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Bermudagrass Freeze Tolerance

Oklahoma State University researchers use laboratory and field evaluations to compare bermudagrass freeze tolerance.

BY JEFF ANDERSON, CHARLES TALIAFERRO, DENNIS MARTIN, YANQI WU, AND MICHAEL ANDERSON

Turfgrass managers spend a considerable amount of time and energy to establish and maintain turfgrasses for aesthetic, environmental, and recreational purposes. Both genetic and environmental components interact to determine how well a chosen cultivar performs in a particular location. An increasing number of fine-textured bermudagrasses are being developed and evaluated for resistance to environmental stresses. Freeze damage is a primary concern in the northern boundaries of the bermudagrass adaptation zone.

Regrowth of CIS-CD7 seeded bermudagrass varied after exposure to a range of sub-freezing temperatures.

Some years are relatively mild and cause little or no damage, while other winters are sufficiently severe to cause extensive winterkill. The costs, in terms of loss of use and dollars to re-establish turf following winterkill, can be substantial. Therefore, our long-term goal is to develop seed- and vegetatively propagated bermudagrasses with high turf quality and improved freeze tolerance.

A common way to compare relative freeze tolerance of a group of cultivars is to establish them in the field and wait for cold temperatures to sort them out. However, during a mild winter, temperatures may not be cold enough to kill any cultivars of interest, and no progress would be achieved. If evaluations were conducted at a northern or high-elevation location, low temperatures may kill most or all of the bermudagrasses. Therefore, several years of observation may be required to experience temperature conditions that distinguish different levels of freeze tolerance within a group of bermudagrass cultivars. Relying on test winters makes it difficult to repeat studies over time and across climatic locations.

Another factor that comes into play during natural freezes is the nature of the freeze itself. Differences in freezing rate or duration, even with the same minimum exposure temperature, can result in different plant responses.[4] Whether or not a snow cover is present can have marked influences on plant survival due to insulation effects. Developmental and morphological features also can be factors in winter survival. The presence of rhizomes can contribute to freeze avoidance by being sufficiently deep in the soil profile to avoid temperature extremes. The well-documented susceptibility of newly seeded bermudagrasses may involve physiological and/or morphological factors such as stolon density.[6]

YEAR-ROUND WINTER INDOORS

Laboratory-based methods to measure freeze tolerance have been developed. One approach has been to acclimate plants naturally in the field, followed by laboratory-based exposure to sub-freezing temperatures. Studies also have been conducted entirely indoors, with plant materials established and acclimated in growth chambers, followed by exposure to a range of temperatures in a freeze chamber. Laboratory-based freeze-tolerance evaluations generally correspond well with field observations and have provided useful information on relative freeze tolerance of turfgrasses.[2]

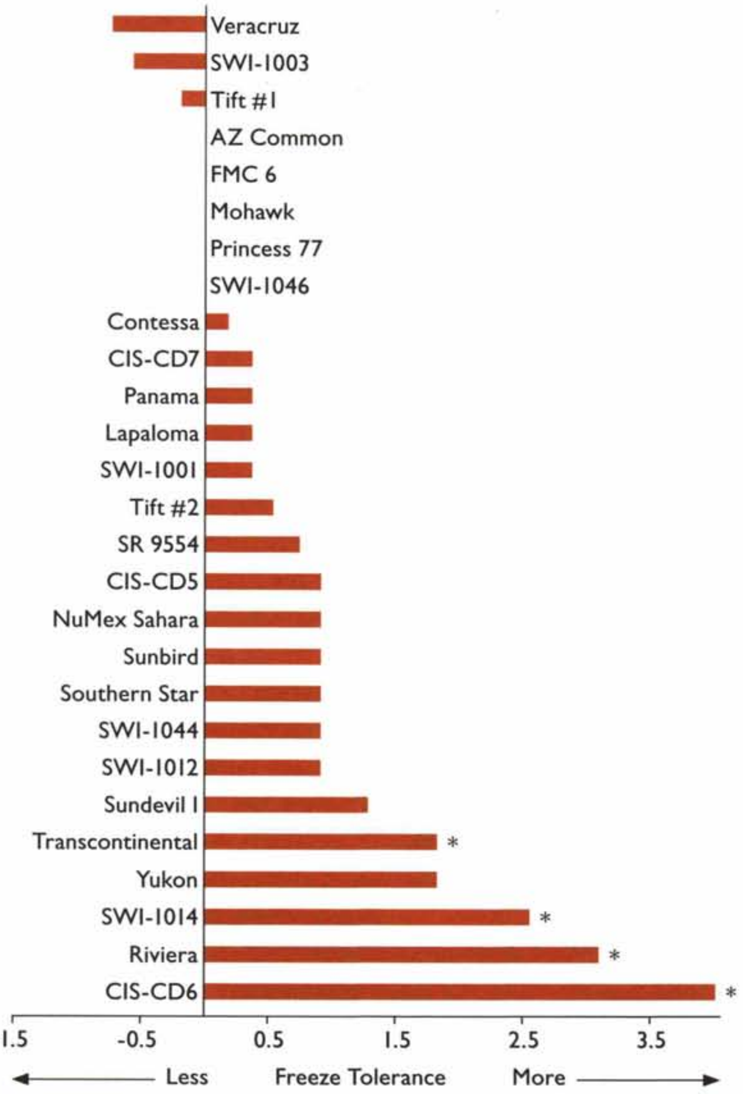
Our objective was to quantify freeze tolerance of advanced lines, recently released cultivars, and standard varieties entered in the 2002 National Turfgrass Evaluation Program (NTEP) bermudagrass trial using laboratory-based methods. Standardized, quantitative information on bermudagrass freeze tolerance is vital to scientists to track progress in developing new cultivars. Freeze tolerance data also are beneficial to turfgrass managers selecting turfgrasses for the transition zone.

Bermudagrass plants were established and maintained in growth chambers. For studies with seed-propagated cultivars, seed from the lots used in the 2002 NTEP bermudagrass trial was obtained from the sponsors. Twenty-seven of the 29 seed-propagated entries were included in this study. Experiments with seed-propagated bermudagrasses were divided into five groups. Entries were randomly selected and assigned to groups with Arizona Common included as a standard in each, allowing the potential for comparisons across groups. Vegetative cultivars were propagated from individual phytomers using Tifway as the standard cultivar in each of the three groups. Experiments were conducted on three dates for each group, constituting replications in time, with staggered plantings allowing uniform establishment periods and plant age.

After plants had acclimated to fall-like temperatures, they were trimmed of top-growth and placed in a freeze chamber with a temperature sensor in each pot. The chamber was programmed to slowly cool the plants, allowing them to be removed over a range of temperatures. Ideally, no damage would occur at the warmest temperatures, and all plants would be killed by exposure to the coldest temperatures.

After being removed from the freeze chamber, plants were thawed and returned to the growth chamber to observe regrowth. Non-frozen controls were treated the same, except without the freeze chamber exposure. Evaluating the temperature-survival curve allowed estimation of a T_{mid} value, similar to the LD_{50} (lethal dose for 50% of the subjects) in a toxicity screen. Data were combined into seeded and vegetative types. Performance relative to the standard cultivar (Arizona Common or Tifway) was determined by subtracting the T_{mid} for each cultivar from the T_{mid} value for the standard in that group.

Figure 1
Deviation temperature (°F) from AZ Common



Freeze tolerance of seed-propagated bermudagrasses relative to Arizona Common. Deviation temperatures represent the T_{mid} value (midpoint of the survival-temperature response curve) of the cultivar minus the T_{mid} value for Arizona Common. Cultivars significantly different from Arizona Common are indicated by an asterisk. Adapted from Anderson et al.[5]

CONSIDERABLE VARIATION IN FREEZE TOLERANCE

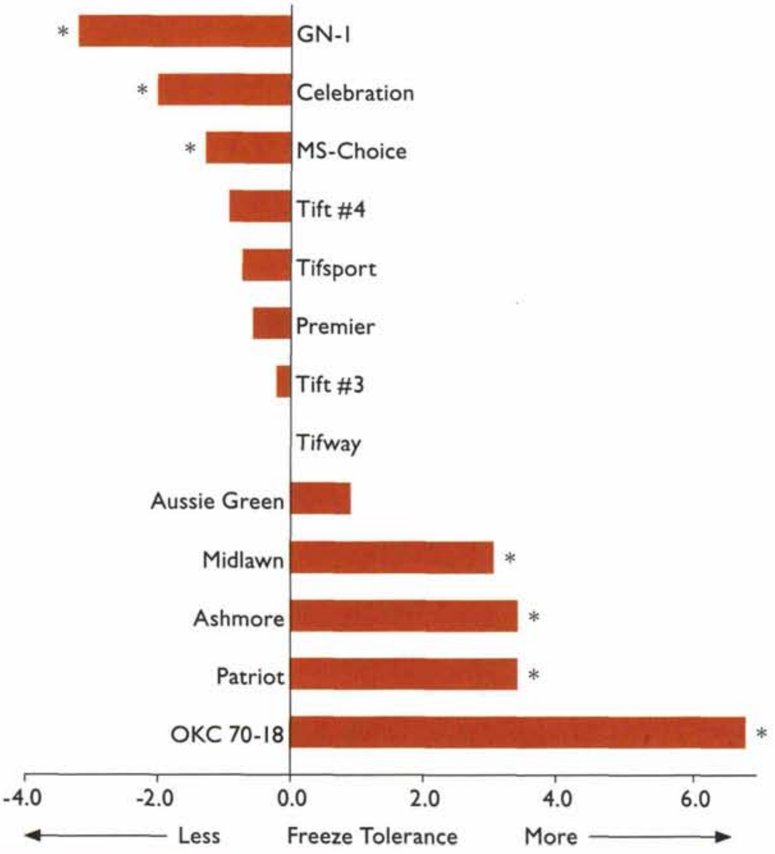
Seed-propagated bermudagrasses ranged in freeze tolerance from 22.5°F (-5.3°C) (SWI-1003) to 16.3°F (-8.7°C) (CIS-CD6). Even though three cultivars were numerically less freeze tolerant than Arizona Common, none of the three was significantly different. FMC 6, Mohawk, Princess 77, and SWI-1046 were identical in freeze tolerance to Arizona Common. Fifteen cultivars had numerically greater, yet non-significant differences, in freeze tolerance relative to the standard. Transcontinental, SWI-1014, Riviera, and CIS-CD6 were significantly more cold hardy than Arizona Common. Although Yukon and Transcontinental differed from Arizona Common by the same amount, the difference was not significant for Yukon at the 5% level due to greater variability in data from Yukon. A previous study that included these two cultivars found Yukon to be significantly more freeze tolerant than Arizona Common.[1]

Laboratory-based methods have been developed to measure turfgrass freeze tolerance. Thermocouple temperature sensors are used to measure soil temperatures.

Bermudagrass plants are acclimated to fall-like temperatures, trimmed of top growth, and placed in a programmable freeze chamber to be exposed to sub-freezing temperatures.

Figure 2

Deviation temperature (°F) from Tifway



Freeze tolerance of vegetatively propagated bermudagrasses relative to Tifway. Deviation temperatures represent the T_{mid} value (midpoint of the survival-temperature response curve) of the cultivar minus the T_{mid} value for Tifway. Cultivars significantly different from Tifway are indicated by an asterisk. Adapted from Anderson et al.[5]

Vegetatively propagated bermudagrasses ranged in freeze tolerance from 20.8°F (-6.2°C) (GN-1) to 11.3°F (-11.5°C) (OKC 70-18). Three cultivars, GN-1, Celebration, and MS-Choice, were significantly less freeze tolerant than Tifway. Tift #4, Tifsport, Premier, Tift #3, and Aussie Green had cold hardiness levels similar to Tifway. Midlawn, Ashmore, Patriot, and OKC 70-18 were significantly more freeze tolerant than Tifway.

Freeze tolerance estimates generally corresponded well with previous experience.[3] Both Midlawn and Patriot exhibited greater freeze tolerance than Tifway as previously reported.[4] Greater freeze tolerance of Riviera than Princess 77 is consistent with earlier findings.[5] In a previous report, we also found GN-1 to be significantly less freeze tolerant than Midlawn.[3]

It is important to distinguish between T_{mid} temperatures determined in the laboratory and air temperatures experienced during a natural freeze. In the laboratory, conditions are set to ensure that plants reach the target temperatures. Critical tissues, such as crowns, of plants in the field will usually be considerably warmer than air temperature due to the thermal buffering capacity of the soil.

Substantial progress is being made by turfgrass breeders to develop seed-propagated and vegetatively propagated bermudagrasses with improved freeze tolerance. Although many factors in addition to freeze tolerance will be assessed in making cultivar selections, choices are now available with freeze tolerance suitable for areas of the transition zone requiring superior winter hardiness.

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CONNECTING THE DOTS

A Q&A with Dr. Jeff Anderson *regarding the use of artificial freeze testing to evaluate turf for cold hardiness.*

Q: *Artificial freeze testing seems like a good method to screen turfgrass selections for freeze tolerance, but how often do laboratory freeze-testing methods disagree with field testing? What other factors besides temperature affect field-grown plants that may lead to these differences?*

A: Research conducted at several universities has shown that field and laboratory results on turfgrass freeze tolerance are usually in agreement. While there are instances when rankings from field studies do not completely match laboratory studies, there also have been cases when results from one field study do not match another. Different locations could have different environmental conditions before a freezing episode, leading to different patterns of acclimation. It also is possible for a cultivar exposed to one environmental stress to be more susceptible to other stresses.

Q: *How long have laboratory freeze-testing methods been used on turfgrasses? Are the methods the same as they were in earlier tests?*

A: Laboratory-based methods of freeze tolerance evaluation have been available for many decades. Ongoing research has led to refinements in testing methods, resulting in greater precision and reproducibility. Important refinements include ice nucleation to negate supercooling and monitoring the temperatures of each experimental unit. Use of microprocessor-controlled chambers and precision monitoring equipment has further improved the precision and reproducibility of the testing procedures.

Q: *Growing plants in the greenhouse to evaluate survival after subjecting those plants to low temperature seems time-consuming. What additional tests are available that scientists can use to measure tissue viability after freezing that don't take as much time?*

A: Viability testing has been a major focus of plant stress studies for many years. Approaches range from whole plant responses to biochemical assays, with each procedure having its strengths and weaknesses. Assays such as electrolyte leakage can be performed much more rapidly than regrowth analysis and have been applied to turfgrasses. When compared, the two procedures are in general agreement. However, there have been instances when electrolyte leakage has either overestimated or underestimated freeze tolerance when compared to regrowth results. One reason may be that freezing stress yields a more gradual electrolyte leakage versus temperature response compared with heat stress, which is very well suited to electrolyte leakage assays. One of the challenges of using electrolyte leakage for freeze tolerance of below-ground structures like crowns and rhizomes is the requirement that tissues be separated from soil/media without introducing artifacts.

Q: *In other articles, the bermudagrass germplasm that Dr. Yanqi Wu collected in China has been mentioned. Have you freeze-tested this Chinese collection and/or evaluated its cold tolerance? From your experience, is it likely that the Chinese bermudagrass germplasm will help improve freeze tolerance of yet-to-be-released bermudagrass cultivars?*

A: The addition of Chinese bermudagrass germplasm to the Oklahoma State University collection provides additional variability that can be used to develop new stress-tolerant, high-quality bermudagrass cultivars. Characterization of this collection and subsequent progeny for freeze tolerance is a priority and will proceed as funding permits. Based on geographic locations of where these plant materials were collected, there is a high probability that a portion of the collected material contains genes that will make plants suitable for locations that experience cold winters.

Q: *How does the "rate of freeze" affect freeze-tolerance measurements?*

A: Plant survival during freezing stress is favored by slow rates of cooling. Most studies use cooling rates of about 2°F per hour, similar to natural conditions. The rate of tissue cooling is not always the same as the rate of air temperature decline, especially for below-ground plant tissues. In addition to the buffering effect of the soil, plant temperatures will be moderated by the heat released when soil moisture freezes. Therefore, the rate of temperature change, the temperature minimum, and the duration of the low temperature exposure will all contribute to the intensity of freezing stress.

Q: *From your experience, does the maturity of the turfgrass stand impact its cold tolerance? Can superintendents expect seeded bermudagrasses to be less cold tolerant the first winter following seeding, and more cold tolerant in subsequent winters?*

A: Although the mechanisms are not fully understood, the long-held belief that seeded bermudagrasses are more freeze susceptible shortly after planting has been reinforced by compelling evidence from research at the University of Arkansas and other locations.

Q: *What should superintendents learn as a "take home" message from your work, Dr. Anderson?*

A: Plant breeding programs around the country are doing an excellent job in developing new bermudagrass cultivars. It is no longer necessary to sacrifice turf quality to achieve stress resistance. Increased freeze tolerance in fine-textured bermudagrass lowers the probability of winter injury in traditional planting locations. While use can be extended to colder locations, even the most freeze-tolerant varieties currently available will be susceptible to winterkill under extreme conditions.

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Editor's Note: An expanded version of this paper can be found at *USGA Turfgrass and Environmental Research Online* (http://usgatero.msu.edu/v06/n18.pdf).

Jeff Anderson, Ph.D., *Professor, Dept. Horticulture & LA, Oklahoma State University, Stillwater, Okla.;* Charles Taliaferro, Ph.D., *Emeritus Regents Professor, Dept. Plant & Soil Sciences, Oklahoma State University, Stillwater, Okla.;* Dennis Martin, Ph.D., *Professor, Dept. Horticulture & LA, Oklahoma State University, Stillwater, Okla.;* Yanqi Wu, Ph.D., *Assistant Professor, and* Michael Anderson, Ph.D., *Associate Professor, Dept. Plant & Soil Sciences, Oklahoma State University, Stillwater, Okla.*