

Pass the salt

Irrigating with salt water may give bermudagrass an edge entering winter.

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Bermudagrass (*Cynodon dactylon* [L.] Pers.), brought to the United States from Africa in the 18th century, is adapted to hot, dry summers and originated in a subhumid environment (11). In the United States, however, bermudagrass is widely grown on golf courses in the transition zone, at the northern limit of its zone of adaptation, where it goes dormant in the winter and may not survive even the most moderate of cool temperatures.

Besides enduring cold weather, bermudagrass turf may also be asked to tolerate salinity in the form of effluent water. Although the use of nonpotable water remains voluntary for many areas of the country, increasing water restrictions in the near future may mandate effluent usage by a growing number of golf courses.

Salt vs. turf

One of the big concerns with using wastewater is the salinity hazard. Effluent water sources often contain soluble salts such as sodium, chloride, sulfur, potassium, calcium and magnesium, which can inhibit water movement into the plant (9). High salt levels

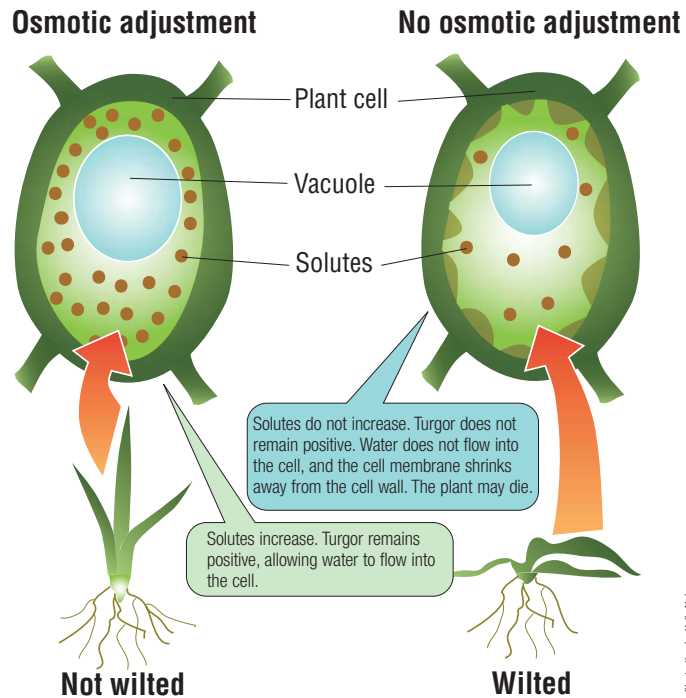


Figure 1. Osmotic adjustment allows solutes to increase, turgor to remain positive and water to flow into the cell. Adapted from Buchanan et al. (2).

KEY points

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Bermudagrass is more tolerant of saline water because it is able to retain cell turgor despite fluctuations in water availability.

Because the processes that occur during cold acclimation are similar to those that occur during salinity stress, we hypothesized that cold hardiness of bermudagrass may be increased by exposure to mild salt stress.

This study found that irrigating bermudagrass with moderately saline effluent may increase the turf's cold tolerance.

in the root zone cause a condition in plants known as *physiological drought*. Less water is available for plant uptake from the soil because the water in the soil is more attracted to the salt (3). Physiological drought is very similar to normal drought as it causes reductions in growth rate, photosynthesis, cytokinin synthesis and transpiration rate.

Bermudagrass can cope with physiological drought because it is able to keep cell turgor high through a process called *osmotic adjustment*. (*Turgor* is the force exerted on a cell wall by the water in the cell; the more water in the cell, the greater the turgor. Turgor gives plants rigidity and allows them to remain erect.) *Osmotic adjustment* is

important because, as solutes build up in the cell, turgor pressure remains high, even under water stress (Figure 1). This can drive the water potential in the roots to become lower than the water potential in the soil, which will allow water uptake even in droughty or salty soils.

Two processes are involved in osmotic adjustment in response to changes in water potential. The first is an accumulation of ions in the vacuole of the cell. Ions such as K^+ , Ca^{2+} and Na^+ can accumulate in the cell to decrease water potential without adjusting turgor pressure during dry or saline conditions. At high levels, these ions can be toxic to the cytosol, so they must be sequestered in the vacuole. Because these ions are compart-

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mentalized in the vacuole, other solutes such as organic acids must accumulate in the cytoplasm to maintain water potential equilibrium in the cell. These organic acids, known as compatible solutes, include proline, glycine betaine, sucrose and sorbitol (13,16). Compatible solutes are able to build up to high levels in the cytosol without interfering with cell metabolism.

During cold stress, plants also accumulate sucrose and other simple sugars as well as proline and glycine betaine. These solutes are reported to stabilize cell membranes and act as *osmolytes* (highly soluble organic compounds that do not interfere with cellular metabolism) to maintain water balances between the cell and the environment (8,13).

Sodium chloride applications on non-hardened plants can induce cold hardening (7). Different stresses can have very similar effects on plant processes, and the processes that occur during cold acclimation are very similar to those that occur during salinity

stress. These similarities include stabilization of membranes, and accumulation of specific proteins, sugars and osmolytes such as proline (2). Because of these similarities, we hypothesized that cold hardiness of bermudagrass may be increased by exposure to mild salt stress before hardening temperatures.

Our objectives were to determine the effects of saline irrigation on bermudagrass canopy growth, visual quality, photochemical efficiency and proline concentration and to determine whether these treatments and effects were associated with changes in freezing tolerance.

Greenhouse research

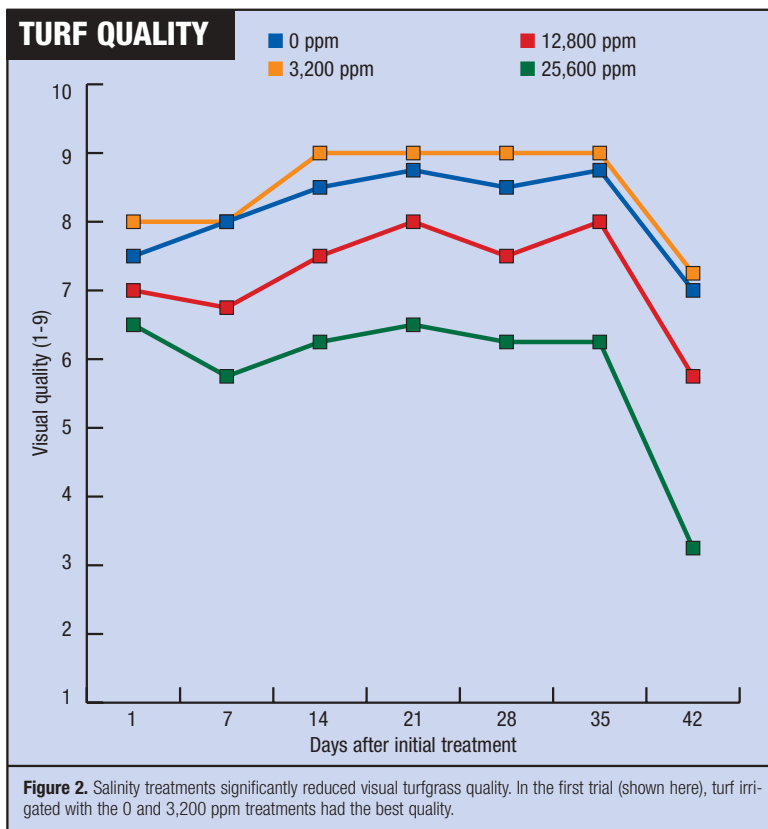
Two greenhouse studies were conducted in the summer of 2002. We used a seeding rate of 0.5 pound pure live seed/1,000 square feet (24.4 kilograms/hectare) of Princess-77 bermudagrass (*Cynodon dactylon* L.) supplied by Charlie Rogers, Ph.D. (Seeds West, Maricopa, Ariz.). Pots of 6 inches (15.2 cen-

timeters) in diameter were filled with a greens-grade sand with a pH of 6.8. Each pot received a soluble application of 20-20-20 at seeding to provide 1 pound nitrogen/1,000 square feet (48.8 kilograms/hectare). Pots were clipped (with scissors) at 0.75 inch (19.1 millimeters) until maturity was reached and then left unclipped for the duration of the study.

Once maturity was reached, salinity treatments began by irrigating with sodium chloride concentrations of 0, 3,200, 12,800 and 25,600 parts per million (ppm) twice weekly. The concentration is the amount (by weight) of salt that was added to distilled water. Thus, 3,200 ppm equals 0.3% salt per unit volume of water, 12,800 equals 1.3%, and 25,600 ppm equals 2.5% salt per unit volume of water. As a reference, seawater has a salinity that is close to 35,000 ppm, or 3.5% salt.

A soluble solution of 20-20-20 was mixed with the salt solution once weekly to provide 1 pound nitrogen/1,000 square feet (48.8 kilograms/hectare) plus micronutrients, and electrical conductivity (EC) of the soil was measured at the beginning and end of the salinity treatments to determine soil salinity level. Quality ratings were taken weekly using the 1-9 scale, where 1 = brown, dead grass; 5 = minimally acceptable; and 9 = dark green healthy grass. Photochemical efficiency of the bermudagrass canopy was obtained using a chlorophyll fluorometer as an indicator of plant health. Plant height was obtained by measuring the tallest plant in each pot at the end of the study.

After two months of saline irrigation, the pots were removed from the greenhouse and placed in a controlled environment chamber and acclimated with cool temperatures and short days (1). After two weeks in the cold chamber, the plants were prepared for placement in a freeze chamber. A 4-inch- (10.2-centimeter) diameter cup cutter sample was removed from the pots, cleaned of all soil by washing and divided into four equal samples. These samples were then placed in a chamber that freezes samples at temperatures ranging from 27 to 19 F (-2.8 to -1.7 C). Samples were then allowed to thaw in the refrigerator overnight at 39 F (3.9 C) and placed in the greenhouse at 72 F (22.2 C) and allowed to recover. Regrowth was then estimated approximately four weeks after freezing (15). Regrowth was measured only



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in the second trial. Additional plant samples were removed at the same time as freezing for proline analysis.

Results and discussion

Turf quality

Salinity treatments significantly reduced visual turfgrass quality (Figure 2). In the first trial, turf irrigated with the 0 and 3,200 ppm treatments had the best quality. In the second trial, however, the 3,200 and 12,800 ppm treatments resulted in the best quality. Chlorophyll fluorescence readings showed similar trends to the quality ratings.

A large reduction in visual quality ratings and chlorophyll fluorescence was expected because of the physiological drought expected from the salt treatments. The moderate stress of the 3,200 and 12,800 ppm treatments did not have a large effect on turfgrass quality. This appears to be in agreement with salinity stress on St. Augustinegrass, where salt treatments as high as 20,700 ppm improved turf density and did not negatively affect leaf color (12). However, others reported turf

color reductions and burning of bermudagrass with high salinity (6).

Soil EC

Soil EC measurements were taken before and after salinity treatments (Table 1). At the beginning of the first trial, all EC readings were low. By the end of the experiment, the EC of the soil from the 3,200 ppm treatment had increased 108% over the control. The 12,800 and 25,600 ppm treatments increased soil EC levels 364% and 505%, respectively, over the control. The second trial showed similar results at the end of the salinity treatments.

Plant height

Heights were measured at the end of the second trial (Table 1). Treatments with higher salinity caused larger decreases in plant height than the treatments with lower salinity. Others have found similar results in zoysiagrass (14). With salinity levels of approximately 12,800 ppm, shoot growth reductions occurred. An earlier study (5) reported 50% top growth reductions of

Tifway bermudagrass with salinity levels of about 21,000 ppm.

Proline

Proline concentrations were determined before and after salinity applications (Table 1). In both trials, there was a large increase in proline concentration after salinity treatment. In the first trial, turf irrigated at the 12,800 ppm salinity rate had the highest production of proline, whereas in the second trial, turf irrigated at the 25,600 ppm rate had the highest. The higher salinity rates were expected to produce the highest amount of proline as the plants were under higher levels of stress. Other researchers (10) have looked at the influence of salinity in bermudagrass and five other turfgrass species and found that levels of proline and glycine betaine increased as salinity increased. The authors also make the statement that in five of the six species (including bermudagrass), an increase in these solutes may make a significant contribution to osmotic adjustment in the cytosol.

Regrowth of plants after freezing was measured in the second trial (Figure 3). Turf

SALINITY EFFECTS

Salt treatment	Soil EC (ppm)		Proline (% plant weight)		Final canopy height	
	Initial	Final	Initial	Final	Inches	Centimeters
Trial 1						
0	5.2×10^{-7} ns	3.1×10^{-6} c	0.0032 ns	0.417 b	—	—
3,200	5.8×10^{-7} ns	6.4×10^{-6} bc	0.0064 ns	0.464 b	—	—
12,800	6.6×10^{-7} ns	1.4×10^{-5} ab	0.0082 ns	0.626 a	—	—
25,600	7.0×10^{-7} ns	1.9×10^{-5} a	0.0128 ns	0.555 ab	—	—
Trial 2						
0	5.5×10^{-7} b	8.6×10^{-7} d	0.0051 c	0.141 c	10.4 a	26.4 a
3,200	3.8×10^{-6} ab	4.1×10^{-6} c	0.0089 c	0.187 c	9.1 a	23.1 a
12,800	7.7×10^{-6} ab	1.2×10^{-5} b	0.0212 b	0.274 b	6.3 b	16.0 b
25,600	1.1×10^{-5} a	1.9×10^{-5} a	0.0313 a	0.381 a	5.2 b	13.2 b

Note. Values followed by the same letter within the same column are not significantly different.

Table 1. Effects of added salinity on soil EC, plant proline concentration and canopy height.

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irrigated with the moderate salinity treatments of 3,200 and 12,800 ppm had the highest percent regrowth after freezing. Although the plants receiving the high salinity treatment rate of 25,600 ppm had the highest proline concentration, they did not have the highest survival. The highest salinity treatment may impose too much stress on the plants before freezing, resulting in a weaker plant less capable of surviving freezing temperatures.

Summary

Superintendents in the transition zone may find that using effluent with a moderate salinity level (1,920-3,840 ppm) has at least one benefit: increased cold tolerance. The increased proline concentration shows that moderate sodium chloride treatments positively influence freezing tolerance. If proline concentrations play a major role in dictating increased cold hardiness levels, then moder-

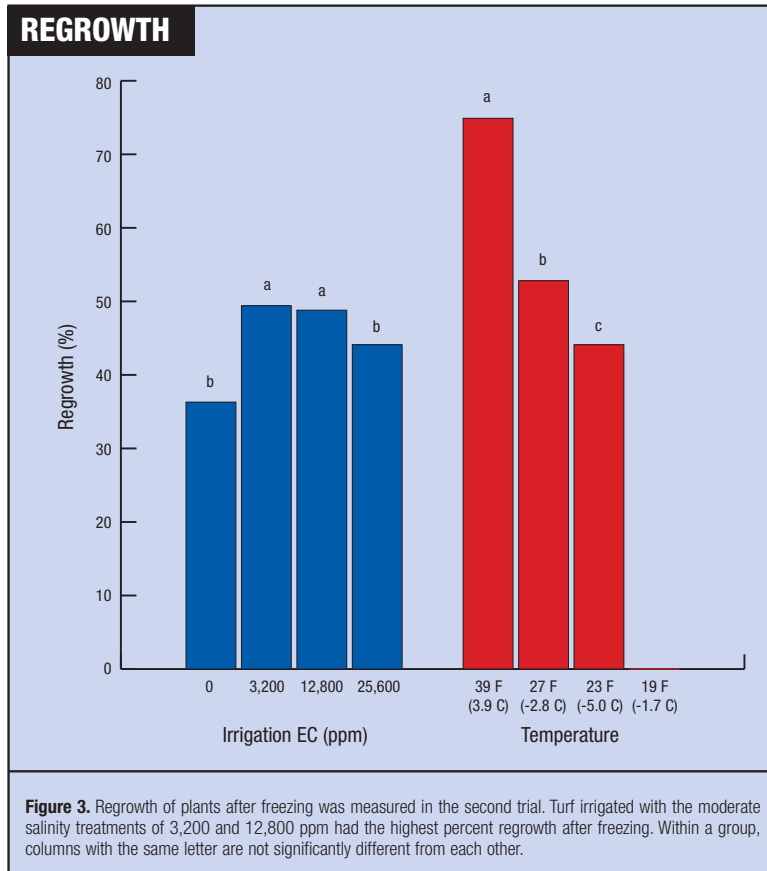
ate levels of salinity stress may very well be beneficial to bermudagrass in surviving cold temperatures. In 1998, researchers (4) suggested that a salinity level of 3,840 ppm could be used as a supplemental irrigation source for Numex Sahara bermudagrass as long as the water deficit was minimized. In this study, a salinity level of 3,840 ppm would have been high enough to affect freezing tolerance positively.

Acknowledgments

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