



# Zoysiagrass winter hardiness

Zoysiagrass cultivar selection is important because winter injury and freeze tolerance are variable.

Zoysiagrass (*Zoysia* species) is a warm-season grass that requires few maintenance inputs and is well-adapted to golf courses in the transitional and warm humid zones of the United States. Thus, expanded use of zoysiagrass could play a key role in making golf courses in the transition zone more environmentally friendly and sustainable. However, one key barrier to widespread zoysiagrass use, especially in northern environments, is a relative lack of winter hardiness compared to cool-season grasses. Winter injury of zoysiagrass was first reported in 1947 (8), when researchers reported that both *Zoysia japonica* Steud. and *Z. matrella* (L.) Merr. survived winters in Maryland, but *Z. japonica* had better spring green-up and less winter injury than *Z. matrella*. Zoysiagrass was first used on golf courses in the 1950s when the cultivar Meyer was released, and it gained immediate popularity because of its heat, freezing and drought tolerance in the transition zone.

## Winter injury in field plots

Many newer zoysiagrass cultivars have better texture, shade tolerance, drought tolerance, establishment rate, divot recovery and pest resistance than Meyer, but they do not have greater winter hardiness. Because other cultivars are less cold-hardy, extensive use of zoysiagrass in the transition zone often remains limited to Meyer (5,6). The objective of this study was to determine the differences in winter injury of commercially available and experimental zoysiagrass cultivars in field plots.

## Methods

Both *Zoysia japonica* Steud. and *Z. matrella*

(L.) Merr. were included in this study. Plants of commercially available and experimental cultivars of zoysiagrass (Table 1) were collected and propagated in the greenhouse in plug trays. Vegetatively established cultivars were planted into trays as plugs or stolons, and seeded cultivars were established in trays with 1 pound seed/1,000 square feet (49 kilograms/hectare). After seven months, plants were transplanted into field plots in June 2004 and again in 2005 at the W.H. Daniel Turfgrass Research and Diagnostic Center, West Lafayette, Ind. Plots received nitrogen at 1 pound/1,000 square feet (49 kilograms/hectare) using urea (46-0-0) on July 1 and Aug. 1 of each year.

Each plot was photographed before and after winter with a digital camera. Zoysiagrass coverage was determined using a digital image-analysis technique that selectively identifies green leaves in digital images (12). Images taken of the maximum green coverage before winter dormancy and images taken after winter dormancy (spring green-up) were used to calculate winter injury. Winter injury was determined using the following formula:

$$\text{Winter injury} = 100 - \left[ \frac{\text{Coverage after winter dormancy}}{\text{Coverage before winter dormancy}} \times 100 \right]$$

Data on maximum green coverage before winter were collected on Sept. 28, 2005 and 2006, and spring green-up data were collected on May 23, 2005, and May 20, 2006. Spring green-up



Aaron Patton, Ph.D.  
Zac Reicher, Ph.D.



was the date when new stolon growth (recovery) started to occur in some cultivars.

### Results

Overall, *Zoysia japonica* cultivars had less winter injury than *Z. matrella* cultivars (Table 2). Zorro and Cavalier had the least amount of winter injury among commercially available *Z. matrella* cultivars over both years, but they suffered greater winter injury than Meyer. *Zoysia japonica* is sold commercially both as seed or vegetative propa-

### Zoysiagrass cultivars

Species/cultivar <sup>†</sup>	Type <sup>‡</sup>	Source
<i>Zoysia japonica</i> Steud.		
6136	V	Bladerunner Farms
6186	V	Bladerunner Farms
BMZ 230	V	TAMU - Dallas
Chinese common <sup>§</sup>	S	NTEP
Companion <sup>§</sup>	S	Seed Research of Oregon
DALZ 0102	V	TAMU - Dallas
DeAnza <sup>§</sup>	V	West Coast Turf
El Toro <sup>§</sup>	V	Seedland
Empire <sup>§</sup>	V	Sod Solutions
Empress <sup>§</sup>	V	Sod Solutions
GNZ <sup>§</sup>	V	Greg Norman Turf
Himeno	V	Zoysian Japan Co.
J-36	S	Jacklin Seed/J.R. Simplot
J-37	S	Jacklin Seed/J.R. Simplot
Meyer <sup>§</sup>	V	NTEP
Palisades <sup>§</sup>	V	TAMU - Dallas
PST-R7LT	S	Pure-Seed Testing
PST-R7MA	S	Pure-Seed Testing
PST-R7TH	S	Pure-Seed Testing
PST-R7ZM	S	Pure-Seed Testing
PZA 32	S	Patten Seed Co.
PZB 33	S	Patten Seed Co.
Victoria <sup>§</sup>	V	West Coast Turf
VJ	V	Bladerunner Farms Inc.
Zenith <sup>§</sup>	S	Patten Seed Co.
<i>Z. japonica</i> × <i>Z. pacifica</i> Goudsw.		
Emerald <sup>§</sup>	V	NTEP
<i>Z. matrella</i> (L.) Merr.		
Cavalier <sup>§</sup>	V	TAMU - Dallas
DALZ 0101	V	TAMU - Dallas
DALZ 0104	V	TAMU - Dallas
DALZ 0105	V	TAMU - Dallas
Diamond <sup>§</sup>	V	TAMU - Dallas
Royal <sup>§</sup>	V	TAMU - Dallas
Zeon <sup>§</sup>	V	Bladerunner Farms
Zorro <sup>§</sup>	V	TAMU - Dallas
<i>Z. sinica</i> Hance		
J-14	S	Jacklin Seed/J.R. Simplot

<sup>†</sup>Cultivars are in alphabetical order by species.  
<sup>‡</sup>Type of establishment (propagation) method typically used by superintendents for each cultivar. Cultivars available by seed are typically seeded, with other cultivars typically established vegetatively by sprigs, plugs or sod. All cultivars were established by vegetative plugs into field plots for this study. S, seeded; V, vegetative.  
<sup>§</sup>Cultivar commercially available in the United States as of 2006.

**Table 1.** Zoysiagrass cultivar, species, typical type of establishment method and source of plant material.



Zoysiagrass winter injury plots at Purdue University's W.H. Daniel Turfgrass Research and Diagnostic Center, West Lafayette, Ind. Photo by Cale Bigelow

gules, but *Z. matrella* is only available as vegetative propagules. All cultivars were established by vegetative plugs in the field for this study, but seeded zoysiagrass cultivars had less winter injury than vegetative cultivars of *Z. japonica* and *Z. matrella* (Table 2).

Chinese common, Meyer and Zenith were the only commercially available cultivars with less than 7% winter injury in both years. Among these cultivars, Meyer is the only vegetative cultivar. Several newer commercially available vegetative cultivars were tested in our study, but these cultivars had greater winter injury than Meyer. Meyer is the most widely used cultivar in the transition zone (5), and our studies indicate that, apart from Zenith and Chinese common, few additional commercially available cultivars are sufficiently winter hardy for use in the northern transition zone. However, many experimental cultivars, including BMZ 230, PST-R7LT, PST-R7MA, PST-R7ZM, PST-R7TH, J-14, J-36, J-37 and PZA 32, exhibited levels of winter injury similar to that of Meyer in both years (Figure 1).

Companion, DALZ 0101, Himeno, Zorro, Cavalier, Zeon, El Toro, 6136, Palisades, GNZ and Royal were among the cultivars whose winter injury was intermediate (14%-79%) both years. Diamond, DALZ 0105, 6186, DALZ 0104, Empress, Victoria and DeAnza had the highest (>91%) winter injury in spring 2005. With the exception of Victoria, these same cultivars along with Empire had the highest (>92%) winter injury in spring 2006. Winter injury of cultivars in our study was comparable to previous reports of winter survival across the nation (6,9,11).



Zoysiagrass winter hardiness is probably genetically controlled. Although *Z. japonica* cultivars as a whole had less winter injury than *Z. matrella* cultivars, some cultivars of *Z. japonica* such as Victoria and DeAnza had more winter injury, whereas others such as Palisades and El Toro exhibited intermediate winter injury. Many commercially available *Z. japonica* cultivars may be hybrids and not a single species. Cultivars such as Victoria, DeAnza, El Toro and Palisades are likely hybrids of *Z. japonica* with *Z. matrella* and/or *Z. pacifica* (Goudsw.) Hotta & Kuroki (7,10), but are classified as *Z. japonica* because of their predominant morphological characteristics. *Zoysia pacifica* and *Z. matrella* have been reported to have poor winter hardiness compared to *Z. japonica* (4). Therefore, Victoria, DeAnza, El Toro and Palisades likely had more winter injury than most other *Z. japonica* cultivars because they are hybrids.

### Differences in winter injury

Winter hardiness is largely affected by environmental conditions like soil moisture, snow cover, soil temperatures and duration of cold. Additionally, winter hardiness is influenced by plant genetics and physiology. Therefore, growth-chamber studies can be used to help remove environmental inconsistencies and help determine the physiological basis for differences in freeze tolerance. Researchers at Oklahoma State University developed a standardized, rapid, reproducible regrowth method for quantifying freeze tolerance of bermudagrass (*Cynodon* species), producing results that are consistent with field observations (1). Their method cold-acclimates plants using a growth chamber set at 46/35 F (8/2 C) day/night cycles with a short day length and low light for four weeks. The objective of this study was to evaluate the freeze tolerance of zoysiagrass cultivars using controlled environment acclimation and freezing procedures.

### Methods

Starting in fall 2005, plants were established in pots with a segment of rhizome containing root, crown and shoot material. Thirteen cultivars with various levels of winter injury were planted in the greenhouse. After 10 weeks of establishment in the greenhouse, plants were cold-acclimated for four weeks using a growth chamber set at 46/35 F (8/2 C) day/night cycles and a 10-hour day length (1).

A cold-stress simulator was constructed by modifying a 19.7-cubic-foot (0.55-cubic-meter) chest freezer (3). Plants were placed in the cold-stress simulator to test for relative freeze tolerance of each cultivar after four weeks of cold acclimation. After various freezing treatments, plants

were thawed in a walk-in refrigerator overnight. Plants were then transferred to a greenhouse and evaluated for regrowth for a period of four weeks after freezing.

### Results

Freeze tolerance of zoysiagrass cultivars ranged from 16.9 F (-8.4 C) in Diamond to 11.3 F (-11.5 C) in Meyer and Zenith (Table 3). *Zoysia matrella* cultivars Diamond, Royal and Zorro and the *Z. japonica* cultivar Victoria had poor tolerance to freezing. *Zoysia japonica* cultivars Meyer, Zenith, Palisades, El Toro, Companion and J-36 were all similar and had acceptable freeze tolerance. Freeze tolerance of Meyer 11.3 F (-11.5 C) in our study

### Winter injury by species and type

Species	Type <sup>†</sup>	Winter injury (%) <sup>‡</sup>	
		2005	2006
<i>Z. japonica</i>		19 a <sup>§</sup>	24 a
<i>Z. matrella</i>		51 b	73 b
<i>Z. japonica</i>	seeded	2 a	2 a
<i>Z. japonica</i>	vegetative	41 b	54 b
<i>Z. matrella</i>	vegetative	51 b	73 c

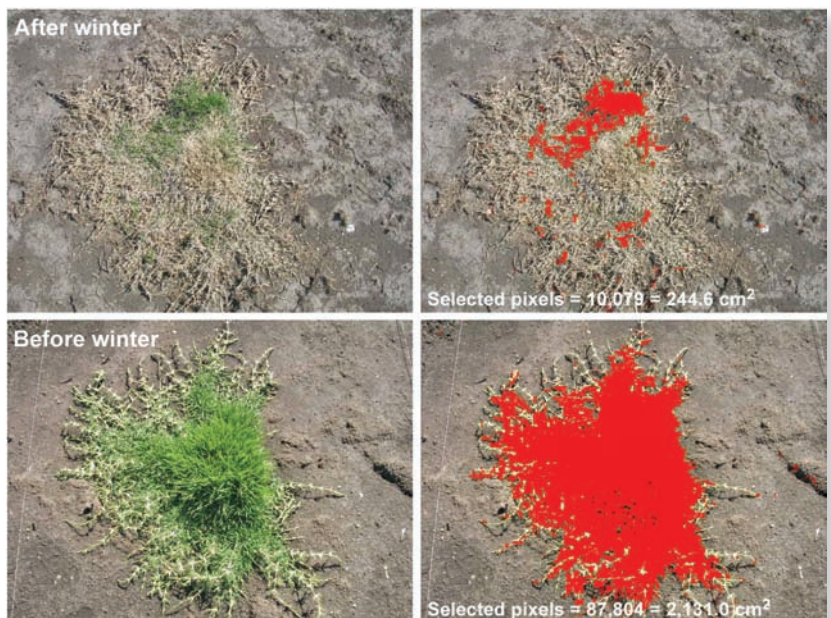
<sup>†</sup>Type of establishment (propagation) method typically used by superintendents for each cultivar. Cultivars available by seed are typically seeded, with other cultivars typically established vegetatively by sprigs, plugs or sod. All cultivars were established by vegetative plugs into field plots for this study.

<sup>‡</sup>Winter injury was determined using the following formula: winter injury = 100 - [(after winter dormancy coverage ÷ before winter dormancy coverage) \* 100]. Coverage of zoysiagrass was determined using digital image analysis.

<sup>§</sup>Within columns, means followed by the same letter are not significantly different.

**Table 2.** Differences in zoysiagrass winter injury by species and by typical type of plant material available for establishment.

Winter injury was calculated using digital image analysis and the following formula: winter injury = 100 - [(coverage after winter dormancy ÷ coverage before winter dormancy) × 100]. Photos by A. Patton





Dormant zoysia fairway at Rolling Hills CC, Evansville, Ind. Photo courtesy of Andy Eble

was similar to that in a previous report of 12.0 F (-11.1 C) to 9.0 F (-12.8 C) (13).

El Toro and Palisades were more freeze-tolerant than anticipated based on our winter-injury data and a previous report (6), but Zorro was less freeze-tolerant than anticipated. Freeze tolerance does not always reflect absolute winter hardiness (2), which can be affected by additional environmental factors in the field such as snow

cover, soil moisture and temperature fluctuations. In addition, in some cultivars, environmental conditions in the field may induce a greater level of cold acclimation than acclimation induced in the growth chamber (2). However, the results from the freeze-chamber and field studies were similar and suggest that this technique could be used to screen breeding material or new cultivars for relative winter hardiness.

Mechanisms involved in the winter hardiness of zoysiagrass are beginning to be understood. As part of this study, we recently investigated the physiological basis for differences in zoysiagrass winter hardiness. We discovered how carbohydrates, proline and certain proteins can affect zoysiagrass freeze tolerance. This new information should help breeders and researchers in the future to improve the freeze tolerance of zoysiagrass cultivars.

### Freeze tolerance

Cultivar	Freeze tolerance (°F)
Diamond	16.9 a
Royal	16.7 a
Zorro	15.8 ab
Victoria	15.3 abc
DALZ 0101	14.0 bcd
DALZ 0102	13.6 cd
Cavalier	13.5 cd
Companion	12.6 de
J-36	12.6 de
El Toro	12.6 de
Palisades	12.2 de
Zenith	11.3 e
Meyer	11.3 e

Note. Freeze tolerance is the temperature at which only 50% of the plants survive. Each entry is the mean of six experimental replications. Higher values indicate poorer freeze tolerance. Means followed by the same letter are not significantly different from each other.

Table 3. Freeze tolerance of zoysiagrass plants. Higher values indicate poorer freeze tolerance.

### Winter injury

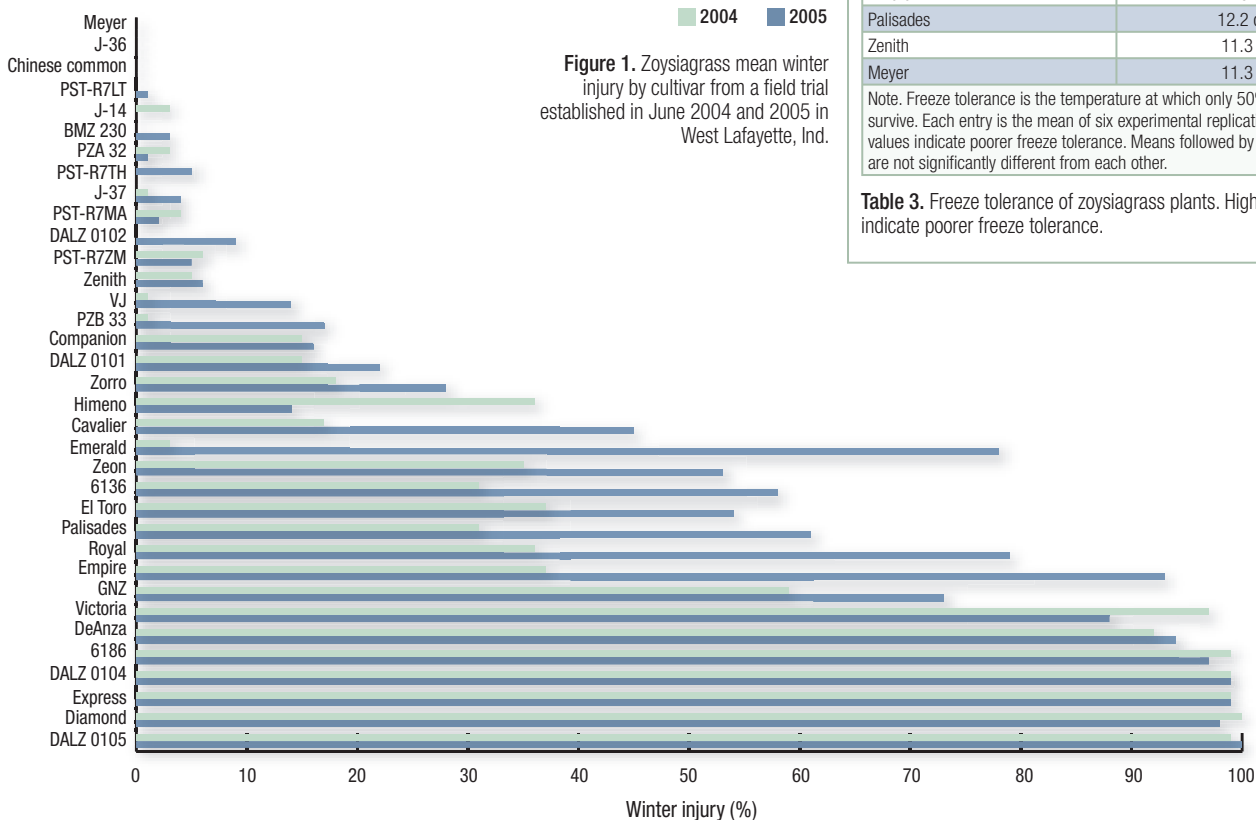


Figure 1. Zoysiagrass mean winter injury by cultivar from a field trial established in June 2004 and 2005 in West Lafayette, Ind.



The freeze tolerance of Meyer zoysiagrass is shown in the photograph as -11.5 C (11.3 F), the temperature at which only 50% of the plants survive. All temperatures in the photograph are in Celsius. Photo by A. Patton

### Summary

Our results show large differences between species and cultivars of zoysiagrass in response to low temperatures and winter. *Zoysia japonica* cultivars generally exhibited less winter injury than *Z. matrella* cultivars. Additionally, seeded zoysiagrass cultivars exhibited less winter injury than other cultivars. Our results indicate that there are a limited number of currently available cultivars (Meyer, Chinese common and Zenith) well adapted to northern areas of the transition zone, but that experimental cultivars with low winter injury are being developed. Relative rankings of the winter injury of zoysiagrass in West Lafayette, Ind., which is north of the transition zone, will be useful for superintendents selecting zoysiagrass cultivars for use in the transition zone. Selecting and establishing cultivars well adapted to the transition zone will help reduce winter injury and ensuing reestablishment costs, thus increasing golf course revenues and sustainability of turfs.

### Funding

We gratefully acknowledge the Midwest Regional Turfgrass Foundation and the Tri-State Superintendents Association for partial support of this project.

### Acknowledgments

The authors thank Jon Trappe for helping with planting; Judy Santini for help with statistical analysis; and Jack Banker, ThermoTech Systems Inc., for technical assistance in constructing and programming the cold-stress simulator.

### Literature cited

1. Anderson, J.A., C.M. Taliaferro and D.L. Martin. 1993. Evaluating freeze tolerance of bermudagrass in a controlled environment. *HortScience* 28(9):955.
2. Anderson, J.A., C.M. Taliaferro and D.L. Martin. 2002. Freeze tolerance of bermudagrasses: vegetatively propagated cultivars intended for fairway and putting green use, and seed-propagated cultivars. *Crop Science* 42(3):975-977.
3. Beard, J.B., J.M. DiPaola and S.M. Batten. 1980. Devel-

- opment of a cold stress simulator to be used in screening for cold hardiness. Texas Turfgrass Research - 1978-1979. Texas Agricultural Experiment Station PR-3675:35-40.
4. Daniel, W.H. 1955. Zoysia for Midwest lawns. p. 34. In: Midwest Regional Turf Foundation Conference Proceedings. Midwest Regional Turf Foundation and Department of Agronomy, Purdue University, West Lafayette, Ind.
5. Dunn, J.H., and K. Diesburg. 2004. Turf management in the transition zone. John Wiley and Sons, Hoboken, N.J.
6. Dunn, J.H., S.S. Bughrara, M.R. Warmund and B.F. Fresenburg. 1999. Low temperature tolerance of zoysiagrasses. *HortScience* 34(1):96-99.
7. Engelke, M.C., R.H. White, P.F. Colbaugh, J.A. Reinert, et al. 2002. Registration of 'Palisades' zoysiagrass. *Crop Science* 42:305-306.
8. Forbes, I., and M.H. Ferguson. 1947. Observations on the zoysia grasses. *The Greenkeepers' Reporter* 15(2):7-9.
9. Fry, J.D. 2002. Zoysia cultivar trial. [Online]. p.30-31. In: Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Kansas State University, Manhattan. [www.oznet.ksu.edu/library/hort2/SRP878.pdf](http://www.oznet.ksu.edu/library/hort2/SRP878.pdf) (verified Feb. 13, 2007).
10. Gibeault, V.A. 2003. Zoysiagrass for California. *California Turfgrass Culture* 53:1-2.
11. National Turfgrass Evaluation Program. 2001. National zoysiagrass test-1996: Final Report 1997-2000. NTEP No. 01-15. USDA ARS, Beltsville Agricultural Research Center and National Turfgrass Federation, Beltsville, Md.
12. Richardson, M.D., D.E. Karcher and L.C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. *Crop Science* 41(6):1884-1888.
13. Rogers, R.A., J.H. Dunn and C.J. Nelson. 1975. Cold hardening and carbohydrate composition of Meyer zoysia. *Agronomy Journal* 67(6):836-838.

### GCM

Aaron Patton (ajpatton@uark.edu) is an assistant professor of turfgrass science at the University of Arkansas, Fayetteville. Zac Reicher is a professor of turfgrass science at Purdue University, West Lafayette, Ind.



### The research says

→ Lack of winter hardiness may limit widespread use of newly released zoysiagrass cultivars in the transition zone.

→ As a whole, *Zoysia japonica* cultivars had less winter injury than *Z. matrella* cultivars, and seeded zoysiagrass cultivars had less winter injury than vegetatively established cultivars.

→ Meyer, Chinese common and Zenith were the commercially available cultivars exhibiting the least winter injury (<7%) in both years, whereas Victoria, DeAnza, Diamond and Empress had the most winter injury (>87%) in both years.

→ Relative rankings of the winter injury of zoysiagrass in West Lafayette, Ind., which is north of the transition zone, will be useful for superintendents selecting zoysiagrass cultivars for use in the transition zone.

→ Establishment rate, divot recovery, color and density are important factors in choosing a zoysiagrass cultivar, but winter hardiness is the most important trait for superintendents in the transition zone.