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Seashore paspalum (*Paspalum vaginatum*, shown above) is being used by more and more golf courses, especially those that depend on irrigation water that is more saline than desired. A primary goal for the seashore paspalum breeding/genetics program at the University of Georgia is to systematically develop grasses with superior stress resistances. Research conducted at the Griffin Campus summarizes their effort to screen ecotypes of seashore paspalum for overall drought resistance in a field dry-down situation and for tolerance to root-limiting stresses.

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PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 225 projects at a cost of $25 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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Seashore Paspalum Ecotype Responses to Drought and Root Limiting Stresses

Robert N. Carrow

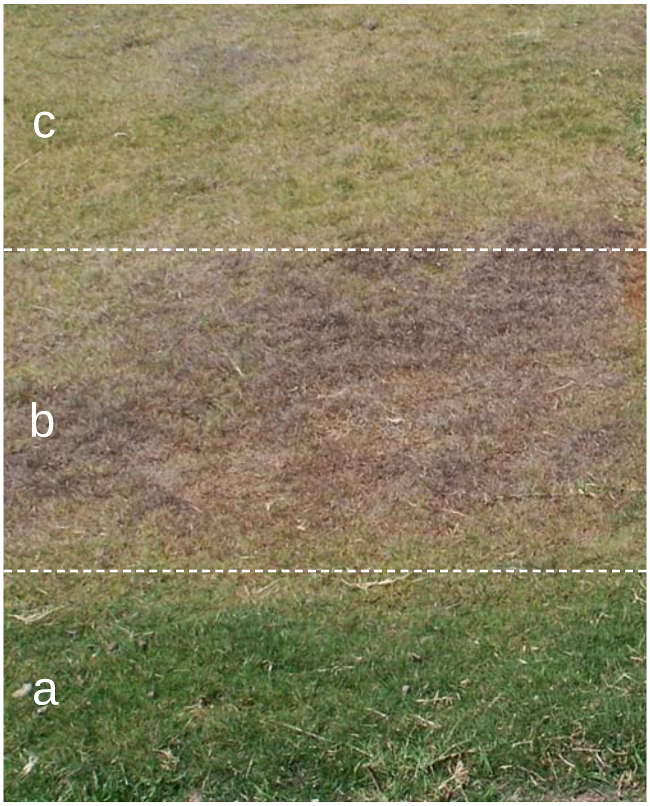
SUMMARY

Research continues at the University of Georgia to screen ecotypes of seashore paspalum (*Paspalum vaginatum*) for overall drought resistance in a field dry-down situation and for tolerance to root limiting stresses. Knowledge gained from these efforts include the following:

- Increasingly, turfgrasses with superior multiple stress tolerances will be desired, especially for major stresses such as drought, salinity, and acid soils.
- Seashore paspalum ecotypes exhibit substantial differences in drought resistance and acid soil tolerance, just as they do for salinity, wear, mowing height, and other stresses.
- Some seashore paspalum ecotypes exhibit drought resistance similar to that of 'Tifway' bermudagrass, while others are far more sensitive to drought.
- Breeders can take advantage of natural variability in stress tolerances to develop seashore paspalum cultivars that possess superior tolerance to not just one stress but several major stresses.
- When making grass selection decisions, turf managers should be aware that great differences in seashore paspalum cultivars exist and they should make sure that the cultivar they select has adequate tolerance to the stresses frequently encountered on their course.

Increasingly, turfgrasses are grown under severe environmental stress conditions such as reduced irrigation, saline irrigation water, and poor soil conditions, not just on golf courses but also for land reclamation purposes and other landscape sites. Grasses with genetic-based resistance to climatic, soil (edaphic), pest, and traffic stresses is foundational for development of environmentally sound turfgrass management regimes and for adaptation to harsh areas.. A primary paradigm for the seashore paspalum (*Paspalum vaginatum*) breeding/genetics program at the University of Georgia of Dr. Ron Duncan, and more recently of Dr. Paul Raymer, is to systematically develop grasses with superior stress resistances (5, 6). A critical step in this process is to determine ecotype tolerance to important stresses.

An important stress is drought resistance, including drought avoidance and tolerance aspects (1). While many physiological, morphological, and anatomical plant adaptations can contribute to drought resistance, our direction for improving drought resistance has been to concentrate on genetic-based resistance to soil chemical and physical factors that directly limit root development and longevity (root maintenance). Unless a



Seashore paspalum ecotypes on a acid sulfate-affected site exhiting a range of drought stress symptoms: a) moderate drought stress (green); b) severe drought stress (leaf dessication--brown); c) moderate to severe drought stress (yellow or leaf firing).

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Rabey Bay, a park along a coastal estuary, is shown before (above) and after (below) establishment of ‘Sea Isle 2000’ seashore paspalum to this highly saline/sodic soil. The soil exhibits acid sulfate conditions: very acid, high sulfates, high sodium, and high soluble salts.

Grass	Average 1999 and 2000[§] Turf Quality	Turf Color	Turf Density	Times in the Top (best) Statistical Group Quality	Color	Density	Total
	--------- 9 = ideal ---------						
Adalayd SP	6.0	6.5	6.2	1	3	1	5
Ada. Select 1 SP	5.8	5.9	6.1	0	2	1	3
HYB 7 SP	6.8	7.2	7.0	7	9	7	23
Q36313 SP	6.3	6.7	6.7	3	4	3	10
Sea Isle 1 SP	7.4a	7.5a	7.5a	12	12	10	34
Taliaferro SP	6.5	7.1	6.6	2	7	2	11
TCR 1 SP	6.6	7.1	6.8	4	8	4	16
TCR 6 SP	6.9	7.3a	7.0	9	11	8	28
Temple 1 SP	7.2a	7.5a	7.3a	11	11	9	31
Tifway bermuda	7.0a	7.1	7.3a	9	8	10	27
$LSD_{(.05)}$ =	0.45	0.28	0.37	-	-	-	-
F-test =	**	**	**	-	-	-	-

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively.

‡ The letter "a" denotes the top (best) statistical group.

§ Thirteen rating dates in 1999 and 2000.

Table 1. Summary of turfgrass shoot performance over 1999 to 2000 (SP = seashore paspalum)

turfgrass can develop a deep and extensive root system and maintain that root system under adverse soil stresses and repeated drought periods, the grass will not have good drought avoidance characteristics and drought stress can result too rapidly for all the drought tolerance attributes to be operative.

Carrow and Duncan (3) and Duncan and Carrow (5) described these soil root-limiting stresses as: 1) high soil strength that limits root growth rate either from naturally hard setting soils or from soil compaction, 2) soil drought that can cause desiccation and death of roots which varies considerably with ecotype, 3) acid soil complex which consists of pH low enough to induce Al/Mn toxicity to roots (usually in association with nutrient deficiencies (e.g. Ca, Mg, K, P) and hard 1:1 type clays such as kaolinite), 4) high sodium levels that cause Na-induced root toxicity by displacement of Ca from root cell walls and plasma membranes, and 5) low soil oxygen either from water logging, soil compaction, or soils with too many micropores/too few macropores.

Acid complex soils are very common in tropical, high rainfall regions and these soils are normally kaolinitic clays, allophanes, or soils with very high Fe/Al oxides (5). Another example of very low acidity stress conditions is acid sulfate

Grass	Turf Coverage May 5	Leaf Firing §, # 18 July (14 DAI)	26 July (7 DAI)	18 Aug (18 DAI)	Average
	--- %	---			
Adalayd SP	93	29	7a	44	27
Ada. Select 1 SP	92	25	3a‡	45	24
HYB 7 SP	96a	33	4a	18a	18
Q36313 SP	88	48	12	50	33
Sea Isle 1 SP	100a	6a	1a	2a	3a
Taliaferro SP	91	22	<1a	26	16
TCR 1 SP	91	43	11	29	28
TCR 6 SP	97a	17a	2a	8a	9a
Temple 1 SP	98a	1a	0a	4a	2a
Tifway bermuda	100a	13a	2a	21	12a
$LSD_{(.05)}$ =	6	16	10	17	13
F-test =	**	*	†	**	*

***, **, † Significant difference at probability level 0.01, 0.05, and 0.10, respectively.

‡ The letter "a" denotes the top (best) statistical group.

§ Dry-down periods: July 5 to July 18; July 20 to July 28; and August 1 to August 18.

Leaf firing: yellowing and/or leaf desiccation resulting from soil dry-down after an irrigation event.

Table 2. Leaf firing and turf cover ratings in 2000 on 9 seashore paspalums and 1 bermudagrass (DAI = days after irrigation)(SP = seashore paspalum)

soils where both high Al/Mn and high Na are present as root toxins. These are usually coastal, marine, 2:1 clays, however, this stress can also occur on some inland soils.

The research summarized in this article relates to screening of ecotypes for overall drought resistance in a field dry-down situation and for tolerance to root-limiting stresses. Studies were conducted at the Griffin Campus of the University of Georgia at Griffin, GA.

Drought Resistance of Fairway Type Seashore Paspalum

On July 16, 1998, nine seashore paspalums and 'Tifway' bermudagrass were established by sprigging on an Appling sandy clay loam (clayey, kaolinitic, thermic typic Kanhapludualt). The A horizon of 20 cm was pH 5.3 and the B horizon was pH 5.1. Fertilization was by soil test for all nutrients except N. Nitrogen was applied each year in April, June,

Grass	1999		2000					
	July 16	Sept 9	June 26			Sept 13		
	0-60 cm	0-60 cm	0-30 cm	30-60 cm	0-60 cm	0-30 cm	30-60 cm	0-60 cm
	---mg dry weight of roots/100 cm^2 of surface area---							
Adalayd SP	428	438	810	77	887	1233a	202	1435a‡
Ada. Select 1 SP	339	741	1177	84	1261	749	131	880
HYB 7 SP	549	559	930	78	1008	784	98	882
Q36313 SP	340	537	475	70	545	554	93	646
Sea Isle 1 SP	411	540	847	60	907	1479a	785a	2264a
Taliaferro SP	513	490	732	107	839	841a	142	983
TCR 1 SP	539	860	845	206	1051	851a	193	1044
TCR 6 SP	561	792	744	45	789	626	114	740
Temple 1 SP	691	892	676	116	792	836a	360	1196a
Tifway bermuda	645	538	724	84	808	1575a	458a	2033a
$LSD_{(.05)}$ =	-	-	-	-	-	740	340	1068
F-test =	NS	NS	NS	NS	NS	†	*	*

*,† Significant difference at probability level 0.05 and 0.10, respectively.
‡ The letter "a" denotes the top (best) statistical group.

Table 3. Rooting data in 1999 and 2000 (SP - seashore paspalum)

July, and late August at 1.0 lb N/1000 ft^2 (0.49 $kg/100m^2$) each date using 10-10-10 in April and August and urea the other months. Mowing was at 0.625 inch (1.6 cm) twice weekly with clippings returned. Irrigation for establishment was to prevent drought stress. Each grass treatment was replicated four times in 3.6 x 3.6-meter plots in a randomized complete block design.

All grasses were subjected to periodic dry-down periods in 2000 to induce drought stress as indicated by leaf firing ----chlorosis/yellowing followed by leaf desiccation and tan/brown appearance of leaves. Visual ratings were obtained for: leaf firing (percent leaves exhibiting leaf firing); visual quality, shoot density, and color (9.0 = ideal for these parameters). Root samples were obtained using three cores of 6.3-cm diameter per plot in early summer and late summer of 1999 and 2000 at 0-30 and 30-60-cm depths.

Results

For the nine seashore paspalums the rating ranges in shoot performance averaged across 1999 and 2000 were: 5.8 to 7.4 for turfgrass quality; 6.1 to 7.5 shoot density; and 6.1 to 7.5 color (Table 1). Ratings included those taken during dry-down

Grass	pH 6.5	pH 4.2	Percent of pH 6.5 cover
	--------- ft^2 ---------		%
Common bermudagrass	33.5	21.5	64
Tifway bermudagrass	23.0	9.6	42
K 7 SP	9.4	4.5	48
HI 19 SP	6.8	2.1	31
FL 4 SP	6.6	1.8	27
K 8 SP	8.3	1.5	18
FL 60 SP	6.3	1.3	21
Meyer zoysiagrass	3.4	1.2	35
HI 101 SP	0.6	1.2	200
HI 35 SP	12.6	1.2	10
K 4 SP	6.4	1.2	19
HI 34 SP	9.3	1.1	12
HYB 7 SP	4.3	1.1	26
PI 509018-3	3.4	1.1	32
TCR 1 SP	9.1	1.1	12
$LSD_{(.05)}$ =	**	**	-
F-test =	2.8	1.0	-

Table 4. Acid soil complex responses of top (best) 15 grasses.

periods as well as under non-drought conditions. Out of a total of 34 shoot performance measurements, grasses ranking in the top (best) statistical group the most frequently were: ‘Sea Isle 1’ (34); ‘Temple 1’ (31), ‘TCR 6’ (28), and ‘Tifway’ bermudagrass (27), while ‘Adalayd’ (5) and ‘Ada-Selection 1’ (3) ranked lowest. These data indicate:

- Considerable variability in shoot performance characteristics exist among seashore paspalum ecotypes. Unusually wide variability in many other traits among seashore paspalum ecotypes has been noted (5) relative to most other grasses.

- Under simulated fairway conditions, some ecotypes of seashore paspalum exhibited overall turfgrass quality, shoot density, and color similar to ‘Tifway’ bermudagrass.

Leaf firing during dry-down periods under field situations integrates both drought avoidance and tolerance aspects (2). In the soil conditions of this study, the repeated dry-downs imposed multiple soil stresses (i.e. high soil strength, soil drought, and some acid-soil complex stress). During three dry-down periods (i.e. no rain or irrigation) in 2000, 7 to 18 days duration leaf firing was noted on all grasses, but there was considerable ecotype differences (Table 2). Grasses demonstrating the least leaf firing averaged over all dry-down periods were: ‘Temple 1’ (2 %), ‘Sea Isle 1’ (3 %), and ‘Tifway’ bermudagrass (12 %), while the highest leaf firing occurred on Q36313 (33 %), ‘TCR 1’ (28 %), and ‘Adalayd’ (27%).

Leaf firing symptoms on the seashore paspalums initially appeared as a slight yellowing of the grass. For the least drought tolerant grasses, this rapidly (within 1-2 days) resulted in appreciable yellowing of many leaves, especially lower leaves. These leaves then became brown or tan at the tip and progressed down the whole leaf as the drought stress continued. Irrigation before the brown or tan symptoms appeared resulted in full recovery but not once leaf desiccation occurred as evidenced by the brown/tan appearance.

The dry-down data illustrates that drought resistance varies considerably across ecotypes from moderate to excellent for this important characteristic. Some seashore paspalums, including 'Sea Isle 1', were as drought resistant as 'Tifway' bermudagrass. Huang et al. (7) observed similar results with drought resistance of 'Sea Isle 1' (experimental PI 509018) equal to 'TifBlair' centipedegrass and better than common bermudagrass or 'Emerald' zoysiagrass. In our study, 'Adalayd' ranked among the lowest for drought resistance, which was consistent with the results of Huang et al. (7).

Rooting differences were not apparent in 1999 or June of 2000 (Table 3). However, after the three dry-down periods in July and August 2000, root differences were observed. Total root growth (0-60 cm) was highest for 'Sea Isle 1', 'Tifway' bermudagrass, 'Temple 1', and 'Adalayd' in September 2000. In terms of deep rooting (30-60 cm) in September, 'Sea Isle 1' and 'Tifway 'bermudagrass were highest and reflected an increase of roots in this zone from late June by 13.1- and 5.5-fold, respectively. 'Sea Isle 1' was reported by Huang et al. (7) to develop apprecia-

Improved cultivars of seashore paspalum are finding their way onto golf courses around the world. The golf course shown above is from the United Arab Emerates where grasses are often managed under severe salinity, drought, and high temperature stresses.

ble total and deep roots, as well as exhibit rapid new root initiation after rewatering following a soil drought.

Multiple Soil Stress Screening of Seashore Paspalum

Eighty-four seashore paspalum ecotypes and three control grasses (common bermudagrass, 'Tifway' bermudagrass, 'Meyer' zoysiagrass) were plugged (9.0 cm diameter by 7.6 cm deep plug; area = 0.07 ft^2) into two adjacent sites: a) site 1--- severe acid soil complex conditions of pH 4.2 to induce Al toxicity stress (50 % Al saturation of cation exchange sites) along with potential nutrient deficiencies (Ca, Mg, K) and high soil strength (kaolinitic clay, 25 % clay in A horizon and 48 % in B horizon) often associated with this stress complex, and b) site 2--- similar to site 1 except limed to pH 6.5.

Both sites were maintained with good soil moisture conditions for the first 24 days after plugging on June 30, 1998, but thereafter no irrigation was applied. Thus, the multiple soil stresses in this study were: acid soil complex + high soil strength + soil drought. Fertilization was at 1.0 lb N/1000 ft^2 as 10-10-10 on July 8, 1998 and May 17, 1999 with Ronstar 2G applied at 2.25 kg product/100 m^2 on March 23, 1999. Each ecotype was replicated four times in a randomized complete block within each site using one plug per plot.

On July 7, 1999, a square grid was laid over each plot and the area of coverage was estimated. The 15 grasses with the greatest coverage in the pH 4.2 plots are presented in Table 4. The two bermudagrasses had the best growth in high pH plots as well as under low pH, where coverage was 42-64 % of the pH 6.5 values. Seashore paspalum growth expressed by coverage at pH 6.5 ranged from 14.1 to 0.46 ft^2. At pH 4.2, the range was 9.6 to 0 ft^2 with the top 15 ecotypes exhibiting a range of 9.6 to 1.1 ft^2. Only 'K7' and 'HI 19' had growth > 2.0 ft^2 under low pH, while 'HI 101' demonstrated greater coverage under low pH versus high pH (this was a consistent trend in all replications of this grass). Thus performance under acid sulfate conditions, where water is less limiting, may differ from acid soil complex situations, which typically are subject to routine drought periods.

These three ecotypes appear to show promise for germplasm improvement for acid complex soils. 'Sea Isle 2000', which was not in the top 15 ecotypes for acid soil complex stress tolerance, was reported by Lees et at. (8) to provide rapid coverage of a highly acid (pH 3.4 to 5.2), saline-sodic (15.4-22.5 dS/m), coastal estuary soil. Thus, performance under acid sulfate conditions may differ from acid soil complex situations.

Comments

Substantial genetic-based variation in tolerance to drought and acid soil complex stresses was apparent across ecotypes of seashore paspalum. Implications are:

- Breeders can utilize genetic-based variation for future cultivar improvements for multiple or individual soil stresses.

- When turfgrass managers are selecting a particular seashore paspalum, it is critical to understand that all paspalums do not perform the same in response to stresses such as drought and acidic soils---just as other studies have demonstrated for wear, salinity, mowing height tolerance, and other stresses (6). Seashore paspalum cultivars released without rigorous evaluation under a stress may not perform as well as those tested and selected for superior tolerance. For example, based on over 300 seashore paspalum ecotypes within the original collection by Dr. Ron Duncan (most collected from harsh sites) the approximate percentage exhibiting superior tolerance to various stresses under rigorous evaluation is: drought (20 %); salinity (2-4 %), acid soil complex (2-4 %), and greens mowing height (1-2 %).

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Literature Cited

1. Carrow, R. N. 1994. A look at turfgrass water conservation. Pages 24-43. *In* J.T. Snow (ed.) Wastewater Reuse for Golf Course Irrigation. Lewis Publishing. Boca Raton, FL. (TGIF Record 29966)

2. Carrow, R. N. 1996. Drought resistance aspects of turfgrasses in the Southeast: root-shoot responses. *Crop Sci*. 36:687-694. (TGIF Record 38639)

3. Carrow, R. N., and R. R. Duncan. 1996. Breeding priorities and approaches for edaphic and climatic constraints on turfgrasses. Pages 64-76. *In* Proc. of the 34th Grass Breeders Work Planning Conf., 15-17 Sept. 1996. Univ. of Georgia, Griffin, GA. (TGIF Record 104265)

4. Duncan, R. R., and R. N. Carrow. 1999. Turfgrass molecular genetic improvement for abiotic/edaphic stress resistance. *Advances in Agronomy* 67:233-305. (TGIF Record 60854)

5. Duncan, R. R., and R. N. Carrow. 2000. Seashore paspalum-the environmental turfgrass. John Wiley & Sons, Hoboken, NJ. (TGIF Record 64879)

6. Duncan, R. R., and R. N. Carrow. 2002. Seashore paspalum offers alternative for the future. *TurfGrass Trends* May issue: 7-12. (TGIF Record 79816)

7. Huang, B., R. R. Duncan, and R. N. Carrow. 1997. Drought-resistance mechanisms of seven warm-season turfgrasses under surface soil drying: II. Root aspects. *Crop Science* 37(6):1863-1869. (TGIF Record 20782)

8. Lees, T. W., D. S. Loch, and G. T. Dwyer. 2003. Revegetating an eroded salt-affected coastal site with halophytic grasses---a case history. Proc. 9th Nat. Conf. on Productive Uses of Saline Lands. 29 Sept.-2 Oct. 2003. PURSL Conference, Rockhampton, QLD.