USGA Sponsored

Research *That Benefits Golf*

Zoysiagrass, Salt Glands, and Salt Tolerance

Observing the density of salt glands may make selecting for salt-tolerant grasses a lot easier.

BY K. B. MARCUM, G. WESS, D. T. RAY, AND M. C. ENGELKE

Water shortages throughout the United States are resulting from rapid urbanization and drought. In the western U.S., limited water supplies have caused some municipalities to implement xeriscape programs. With 50% or more of total urban water consumption being utilized for landscape irrigation in western states, many municipalities are requiring use of recycled or other saline secondary water sources for turf landscapes.

Though there is increasing need for improved salt-tolerant turfgrass cultivars, breeding progress has been limited. Turf breeders typically need to select among hundreds or thousands of progeny to come up with an improved cultivar. Selection for salt tolerance among so many progeny is difficult, time-consuming, and expensive. Therefore, accurate and efficient salt-tolerance screening tools are needed to expedite turf cultivar development. These tools may be morphological or physiological markers that can be used to predict salt tolerance.

SALT GLANDS — A SALT-TOLERANCE MECHANISM IN TURF

Most plants, including grasses, exclude saline ions (sodium, chloride, etc.) from shoots and leaves to minimize their toxic effects. Saline ion exclusion from shoots has been associated with salt tolerance among grasses in a number of studies and is a major physiological process associated with salt tolerance.

Salt glands are found in a number of warm-season (C4) grasses, including bermudagrass, zoysiagrass, buffalograss, saltgrass (*Distichlis spicata* var. *stricta*), dropseeds (*Sporobolus spp.*), gramagrasses (*Bouteloua spp.*), and curly mesquite (*Hilaria belangeri*). Salt glands, which are actually miniature ion pumps, secrete salt from leaves and can be a major means of excluding saline ions in salt-tolerant grasses. In fact, in salt-tolerant grasses having active glands, secreted salt crystals can be seen on leaves of plants growing in salty soils.

Salt glands, which are modified leaf microhairs (trichomes), are microscopic two-celled structures that lie flat on the leaf surface in rows parallel to stomates. Unlike internal physiological plant markers, salt glands are externally visible and morphological. They can be easily observed on grass leaves. The goal of this research was to determine if salt gland density can be used to predict turfgrass salt tolerance, and if they can be used as an effective salt-tolerance selection tool by turfgrass breeders.

THE EXPERIMENT — SALT TOLERANCE

Fifteen zoysiagrasses (Japanese lawngrass, *Zoysia japonica*) were tested for salinity tolerance using a solution culture-hydroponics growing system. This system allows precise control of salinity levels and can accurately determine differences in salt tolerance among turfgrass varieties. It also allows monitoring of both root and shoot responses to salinity. To compare salt tolerance among entries, changes in shoot growth (clipping weight), root growth, and visual quality (percent green leaf area) were observed at six different salinity levels over a growth period of several months.

Throughout the experiment, grasses were clipped twice per week at one inch. As salinity increased, leaf clipping weight decreased linearly. The relative shoot growth and visual quality (percent green leaf area) at high salinity were used to indicate the relative salinity tolerance of varieties. The most salt tolerant varieties were El Toro and Palisades, and the least tolerant were Sunrise, K162, JS-23, and K157.

SALT GLANDS — A POTENTIAL TOOL FOR TURFGRASS BREEDING

Salt gland densities were determined for all entries, growing under both salt-free (control) and saline conditions. Densities were determined using a light microscope, with 120 observations taken on each zoysiagrass variety (each observation was a gland count).

It had been previously found that salt tolerance in zoysiagrasses and in general among Chloridoid warm-season grasses (bermudagrass, buffalograss, zoysiagrass, gramagrasses, *Sporobolus*, and saltgrass) was related to the amount of salt that the salt glands were able to secrete (the amount pumped out of the leaves).

In addition, results of this study show that salt tolerance and salt gland activity are related to the actual density of salt glands on the leaves, or the number of glands per unit of leaf area. There is a positive correlation with both leaf salt gland density and salt tolerance. In other words, as leaf salt gland density increases, so does salt tolerance.

If salt gland density is to be a valuable screening tool for turfgrass breeders, it must be genetically, not environmentally, controlled. In other words, salt gland density must be highly heritable (passed from parent to offspring). To determine this, we measured salt gland density of varieties growing both in a saline environment and in a salt-free environment.

It was found that salt glands are not induced by salt stress, i.e., within a variety there was no difference in gland density between a plant grown in saline conditions and one grown in salt-free conditions. In other words, the grasses are "born" with a certain density, depending on their genetics. Averaged across all genotypes and within a genotype, there was less than a 1% difference between control (non-stressed) and salt-stressed grasses, indicating a very high heritability for this trait.

Table 1

Predicting salt tolerance of zoysiagrasses, based on the relative clipping weight and on visual quality (percent green leaf area) at high salinity. Grasses are listed from highest to lowest salt tolerance. Shoot growth and green leaf area variables were highly correlated ($R^2 = 0.73$) and are equally effective in predicting salinity tolerance.

Grass	Relative Clipping Wt.	% Green Leaf Area
El Toro	83	52
Palisades	68	45
Meyer	56	20
J3-2	55	48
P58	55	47
Belair	54	54
Crowne	52	24
K12	23	9
J21	20	6
J94-5	19	3
Korean Common	12	2
K16	20	0
Sunrise	0	0
JS-23	0	0
K157	0	0

A greenhouse hydroponic system was used to investigate turfgrass salinity tolerance. This system allows for precise control of salinity levels, and both shoot and root responses to salinity can be monitored.

Salt gland density on grasses grown in salt-free conditions predicted salinity tolerance as well as plants grown under saline conditions. This is the first report of a morphological (visual) trait that can be used to predict salt tolerance of grasses. Salt gland density is an innate, genetically controlled, heritable trait that does not require environmental stress conditions to express it.

Accurately screening hundreds or thousands of breeding selections for salt tolerance is difficult and expensive. Salt gland density is a much easier screening procedure that could expedite selection of salt-tolerant grasses in that the breeder need only measure salt gland density on leaves of plants growing under regular (non-salt) conditions.

LITERATURE CITED

1. Access, newsletter of the American Water Works Association, May 2003, Vol. 2, Issue 2, pp. 1, 3.

2. Amarasinghe, V., and L. Watson. 1989. Variation in salt secretory activity of microhairs in grasses. *Aust. J. Plant Physiol.* 16:219-229.

3. Arizona Department of Water Resources. 1995. Modifications to the second management plan: 1990-2000. Phoenix, Ariz., 74 pp.

4. California State Water Resources Control Board. 1993. Porter-Cologne Act provisions on reasonableness and reclamation promotion. California Water Code, Section 13552-13577.

5. El Paso Water Utilities Public Service Board. 1992. El Paso Water Resource Management Plan, Nov.

6. Fahn, A. 1988. Secretory tissues in vascular plants. *New Phytol.* 108:229-257.

7. Gorham, J., R. G. Wyn Jones, and E. McDonnell. 1985. Some mechanisms of salt tolerance in crop plants. *Plant Soil* 89:15-40.

8. Hannon, N. J., and H. N. Barber. 1972. The mechanism of salt tolerance in naturally selected populations of grasses. *Search* 3:259-260.

9. Johnson, R. C. 1991. Salinity resistance, water relations, and salt content of crested and tall wheatgrass accessions. *Crop Sci.* 31:730-734.

10. Kjelgren, R., L. Rupp, and D. Kilgren. 2000. Water conservation in urban landscapes. *HortSci.* 35(6):1037-1040.

11. Marcum, K. B. 2001. Growth and physiological adaptations of grasses to salinity stress. Pages 623-636. *In:* M. Pessarakli (ed.), Handbook of Plant and Crop Physiology, Marcel Dekker, Inc., N.Y.

12. Marcum, K. B. 1999. Salinity tolerance mechanisms of grasses in the subfamily Chloridoideae. *Crop Sci.* 39:1153-1160.

13. Marcum, K. B., and C. L. Murdoch. 1990. Salt glands in the Zoysieae. *Ann. Bot.* 66:17.

14. Marcum, K. B., S. J. Anderson, and M. C. Engelke. 1998. Salt gland ion secretion: A salinity-tolerance mechanism among five zoysiagrass species. *Crop Sci.* 38:806-810.

15. Naidoo, G., and Y. Naidoo. 1998. Salt tolerance in *Sporobolus virginicus*: The importance of ion relations and salt secretion. *Flora-Jena* 193:337-344.

16. Smith, C. S., and R. St. Hilaire. 1999. Xeriscaping in the urban environment. *New Mexico J. Sci.* 38:241-250.

17. Wu, L., and H. Lin. 1994. Salt tolerance and salt uptake in diploid and polyploid buffalograss (*Buchloe dactyloides*). *J. Plant Nutr.* 17:1905-1928.

18. Yeo, A. R. 1983. Salinity resistance: Physiologies and prices. *Physiol. Plant.* 58:214-222.

K. B. MARCUM, PH.D., *is an assistant professor, Department of Applied Biological Sciences, University of Arizona*; G. WESS *is a graduate student*; D. T. RAY, PH.D., *is a professor, Plant Genetics, Department of Plant Sciences, University of Arizona*; M. C. ENGELKE, PH.D., *is a professor, Texas A&M University Research and Extension Center, Dallas.*