Santen, E., & Han, D.Y. (2005). Fan and syringe application for cooling bentgrass greens. Crop Science 45, 245-250. Retrieved April 14, 2005 from www.hcs.crop.scijournals.org/cgi/content/full/45/1/245
8. Huang, B. & Gao, H. (2000). Growth and carbohydrate metabolism of creeping bentgrass cultivars in response to increasing temperatures. Crop Science 40, 1115-1120. Retrieved April 7, 2005 from http://crop.scijournals.org/cgi/content/full/40/4/1115
9. Huang, B. & Liu, X. (2003). Summer root decline: Production and mortality for four cultivars of creeping bentgrass. Crop Science 4, 258-265. Retrieved April 14, 2005 from http://crop.scijournals.org/cgi/content/full/43/1/258
10. Jiang, Y. & Huang, B. (2001). Osmotic adjustments and root growth associated with drought preconditioning-enhanced heat tolerance in Kentucky bluegrass. Crop Science 41, 1168-1173. Retrieved April 15, 2005 from http://crop.scijournals.org/cgi/content/full/41/4/1168
11. Skene, K.G.M. (1972). Cytokinin-like properties of the systemic fungicide benomyl. Journal Horticulture Science 47, 179-182.
12. Wang, D. & Luthe, D.S. (September 2003). Heat Sensitivity in a Bentgrass Variant. Failure to Accumulate a Chloroplast Heat Shock Protein Isoform Implicated in Heat Tolerance. Plant Physiology 133, 319-327. Retrieved April 15, 2005 from www.plantphysiol.org/cgi/content/abstract/133/1/319
13. Wang, Z., Xu, Q., & Huang, B. (2004). Endogenous cytokinin levels and growth responses to extended photoperiods for creeping bentgrass under heat stress. Crop Science 44, 209-213. Received April 15, 2005 from http://crop.scijournals.org/cgi/content/full/44/1/209
14. Wehner, D.J. & Watschke, T.L. (1981). Heat tolerance of Kentucky bluegrass, perennial ryegrass, and annual bluegrass. Agronomy Journal 73, 79-84.
15. Xu, Q. & Huang, B. (2000). Growth and physiological responses of creeping bentgrass to changes in air and soil temperatures. Crop Science, 40,1363-1368. Retrieved April 7, 2005 from http://crop.scijournals.org/cgi/content/full/40/5/1363
16. Xu, Q. & Huang, B. (2001). Lowering soil temperatures improves creeping bentgrass growth under heat stress. Crop Science 41, 1878-1883. Retrieved April 15, 2005 from http://crop.scijournals.org/cgi/content/full/41/6/1878
17. Zhang, X. & Ervin, E.H. (2004). Cytokinin-containing seaweed and humic acid extracts associated with creeping bentgrass leaf cytokinins and drought resistance. Crop Science 44, 1507-1510 Retrieved April 15, 2005 from http://crop.scijournals.org/cgi/content/full/44/5/1737