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AGRONOMY

Thermal Tolerance:
The Role of Heat Shock Proteins

By Karl Danneberger, Ph.D.

Plants live within a narrow temperature range of 32 to 122 F (0 to 50 C) with metabolic processes restricted to 50 to 104 F (10 to 40 C). Optimum shoot growth for cool season turfgrasses occurs between 60 to 75 F (10 to 24 C). When temperatures are outside the optimum range, turfgrass growth is hindered or reduced. High temperatures result in morphological changes including reduced shoot and root growth, decreased stand density and leaf width.

Physiological changes for cool season turfgrasses include reduction in photosynthesis, and an increase in respiration and photorespiration, resulting in decreased carbohydrate levels. As temperatures approach lethal levels, degradation of proteins, and membrane disruption occur resulting in overall shutdown of cellular functions. As cellular functions are disrupted or destroyed, cell death occurs leading to plant death.

The killing or lethal temperature for cool season turfgrasses is dependent on the temperature and exposure time. Upper limit for cool season turfgrasses is considered to range from 113 to 131 F (45 to 55 C), with killing temperatures for Kentucky bluegrass, perennial ryegrass, and annual bluegrass occurring around 117 F (47 C).

Indirect temperature stress where temperatures are above the optimum but below lethal, are common on cool season turfgrasses. Decrease in shoot and root growth along with a reduction in stand density are common symptoms observed by golf course superintendents and turfgrass managers during summer stress times.

On the other hand, direct high temperature kill of turfgrass plants from a historical perspective is considered a rare event.

On the other hand, direct high temperature kill of turfgrass plants from a historical perspective is considered a rare event. However, as we expand the use of cool season turfgrasses, especially creeping bentgrass, into climactic regions that are considerably less adaptable due to higher temperatures, and as management practices become more "on the edge" (low height of cut, wear, etc.), the probability of direct temperature kill increases.

Heat shock response

We have studied how turfgrass plants respond to thermal stress. Although not a common event, turfgrasses — especially cool season turfgrasses, in the transition zone can reach canopy temperatures considered lethal, yet the plants survive without any apparent damage.

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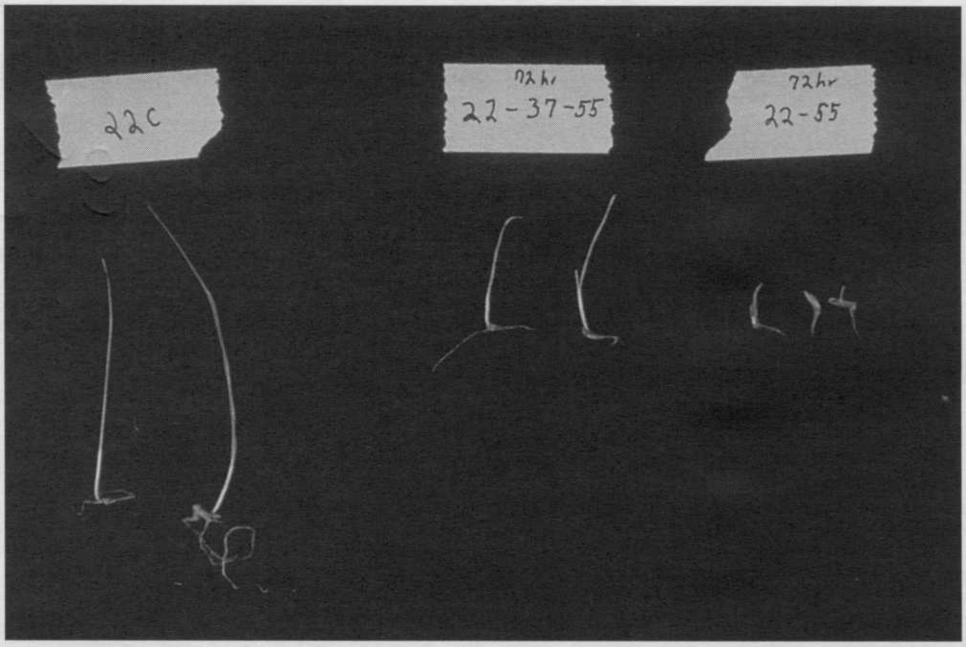


Figure 1. Perennial ryegrass seedlings were exposed to various heat treatments. On the left, these seedlings were grown for 7 days at 68 F. The seedlings on the right were grown at 68 F but exposed for 1 hour at 131 F on the fourth day then returned to 68 F. The seedlings in the middle received 1 hour of 99-104 F followed by 2 hours at 131 F.

For example, we did a laboratory study where we took perennial ryegrass seedlings and grew them at an optimum temperature of 68 F (20 C) for seven days. A second group of seedlings we grew at the same temperature of 68 F but on the fourth day these seedlings received l hour at 131 F (55 C) then returned to 68 F for the remaining days. The third group of seedlings on the fourth day received l hour at 99-104 F (37-40 C) followed by 2 hours at 131 F then returned to 68 F for the remainder of the experiment.

The results from this type of experiment are shown in Figure 1. The seedlings grown at 68 F were well developed and healthy. The seedlings on the far right that were exposed to the 1-hour of 131 F were killed. The seedlings in the middle, which received a 2-hour acclimation temperature before the 131 F lethal temperature, survived.

The question that arises is how does a turfgrass plant, or any plant, survive a lethal temperature?

The question that arises is how does a turfgrass plant, or any plant, survive a lethal temperature?

Over the last 20+ years considerable research on how eukaryotic organisms respond to "heat shock." If we look at what happens during elevated temperatures, normal protein synthesis slows or stops. At the same time, as temperatures rise the production of specific proteins called heat shock proteins occur (Parsell and Linguist, 19993; Vierling, 1991). Heat shock proteins (HSP) are synthesized when supraoptimal temperatures (~98-104 F) are reached but below lethal temperatures.

The correlation between HSP formation and cellular resistance to thermal stress has led to the hypothesis that the accumulation of HSP's increases the thermal tolerance of organisms. It believed that HSP work as "molecular chaperones."

Molecular chaperones are proteins that bind to partially folded proteins promoting correct folding or preventing unfolding (Hendrick and Hartl, 1993; Waters et al., 1996). The unfolding or aggregation of pro-

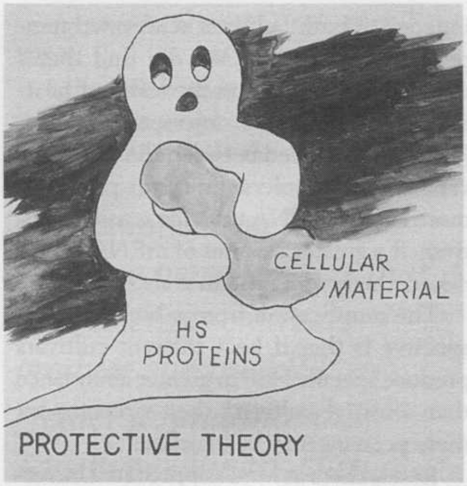


Figure 2. Heat shock proteins are believed to provide thermal protection to plants by helping prevent normal proteins from unfolding during high temperature periods.

teins is a direct result of elevated temperatures, which leads to cellular death. It is hypothesized that these HSP proteins work like matrices to prevent the unfolding of normal proteins during periods of high temperature (Figure 2). The HSP are highly conserved among the eukaryotes.

The major classes of HSP are based on their molecular weight and are known as HSP100[1], HSP90, HSP70, HSP60 and small HSPs (17 to 30 kDa). Regarding plants in general, the small HSPs are the most important in thermal tolerance and the ones produced in the greatest abundance.

The small HSPs are divided into five classes partially based on cellular location:

- chloroplast,
- endoplasmic reticulum,
- two classes in the cytosol, and
- mitochondria.

HSP in turfgrasses

Over the years, there has been considerable research on turfgrass responses to high temperature stress. The majority of these studies have looked at whole plant morphological and physiological responses. Little research has been conducted into understanding the thermal tolerance response at the molecular level.

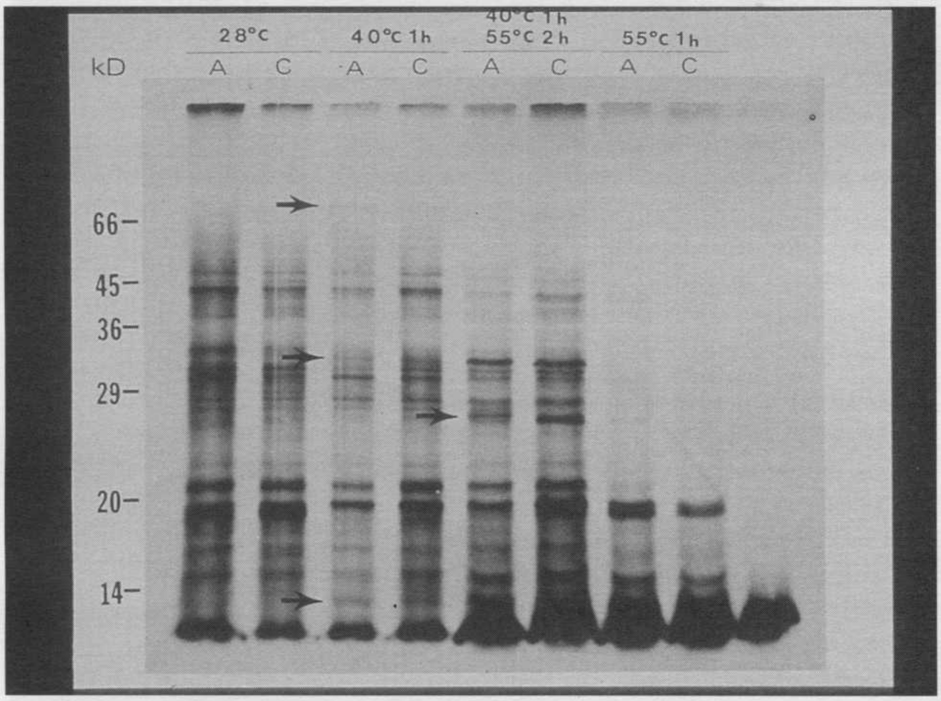


Figure 3. In vitro translation products of total RNA from "Accolade" (A) and "Caravelle" (C) perennial ryegrass seedlings. The arrows point to the presence of mRNA translating for heat proteins.

Little research has been conducted into understanding the thermal tolerance response at the molecular level.

During a 10 year period, we studied the heat shock response and production of heat shock proteins in turgrasses (DiMascio et al., 1994; Dimascio and Danneberger, 1990: DiMascio et al., 1989; Danneberger, et al., 1987; Sweeney et al., 1997).

In one study (Diemascio et al., 1994) we compared a heat-tolerant perennial ryegrass cultivar (Accolade) with a heat sensitive perennial ryegrass cultivar (Caravelle). We found that a broad range of HSP was induced in both cultivars at elevated temperatures (Figure 3). We did find that a detectable difference in the levels of heat-induced HSP 26 messenger RNA (mRNA)[2] occurred between the two cultivars. The heat tolerant cultivar produced more HSP26 mRNA than the sensitive cultivar. If a greater amount of mRNA is produced, then more protein is also produced.

The ramification from a breeding perspective is that if heat tolerant cultivars produce specific HSP in greater abundance than sensitive cultivars, then screening for these proteins may be beneficial.

Researchers at Mississippi State University have studied HSP response in creeping

TURFGRASS MANAGEMENT STRATEGIES

In summary, the heat shock response occurs in the following steps:

- As temperatures rise above the optimum, normal protein synthesis begins to slow.
- Once temperatures rise to a supraoptimal range (acclimation phase) a special group of proteins called heat shock proteins (HSP) form in the plant. The formation of HSP is associated with thermal tolerance.
- Heat-tolerant cultivars tend to produce more messenger RNA (mRNA) for certain HSP than nontolerant cultivars.
- Once the heat shock period passes, the HSP mRNA degrades and normal protein synthesis resumes. It maybe that heat-tolerant species or cultivars resume normal protein synthesis quicker after the heat shock period. This is believed to give a competitive advantage to heat-tolerant cultivars over nontolerant cultivars.

The insight gained from understanding the heat shock response is directly related to management strategies. Survival at high temperatures is dependent on the turfgrass plant successfully going through an acclimation phase.

If this phase is disrupted by a rapid rise in temperature, thermal tolerance will not be achieved. Thus, management practices that could interfere with the acclimation phase should be avoided. Some of these practices are:

- **Topdressings** – should be avoided during midday. The application of topdressing during high temperatures can cause a rapid increase in plant temperatures by acting as a cover or blanket, in effect, heat shocking the plant.
- **Clippings** – should be removed during periods of high temperature. Clipping left on a green or more likely a shortcut fairway turf, can act as a blanket or topdressing causing a rapid rise in temperature. Collecting or blowing the clippings off the turf can help reduce temperature buildup.
- **Mowing** – height should be raised to help reduce the heat load of the turf.
- **Mechanical** – practices such as brushing and verticutting should be done (if at all) will care during high temperature periods. The mechanical damage that can occur can cause rapid increase in the plant temperature.

bentgrass (Park et al. 1996; Park et al. 1997).

In their first study, they found the heat tolerant creeping bentgrass variants produced HSP25 while the nontolerant variants did not (Park et al. 1996). In a follow-up study looking at the recovery from heat shock, both the heat-tolerant and nontolerant variants produced the HSP25 but greater production of HSP25 mRNA in the heat-tolerant variants of creeping bentgrass was observed (Park et. al. 1997).

The ramification from a breeding perspective is that if heat tolerant cultivars produce specific HSP in greater abundance than sensitive cultivars, then screening for these proteins may be beneficial.

They also found that once the heat shock period passed, normal protein synthesis occurred sooner in the heat-tolerant variants than the nontolerant.

Park et al. (199) proposed that in the field HSP would be produced during midday during temperature stress, and then when temperatures decreased later in the day, the heat-tolerant creeping bentgrass would be able to resume normal protein synthesis sooner, and capture the remaining sunlight more efficiently.

NOTES

[1] 100 is expressed in kiloDalton (kDa) which is a molecular weight measurement. A Dalton is the unit of mass equivalent to the mass of a hydrogen atom (1.66 x 10 –24 gram). Kilo-is the metric prefix meaning 10^3.

[2]mRNA is a linear sequence of nucleotides (transcribed from DNA) that carries the protein-building instructions.

— The author is Senior Science Editor for Turfgrass Trends and a professor at The Ohio State University.

REFERENCES

Danneberger, T.K., J.C. Kamalay, and P.M. Trinity. 1987. Hybridization of DNA probes for heat shock proteins from corn and soybeans to DNA extracted from five turfgrasses. Agronomy Abstracts 132.

DiMascio, J.A. and T.K. Danneberger. 1990. Heat shock protein synthesis in turfgrass. United States Golf Association Green Section Record 28(4):13-15.

DiMascio, J.A., T.K. Danneberger, J.C. Kamalay, and R. Tejwani. 1989 Heat-shock protein genetic diversity in Kentucky bluegrass cultivars via RFLP. Agronomy Abstracts 156.

DiMascio, J.A., P.M. Sweeney, T.K. Danneberger, and J.C. Kamalay. 1994. Analysis of heat shock response in perennial ryegrass using maize heat shock protein closes. Crop Science 34:798-804.

Hendrick, J.P. and F. Hartl. 1993. Molecular chaperone functions of heat-shock proteins. Annual Review of Biochemistry 62:349-384.

Park, S.Y.R. Shivaji, J.V. Krans, and D.S. Luthe. 1996. Heat-shock response in heat-tolerant and nontolerant variants of Agrostis paulustris Huds. Plant Physiology 111:515-524.

Park, S.Y.,K.C. Chang, R. Shivaji, and D.S. Luthe. 1997. Recovery from heat shock in heat-tolerant and nontolerant variants of creeping bentgrass. Plant Physiology 115:229-240.

Parsell, D.A., and Linguist, S. 1993. The functions of heat proteins in stress tolerance: degradation and reactivate proteins. Annual Review of Genetics 27:437-496.

Sweeney, P.M., T.K. Danneberger, J.A. DiMascio, and J.C. Kamalay. 1997. Analysis of heat shock response in perennial ryegrass. In Recent cell and molecular genetics approaches to turfgrass improvement. Eds. M.B. Stricklen and M. Kenna. Ann Arbor Press, Michigan. Pp. 145-154.

Vierling, E. 1991. The roles of heat shock proteins in plants. Annual Review of Plant Physiology and Plant Molecular Biology 42:579-620.

Waters, E.R., G.J. Lee, and E. Vierling. 1996. Evolution, structure and function of the small heat shock proteins in plants. Journal of Experimental Botany 47:325-338.

Measuring sod strength of Kentucky bluegrass and Supina bluegrass

By John C. Sorochan and John N. Rogers, III

The extent of root, rhizome, and/or stolon growth determines turfgrass sod maturity. In 1998, at Michigan State University, the Calrochan Sod Puller (CSP) was developed to measure the force necessary to tear a piece of sod.

The CSP uses a battery powered hydraulic pulley to provide a consistent pulling force, and is attached to a load cell.

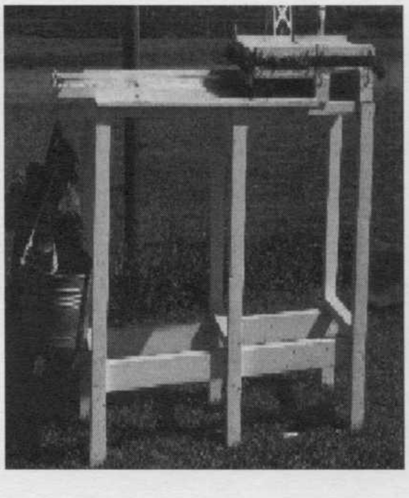
In August 1999, sod strength measurements of different turves were collected from the Manderley turfgrass sod farms in Napean, Ontario, Canada. The objective of this investigation was to introduce the CSP as a method for determining turfgrass maturity.

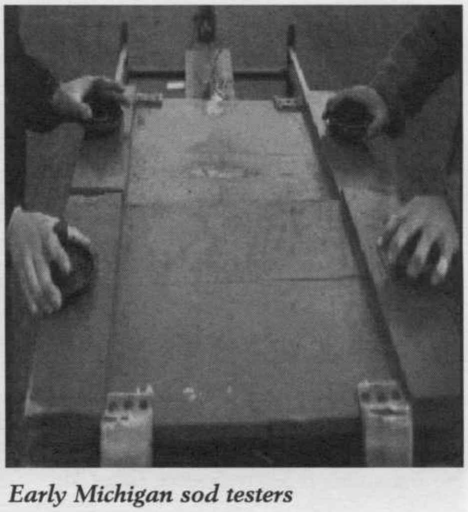
In short, sod strength measurements for Kentucky bluegrass increased with sod maturity and maintenance intensity. Results suggested that a minimum sod strength value of 38 pounds (17 kilograms) is necessary before Kentucky bluegrass sod (16 inches x one-half inch) is mature enough to harvest for commercial sod production. The consistency of the sod pull measurements suggest that the CSP is a useful tool for evaluating turfgrass maturity. Applications to other turfgrass research, particularly establishment investigations, are warranted.

The consistency of the sod pull measurements suggests that the CSP is a useful tool for evaluating turfgrass maturity.

One potentially fruitful area — given the increased sales of creeping bentgrass sod for golf course putting greens, tees, and fairways — is sod testing with the CSP on bentgrass. This could provide an important component to determine when the sod is ready for harvesting.

Thatch is a potential problem with the production and sale of creeping bentgrass sod. Testing with the CSP will provide sod producers with a quantitative value for determining when they can harvest creeping bentgrass sod early enough to avoid any thatch problems.





Early Michigan sod testers

Early sod testers

Many devices have been constructed to evaluate turfgrass strength and its relationship to sod maturity. Mature and harvestable sod depends on the extent of root, rhizome, and/or stolon growth (Rieke, et al., 1968).

The earliest sod strength tester known used a bucket with sand added to measure the force, in kilograms, needed to tear or break a piece of sod (Rieke, et al., 1968) (Figure 1).

Advanced sod stretchers used a winch as the principal stretching force (English and Rieke, 1971) (Figure 1). Unfortunately, these sod stretchers have potential for imprecise measurements due to the inconsistency of the sod stretch measurements (Burns and Futral, 1980).

In 1980, Burns and Futral developed a method to measure sod strength using the Instron universal testing instrument (Mod 1130, Instron Corporation, Canton, MA). However, Burns and Futral (1980) determined that the Instron is too expensive to use solely for sod testing in most programs.

In 1998, at Michigan State University, the Calrochan Sod Puller (CSP) was developed to measure sod strength (Figure 2). The design of this component is reflective of the earliest Michigan sod strength testers developed in 1968 and 1971, where the testing involves placing a piece of harvested sod on a horizontal surface with one-half fixed.

Unlike the earlier versions, the CSP braces the sod between two components by clamping down four 10-cm wide metal bars, each threaded with 29 8-mm metal golf spikes.

Sod puller unit (CSP)

A battery powered hydraulic pulley, providing a consistent pull, performs the force required to tear a piece of sod. Actual sod strength is measured in pounds (or kilograms) using a Chatillon digital force load cell instrument model DFI (Chatillon Force Measurement, Greensboro, NC) to measure the peak force value.

Actual sod strength is measured in pounds (or kilograms) using a Chatillon digital force load cell instrument model to measure the peak force value.

The objective of this article is to introduce a quantitative method for determining turfgrass tearing strength. A second objective is to establish an acceptable minimum sod strength value to determine turf maturity for harvesting.

Materials and methods

On Aug. 28, 1999, random sod samples were harvested from five Kentucky bluegrass farms and two Supina bluegrass farms in Napean, Ontario, Canada. The Kentucky bluegrass sod farms were seeded as a blend of Alpine (25%), Eclipse (25%), Regent (25%) and Welcome (25%), and were harvested for testing at 276, 353, 355, 375 and 395 days after seeding (DAS).

The Supina bluegrass was seeded as a monostand of Supranova and harvested at 360 and 379 DAS. The Supina bluegrass harvested at 360 DAS was established in Conwed Sodnet (Conwed Plastics, Minneapolis, MN) to provide additional strength.

All sod farms consist of a native soil ranging from sandy loam to sandy clay loam soils, with the exception of the Kentucky bluegrass harvested at 395 DAS which was grown in peat. All sod farms with the exception of the Kentucky bluegrass harvested at 276 DAS were currently in production for commercial harvesting.

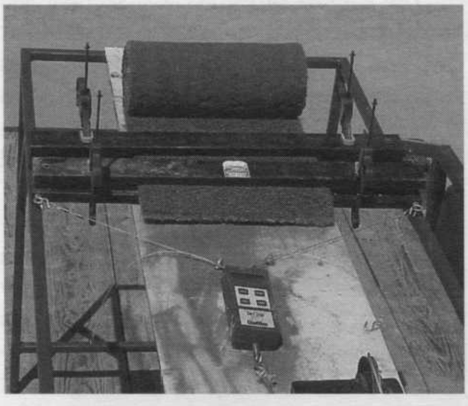
Management practices on all sod farms tested were different in terms of intensities for fertilizer, mowing and irrigation. Those differences in rates of nitrogen applied, irri-

TABLE 1. MANAGEMENT PRACTICE FOR KENTUCKY BLUEGRASS (KBG) AND SUPINA BLUEGRASS (SBG) SOD PRODUCTION, NAPEAN, ONTARIO, CANADA 1998-99

Species (age in days after seeding (DAS))	Nitrogen from seeding to harvest (lbs N per acre)	Irrigated	Mowing at 1 inch
KBG (276 DAS)	500	None	Every 3 days
KBG (353 DAS)	950	None	Every 3 days
KBG (355 DAS)	1500	Yes	Every 2 days
KBG (375 DAS)	1990	Yes	Every 2 days
KBG (395 DAS)	2240	None	Every 3 days
SBG (360 DAS)	1400	Yes	Every 2 days
SBG (379 DAS)	1400	Yes	Every 2 days

gation and mowing heights are outlined in Table 1.

Eight replications of the peak sod stretching measurements were collected, in kilograms, using the Calrochan Sod Puller. Sod stretching measurements for the non-washed samples were taken on Aug. 28, 1999, and washed sod measurements were taken on Aug. 29, 1999. Harvested sod measured 16 inches wide by one-half inch thick, and was pulled with a three-inch spacing between the clamp bars (Figure 2). Statistical analysis was determined at a 0.05 probability level using the SAS System for Windows.



Close up of sod on CSP

Building Sod Strength

Sod strength measurements for Kentucky bluegrass increased with sod maturity (Figure 3) and maintenance intensity (Table 1).

A turfgrass strength value of 38 pounds (17 kilograms) was established as a minimum value necessary to produce a harvestable sod (Figure 3.) This minimum value of 38 pounds was determined as a result of the sod strength tests from the Kentucky bluegrass sod farms harvested at 276 and 353 days after seeding (DAS). The sod harvested at 353 DAS was considered immature sod, but was strong enough for commercial sod production.

Conversely, the sod harvested at 276 DAS was considered too immature for handling and was not yet ready for commercial sod production.

Washed sod strength decreased significantly in two of the three Kentucky bluegrass and in one of the two Supina bluegrass sod farms tested (Figure 4). The soil removal process from the sod involves

As a result of the washing process, the size of the sod piece is increased to 30% to 50% of its original size.

pushing the soil from the underside of the sod through the top with high-pressure water.

As a result of the washing process, the size of the sod piece is increased by 30% to 50% of its original size. Removal of the soil

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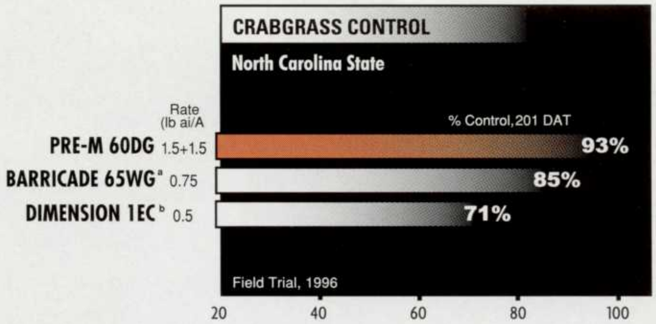

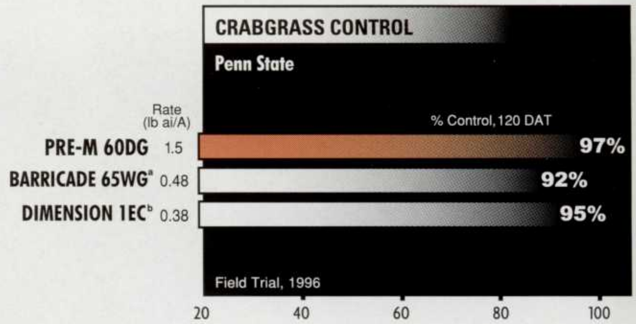

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TEAM[c]	H	M	M	M	M	M	NR	NR
RONSTAR[d]	M	H	NR	M	M	NR	NR	NR
SURFLAN[c]	H	H	H	M	MH	M	H	H
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*Source: Kline & Company Report, US Acre Treatments by Turf Management.

Sod pull at Manderley

and the increased stretching potentially weakens the sod, and therefore may contribute to the lower sod strength values obtained as compared to the sod with soil intact. (The actual length of the sod is increased by 30 to 50% when it is run through the washing process. The process of removing soil from sod actually stretches the sod at the same time.)

Consistency of measurements

The correlation and consistent trends obtained during this investigation suggests that the Calrochan Sod Puller is an excellent apparatus to measure turfgrass sod strength. Additionally, the consistency of the measurements obtained, as a result of the uniform pulling force of the CSP, established a minimum sod strength value of 37 pounds (17 kg) for harvestable Kentucky bluegrass sod.

The CSP is an effective tool for obtaining quantitative values of turfgrass sod strength. These results warrant further research to develop quantitative sod strength minimums for other turfgrass species. CSP measurements will also benefit future research, particularly establishment investigations, where limits of acceptability are necessary.

Utilizing the CSP ensures that an acceptable sod is being harvested for commercial sales, adding a comfort level for both the producer and the purchaser of the sod.

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REFERENCES

Burns, R. E. and J. G. Futral. 1980. Measuring sod strength with an Instron Universal Testing Instrument. Agron. J. 72:571-573.

English, K. R. and P. E. Rieke. 1971. Fertilizing for sod strength. Michigan State University Sod Producers Field Day Rep. 1:19-22.

Rieke, P. E., J. B. Beard, and C. M. Hansen. 1968. A technique to measure sod strength for use in sod production studies. Agron. Abstr. P. 60.

Control of bluegrass in bentgrass fairways & efficiency of foliar feedings

Editors' note: Send your turfgrass questions to our Management Forum panel for quick response. *See page 12 for details.*

Q *Is there a selective way to remove bluegrass from a bentgrass fairway? We are mowing the fairway at 5/8-inch and the collars of greens even lower. But, the bluegrass still is out competing the bent, even at the low height. What can be done?*

Dr. Richard Hull at the University of Rhode Island's Department of Plant Science says that the first question that needs to be answered is which bluegrass species is invading the bentgrass fairways? If it is a perennial form of Poa annua (Poa annua var. reptans), then there is no surprise that it can tolerate close mowing. However, it could be rough bluegrass (Poa trivialis), especially if the fairways are somewhat shaded.

If the culprit is Poa annua, there are few, if any, herbicides that will selectively remove it from bentgrass without damaging the bent. However, some plant growth regulators (PGR) have been found to discourage Poa annua in bent, but this requires a prolonged effort.

If rough bluegrass is present, it can readily be identified by its stoloniferous growth habit, lack of rhizomes and a 2-6 mm pointed ligule. Its control will also present a problem but it is less likely to be the grass in question.

The question sort of suggests that the invading grass is Kentucky bluegrass (Poa pratensis). If it is Kentucky bluegrass, it is undoubtedly a prostrate type that can tolerate close mowing. Again, there is no effective herbicide that will selectively remove Kentucky bluegrass from bent.

Most grass herbicides are more likely to be toxic to bentgrass than to Kentucky bluegrass. Even PGRs are less likely to be effective in preferentially weakening this bluegrass. In short, this problem has no clear solution. I would suggest that the superintendent check the mowing height to be sure the cut is 5/8-inch. If it is, try lowering it a bit and see if the bluegrass is discouraged. A lower cutting height should not seriously weaken the bentgrass. The cutting height might be gradually lowered until at some point the bluegrass should give up and let the bentgrass take over.

> *"Most grass herbicides are more likely to be toxic to bentgrass than to Kentucky bluegrass." — R. Hull*

Dr. Joseph Neal at North Carolina State University replies: First, an accurate ID is always helpful in developing a weed management plan; although in cooler regions of the country, I have seen Kentucky bluegrass tolerating 1/2-inch mowing and other bluegrasses that tolerate close mowing even better than Kentucky bluegrass.

Selectively removing one perennial turfgrass from another is always a challenge. I suggest two approaches that may work.

- **Option #1:** If the bluegrass grows a little taller than the bentgrass at any time of year you could skip one mowing then wipe the taller grass with Roundup. We have used this technique in the past to remove weedy grasses from bluegrass variety trials.
- **Option #2:** Spot renovate in early fall. Spray the bluegrass patches with glyphosate and reseed areas with bentgrass.

> *"Selectively removing one perennial turfgrass from another is always a challenge." — J. Neal*

How efficient is foliar feeding?

Given that grass is a root feeder, what is the mechanism for foliar feeding? Foliar fertilization works, of course, but is it as efficient as root feeding? Is it better for quick-hit feeding? For normal fertilization, are you wasting a lot of nutrients (and money) by going the foliar route?

Dr. Richard Hull responds: Plant leaves are not designed for nutrient uptake from nutrient solutions applied to their surfaces. The leaf is engineered to absorb light and resist water loss from its surface. This latter property is not conducive to effective nutrient absorption by leaves. However, the wax impregnated cuticle and surface epicuticular wax layer are penetrated by numerous very small water lined pores.

These transcuticular pores have a diameter of less than 1 nm (a billionth of a meter) but are abundant (~ten billion per sq-cm). These pores are readily permeable to small solutes such as urea but not to large molecules such as metal chelates. The pores are lined with negative charges so they are attractive to cations (ammonium, potassium, magnesium, etc.) but tend to repel anions (nitrate, phosphate, sulfate, etc.).

Uncharged molecules can be transported readily through these pores. Nitrogen fertilizers based on urea or ammonium ions can be transported through the pores. Also, a large concentration gradient along the pores can overcome repulsion of anions by the fixed negative charges. Foliar applied solutions of negatively charged nitrate and phosphate can be absorbed readily if the ion concentration is reasonably high.

Foliar penetration of fertilizer solutions does not occur through the leaf's stomates. The inner walls of guard cells are covered with cuticular wax making their substomatal surfaces mostly impermeable to water soluble materials. The fact that stomates do not play a role in foliar absorption of nutrients is supported by the fact that foliar absorption is actually greatest at night when stomates are closed.

The rate of foliar penetration by nutrient ions does increase as the number of stomates increases, but that is due to the fact that micropores in the cuticle (over the cell walls between guard cells and their neighboring cells) are more numerous and appear to be more permeable than other micropores elsewhere on the leaf surface. Unlike their brethren, these stomate micropores can even allow the passage of metal chelates and other larger (pesticide) molecules.

After having crossed the surface wax and cuticular layers of the leaf epidermal cells, nutrient uptake into the cell protoplasts is much the same as nutrient uptake by root cells.

The only real difference between the two organs is that light increases absorption of nutrients by leaf cells but has no impact on uptake by roots. Apparently some of the energy required for nutrient transport across the cell membranes of leaf cells is directly supplied by photosynthesis.

Intact leaves rarely exhibit light stimulated nutrient uptake because of the high resistance offered by the slow diffusion through cuticular micropores.

> *"Foliar fertilization is not very efficient. Uptake by leaves is much less than that by roots although this can vary depending on the nutrient status of the foliage..." — R. Hull*

Foliar fertilization is not very efficient. Uptake by leaves is much less than that by roots although this can vary depending on the nutrient status of the foliage, concentration of the foliar spray, age of leaves, etc. Consequently, foliar feeding would never be recommended as a general fertilization strategy.

Foliar applications do have a place for providing some micronutrients when a quick response is desired. Foliar applications of iron chelates make sense because the leaching of iron into the root zone and transport from roots to leaves takes time (several days or weeks)

A urea application to leaves will correct a nitrogen deficiency more quickly than a granular treatment even if watered into the turf. The time of response will not be very much more rapid but when preparing for a big event, it may be worthwhile.

Finally, foliar burning is always a potential problem following fertilizer spray applications and this should be considered when deciding if foliar feeding is desirable. Over application of soluble fertilizer with the expectation of later absorption by roots as the solution is washed off leaves is probably not a good strategy because of the high potential for foliar burn that this approach creates.

SEND US YOUR QUESTIONS

Do you have tough turf questions and need expert advice? Please send your questions to TurfGrass Trends and we'll have our panel of experts find the answers. Our Management Forum panel includes several distinguished experts in the field of turf:

- **Dr. Richard Hull**, Plant Physiology, University of Rhode Island
- **Dr. Karl Danneberger**, Agronomy, The Ohio State University
- **Dr. Noel Jackson**, Plant Pathology, University of Rhode Island
- **Dr. Joe Neal**, Weed Science, North Carolina State University
- **Dr. Rick Brandenburg**, Insects, North Carolina State University

Contacting us is easy. Just call Curt Harler at 440/238-4556, fax him at 440/238-4116 or e-mail him: curt@curtharler.com.

Growth regulator may help in crabgrass control

By Greg Wiecko

Plant Growth Regulators (PGRs) are typically used to inhibit the growth and/or development of plants. PGRs act by interfering with the biochemical processes responsible for cell division or cell development, especially in organs such as crowns, rhizomes and stolons (i.e. the primary sites of plant growth and development processes).

PGRs are classified into two groups: Type I PGRs inhibit or suppress both development and growth. Type II PGRs inhibit only plant growth. In recent years, more attention has been devoted to Type II. Primo (trinexapac-ethyl) belongs to this group and presently enjoys considerable attention from researchers representing various disciplines of turf science.

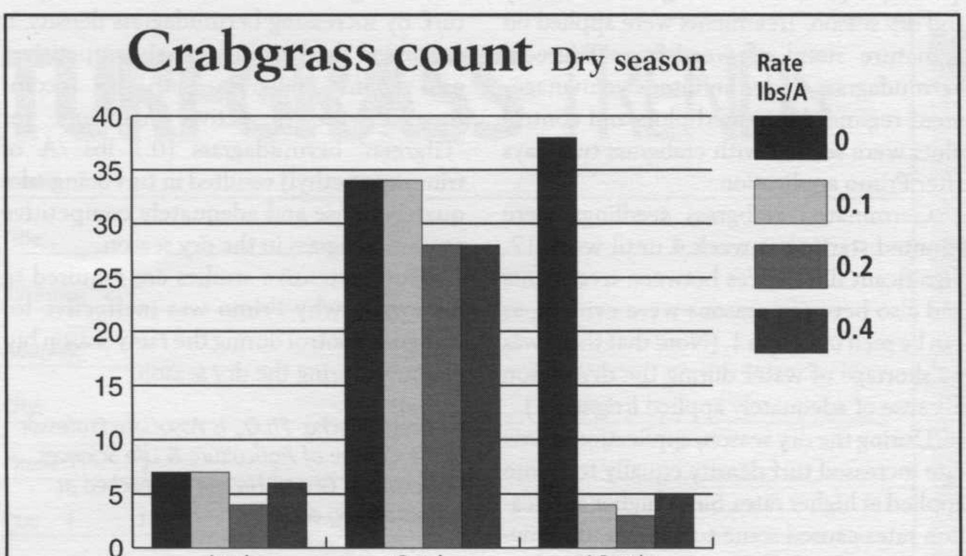
During the 1999 American Society of Agronomy Conference, more than half of all presentations addressing the usage of PGRs in turf focused on Primo which suppresses plant growth by inhibiting gibberellin synthesis.

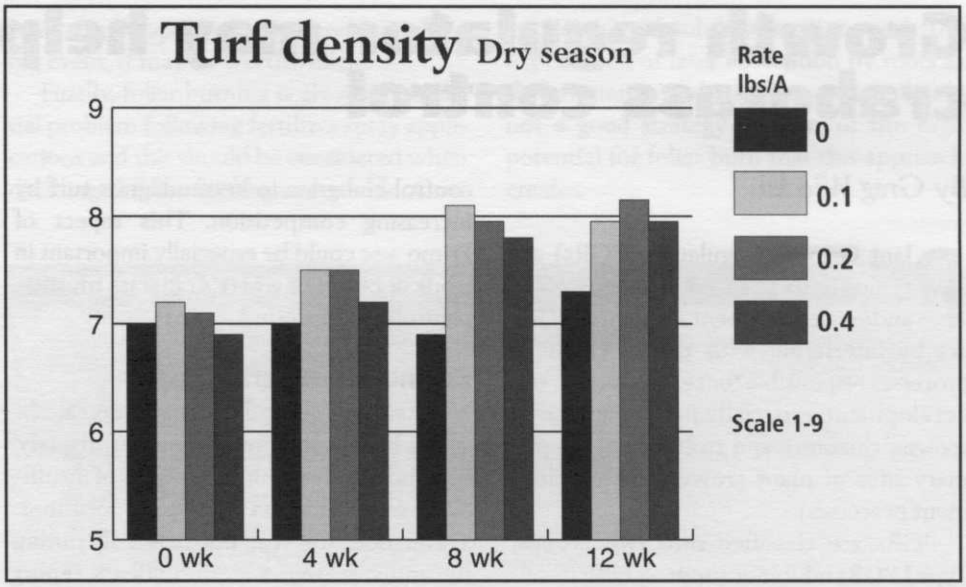
Studies conducted on Guam provide evidence that Primo can also be used to control crabgrass in bermudagrass turf by increasing competition. This aspect of Primo use could be especially important in tropical climates where crabgrass must be controlled year-round.

Bermuda and crabgrass

Maintaining bermudagrass in tropical climates has several limitations. Surprisingly, bermudagrass exhibits symptoms of insufficient solar radiation in tropical locations. Throughout the year, but especially during the rainy season, superintendents report problems typical for bermudagrass grown in shady conditions. In general, these are manifested by reduced density and increased weed infestation. Bermudagrass in general does not tolerate low light intensity and if grown without adequate light, thins out and alters its growth habit from horizontal to vertical, making it more vulnerable to weed, insect and disease infestation and wear.

Application of PGRs such as Primo increases turf density by decreasing the internode distance between blades. Researchers have collected a body of evidence indicating that increased turf density reduces opportunities for weed germination





and infestation. There is also substantial evidence indicating an increase in turfgrass density can be achieved by using the label recommended rate of Primo.

The manufacturer recommended rate of Primo for 'Tifgreen' bermudagrass is 0.75 pts/A (0.1 lbs/A trinexapac-ethyl). However, previous studies in tropical climates on bermudagrass showed an effective rate that was double the manufacturers' recommended rate to provide the desired results.

Consequent studies conducted on Guam examined Primo application at three rates: label recommended (1X), double (2X) and quadruple (4X) rates during both the rainy and dry season. Treatments were applied on a mature stand of weed-free 'Tifgreen' bermudagrass under an intensive management regime. All treated plots and control plots were seeded with crabgrass two days after Primo application.

Germinated crabgrass seedlings were counted starting at week 4 until week 12. Significant differences between treatments and also between seasons were evident, as can be seen in Graph 1. (Note that there was no shortage of water during the dry season because of adequately applied irrigation.)

During the dry season, application at low rate increased turf density equally to Primo applied at higher rates. Since higher application rates caused some turf injury, the lowest rate is considered the most beneficial.

In all instances, denser turf effectively prevented infestation by crabgrass. The number of seedlings found on 5x5 plots dropped from around 30 at week 6 to 5 and below at week 12. On the other hand, Primo appeared rather ineffective during the rainy season. Graph 2 shows that turf density remained unchanged regardless of what rate was applied.

Crabgrass counts during the rainy season were approximately three times higher than the dry season, and did not change substantially over the evaluation period.

It appears that Primo can be used to prevent crabgrass infestation of bermudagrass turf. By increasing bermudagrass density, it enhanced the bermudagrass' competitiveness against crabgrass. The label recommended rate of active ingredient for 'Tifgreen' bermudagrass (0.1 lbs /A of trinexapac-ethyl) resulted in turf being adequately dense and adequately competitive against crabgrass in the dry season.

More extensive studies are required to determine why Primo was ineffective for crabgrass control during the rainy season but effective during the dry season.

*— **Greg Wiecko**, Ph.D., is Associate Professor in the College of Agriculture & Life Sciences, University of Guam. He can be reached at gwiecko@uog.edu*

Sneak preview of the Olympics

Curt Harler
Managing Editor

In September, all eyes will turn to Sydney, Australia for the Olympic Games. Keystone of this Olympiad is Stadium Australia, a state-of-the-art facility seating 110,000 spectators.

The Legend Couch turf, grown at Windsor Turf Farms in Windsor, Australia, already has had several tryouts. One of the toughest was hosting the "State of Origin"rugby tournament.

Before Opening Ceremonies on Sept. 15, there will be a total of 28 events – several drawing more than 100,000 spectators — at the Stadium. The grass came through with flying colors. The turf was brought to the Stadium in 1.5-sq. meter blocks (about five-feet square) and installed over several day's time. Should it be necessary to replace every part of the playing surface, the job can be done and the field made ready in four days.

I wandered around in the stadium in mid-May and the grass was in great shape. The playing field is basically the equivalent of the world's largest putting green and is built along the lines of many other premium athletic facilities. Drain tile runs through a clay base. Above that sits a consolidated stone layer, then gravel, then sand. The turf sits on top of the sand.

While there will be much ado about the turf, here are some other fascinating facts about the stadium. Stadium Australia will be able to serve 63,000 schooners of beer per hour. Gotta love those Aussies.

The stadium cost $650 million to build, but the job came in roughly on budget and was completed three months early. Construction finished last March.

When the Games are over, it will be down-sized to 85,000 capacity. The stands in the North and South ends are the only seats not protected from rain and sun. Following the Olympics they will be removed.

The track, which cost $20 million to build, will be rolled up and used at another stadium as a practice track. The existing turf area in Stadium Australia then will be expanded to cover the entire surface of the stadium floor. That will make the stadium available for cricket or Aussie Rules football.

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