New Zoysia Varieties Offer Enhanced Ability to Extract Salt from Soil and Water

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Management of salinity has become integral to the sustainability of the golf industry. Dwindling fresh water resources and recurrent droughts have made the use of marginal water, sourced from either reclaimed municipal sources or aquifers contaminated by saltwater intrusion, routine, especially in the south. In recent decades, the industry has turned to Paspalum, a known halophyte, as a species to address high salinity situation including coastal developments, saline soils and more recently the utilization of effluent and alternative water resources.

Salt tolerance in plants is the product of a complex suite of processes including exclusion of the sodium ion from uptake by the plant (as often suggested in use of the Paspalum species) as well as uptake of sodium from the soil into the root, transfer to the leaf, and sequestration into the cell vacuole (Binzel et al. 1988, Binzel and Reuveni 1994). The efficiency and coordination of these processes, coupled with other physiological and biochemical mechanisms associated with salt tolerance ultimately determine the capacity of the plant to tolerate a saline environment. When the capacity of these mechanisms is overwhelmed, the result is that the plant ultimately succumbs to the salt injury. This injury is initially manifested as leaf burn or firing, followed by death. Not only can the biological capacity of the plant tissue become overwhelmed, but the accumulation of salts within the soil profile can result in total soil structure degradation and collapse.

The level of salt in these marginal sources may only be modest (on the order of hundreds of ppms), but continued application in the absence of significant rainfall leads to the accumulation of much more extreme levels of salts, on the order of thousands of ppms of salt (i.e. 2000-4000 pm or 2-4 dS/m). Mechanical intervention is required to aid in reducing the toxic ion level in the soil profile and short of physical extraction, these salts must be resolubilized and moved downward away from the crown and growing points of the plant. Frequent rain events naturally provide a “leaching or flushing” action, however during periods of prolonged drought, routine irrigation practices will not be sufficient to “move” the salts downward and out of harm’s way. This has led to the mechanical practice of flushing or leaching, to reduce soil salinity below a threshold that permits plant survival. Unfortunately, this leaching represents a sizeable consumption of water; and leads to elevated costs, not only from the water itself, but nutrients inevitably flushed as well, and the associated management costs of conducting the flush.

One approach is to utilize turfgrasses that can withstand somewhat elevated levels of salts in the soils. Several studies have documented the relative salt tolerance of seagrass (Paspalum) and zoysiagrasses as compared to other warm season grasses (Marcum and Murdoch 1994, Udin et al. 2012). Although both zoysia grass and Paspalum are considered salt tolerant, there are striking differences in how these plants deal with salinity. Zoysiagrasses extract salts from the soil profile and Paspalums exclude salts from being absorbed into the plant.

Even with halophytes, a level of soil salinity can easily be reached which results in destruction of soil structure generally associated with the lack of soil water and air movement. Even Paspalum can fail at high levels and remedial flushing and removal of these accumulated salts is required.

A key difference is that all Zoysias possess salt glands and Paspalums do not. These glands, which are modified trichomes (plant hairs), enable zoysiagrass to actively absorb – uptake salts into the plant and to excrete a portion of the salt to the shoots and leaf surface. Several investigators have reported variation in the relative salt tolerance of different zoysia lines, as well as differences in the amount of salt that accumulates in the tissue (Marcum et al. 1998, Qian et al. 2000, Udin et. al 2012, Yamamoto et al. 2016). This ability to pump excess salt out of the leaf tissue and onto the leaf surface may enhance the ability of some Zoysias to not only tolerate salt, but remediate their immediate environment as well.

RESEARCH OBJECTIVE

The goal of this study was to assess the salt tolerance of several new Zoysia selections under development and to evaluate their performance relative to commercial cultivars of Zoysia and seagrass (*Paspalum vaginatum*). Among the recent generation of Zoysiagrasses commercially available, 'Diamond' (*Z. matrella* origin) has been shown to have high salt tolerance in several studies (Chen et al. 2009, Marcum et al. 1998 and Qian et al. 2000), and is often compared to selections of seagrass (Paspalum) when evaluating salt tolerance of warm season turf grasses. Data was also collected on the levels of sodium and chloride accumulated in the shoot tissue during the experiment. The retention of sodium and chloride in and on the leaf blades can have important downstream implications, as management practices are developed to minimize salt buildup in the soil.

METHODOLOGY

The experiment was conducted in a controlled environment facility to minimize variation in environmental factors, and enable the focus on the genetic variation for salt tolerance. Laboratory and greenhouse procedures that have been developed over the past 3 decades were used. Briefly explained, once plants are acclimated to saline water supply, they are grown in soilless media and sub-fertigated with balanced nutrient solutions to optimize growth and development. Sub-irrigation is required for studies where the goal is to harvest tissue and examine salt accumulation by the plant. This ensures that salt in and on the tissue is solely from salt taken up through the roots and not from contamination attributable to salt splashing onto the leaves.

Three pots were segregated and maintained under non-salt (control) conditions, while seven pots were included in the salt treatment study. At the onset of salt treatment, NaCl from a concentrated stock solution was added incrementally (2833 ppm NaCl per day) to the fertigation solution applied to the plants receiving salt, until a final concentration of 17,000 ppm (27 dSm^{-1}) was achieved. Both control and salt treated plants were clipped as needed throughout the experiment. Dried clippings from each pot were collected throughout the course of the 8-week experiment and pooled.

Percent leaf firing was used as a relative measure of salt tolerance, as turfgrass quality is a better reflection of the performance of the grass in response to salt than clipping yield (Marcum and Murdoch 1994). At the completion of the study, digital images were recorded of the randomized pots and these images were then used for the quantification of % leaf firing using APS Assess 2.0 software (American Phytopathological Society). The pooled dried clippings from each pot were weighed to determine the total accumulated leaf dry weight during the experiment, and the clippings sent to Waters Agricultural Laboratories, Inc. (Camilla, GA) for the determination of Na and Cl content of the tissue. Statistical analyses were performed using JMP[R] 13.1.0 (SAS Institute, Inc.).

Results

Figure 1 establishes that newly released varieties M-66 and M-85 accumulate higher levels of sodium in the leaf tissue as compared to the other lines tested including Paspalum, and offer an alternative approach to dealing with saline sites, i.e., absolute physical uptake and removal of salts without using excess water for leaching or flushing. (Table 1). The nature of putting greens and other highly managed surfaces (football, soccer, tennis, baseball) results in frequent clipping (and removal of these salt laden clippings) on a routine basis. This enhanced active sodium extraction translates to the ability to better manage the amount of deleterious salt that accumulating in the soil. While it does require catching and removing clippings, the salts go with it and reduces the overall need for enhanced internal drainage (USGA's greens profile), and reduces the amount of water required to maintain top quality turf surface.

The new lines are as salt tolerant as the industry standard, Diamond and appear to be more functional than Paspalum in saline sites considering the greater shade tolerance, traffic tolerance and low nutritional needs and lower water consumptive demands of zoysiagrasses. An extremely high level of salt (17,500 ppm) was used for this study to magnify the genetic potential for salt tolerance between the lines. In practice, the concentration of salt in applied irrigation water will be significantly less, i.e. Colorado River water delivered to Scottsdale is in the range of 600 to 650 mg per liter (Tenney, 2017). Thus, while all of the varieties showed salt injury, it can be expected that under the level of salinity found in most irrigation waters, acceptable turf quality can be readily achieved. And while under those more moderate salinity levels all of the lines will likely exhibit satisfactory appearance, M-66 and M-85 will do so while at the same time removing greater amounts of sodium from the soil and water.

Another feature of the Zoysias is the dramatically lower above ground dry matter accumulation (Figure 4) as compared to Paspalum. The grasses completely filled the soil surface of the pots at the onset of the experiment, so biomass accumulation was entirely due to vertical growth. The general level of maintenance of any grass is predicated on the amount of effort required to produce an acceptable level of performance, i.e. turf quality and playability. Under salt stress, while we see exceptional growth in Paspalum, it would come at the expense of considerably higher maintenance costs whereas the zoysiagrass level of maintenance would be much lower, while still affording optimal appearance and enhanced salt extraction.

CONCLUSIONS

The results of this study reveal that while there are several options for warm season grasses that will tolerate salinity, selection of varieties of Zoysia that exhibit elevated levels of sodium extraction from the soil and water can potentially minimize the amount of sodium that builds up in the soil. This inherent ability of zoysiagrass to extract salts from the soil profile may provide for novel approaches to the design, construction and maintenance of golf courses and sport fields. If putting greens no longer need to be flushed to remove salts, not only is water conserved, but nutrients are not flushed along with the salts, further minimizing costly inputs, as fertilizer requirements will be reduced. There is a need to examine the capacity of these zoysias to minimize salt build up in the soil, and perhaps even remediate existing build up in situations under maintenance (mowing, etc.) that would be consistent with their end use in golf courses or sports fields.

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Appendix

Table 1

Variety	Na(mg/dry wt)		% of paspalum
M-66	3.88	a	169.73
M-85	3.80	a	166.23
DR2	3.21	ab	140.32
L1f	2.57	b	112.63
Zorro	2.41	b	105.41
Zeon	2.34	b	102.56
Diamond	2.33	b	102.01
M-60	2.31	b	101.14
Paspalum	2.28	b	100.00

Figure 2. Amount of sodium extracted by the leaf tissue

Variety	Texture	mean Na (mg/g dry weight)	std error
DR2	coarse	3.20	0.30
M-66	long fine	3.88	0.09
Zeon	long fine	2.34	0.32
Zorro	long fine	2.41	0.41
Paspalum	Paspalum	2.28	0.14
Diamond	short fine	2.33	0.09
L1f	short fine	2.57	0.14
M-60	short fine	2.31	0.10
M-85	short fine	3.80	0.22

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