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Rooting Characteristics of Buffalograsses Grown in Flexible Plastic Tubes

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Abstract. **Rooting characteristics of 22 buffalograss [*Buchloë dactyloides* (Nutt.) Engelm.] genotypes were determined by growing plants in clear, sand-filled polyethylene tubes in a glasshouse. Differences were observed among entries for average maximum root depth, total root weight, root count and weight at increasing 100-mm depth increments, and total shoot weight. Average maximum root depth was positively correlated with total root weight (r = 0.59) and with root count at each 100-mm root profile depth. Root count and weight across all vertical root profile sections were highly correlated (r = 0.81). Total shoot weight was weakly correlated with average maximum root depth but not at all with total root weight. Grasses with superior rooting characteristics (deeply rooted, with larger root mass and count in the lower root profile sections) included AZ-143, NTDG-1, and '315' (NE84-315).**

Development and use of drought-resistant turfgrasses are of primary interest to those in the turfgrass industry, as water availability for irrigating landscapes is becoming increasingly limited. Improved understanding of turfgrass drought-resistance mechanisms would improve turfgrass management strategies and speed the development of drought-resistant cultivars. Deep rooting and extensive root branching, particularly at lower root profile depths (Kramer, 1983), are considered important root system characteristics favoring plant water uptake and survival under dry soil conditions (Russell, 1977). Deep rooting is considered a drought-resistance mechanism in numerous plants (Levitt, 1980).

Deep rooting and large root volumes have been associated with drought resistance under dry soil conditions in wheat (*Triticum aestivum* L.) (Narayan, 1991) and rice (*Oryza sativa* L.) (Zuno-Altoveros et al., 1990). In turfgrass, differences in rooting characteristics have been noted among cultivars of Kentucky bluegrass (*Poa pratensis* L.) (Ensign and Weiser, 1975) and creeping bentgrass (*Agrostis palustris* Huds.) (Lehman and Engelke, 1991; Salaiz et al., 1991). Differences in vertical root distribution among 10 bermudagrass [*Cynodon dactylon* (L.) Pers.] cultivars were associated with maintenance of turf quality under drought stress in a greenhouse (Hays et al., 1991). Root depth, root count at lower root profile depths, and total root weights of 11 zoysiagrasses (*Zoysia* spp.) grown in flexible plastic tubes in a glasshouse were positively correlated with field drought resistance (Marcum et al., 1995).

Buffalograss, which is native to the semi-arid North American "short grass" prairie (Turgeon, 1991), is often used for landscaping in low-rainfall areas and is considered to have good to excellent drought tolerance (Emmons, 1995; Kim, 1987). However, to our knowledge, little is known concerning the rooting characteristics of buffalograsses. The objective of these experiments was to determine if differences exist in the genetic potential for rooting of a broad range of buffalograss genotypes grown under nonlimiting conditions in a glasshouse.

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Materials and Methods

Twenty-two buffalograss entries (see Table 1) were initially seeded or planted vegetatively into plug trays containing sterilized growing medium (25% Canadian sphagnum peat, 55% no. 3 grade horticultural vermiculite, and 20% horticultural perlite). Seeded entries were 'Sharps Improved', 'Bison', 'Top Gun', 'Plains', and all NTDG entries. Grasses were maintained by clipping weekly at 50 mm and fertilizing weekly at a rate of ≈3.1 kg N/ha from a fertilizer solution (20N–8.7P–16.6K) until densely established.

Plugs (25 mm in diameter) of the 22 entries were transplanted into sand-filled polyethylene tubes [25 mm in diameter × 900 mm long (0.076-mm wall thickness)] (Chiswick, Sudbury, Mass.) on 18 Sept. 1991. The tubes were filled with a fine silica sand of uniform particle-size distribution (96% between 0.15 to 1.0 mm in diameter) and had been uniformly mixed with a 14N–6.7P–16.6K resin-coated fertilizer (Osmocote) to provide an N level of 5 $g \cdot m^{-2}$. Before the plugs were planted, the tubes were inserted into PVC pipe (43-mm inside diameter) and suspended in racks tilted 30° from vertical (Lehman and Engelke, 1991).

Tubes were placed in a glasshouse ranging from 16 to 26C during the study. Natural daylight was supplemented by high-pressure sodium vapor lights at 400 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for 12 h daily. The sand medium was maintained at field capacity by mist irrigation three times daily. Tubes were arranged in a randomized

Table 1. Average maximum root depth (AMRD = average of three deepest roots), total root fresh weight, and shoot dry weight of 22 buffalograss entries grown on a sand medium in flexible plastic tubes in a glasshouse.

Entry	AMRD (mm)	Total root wt (mg)	Shoot wt (mg)^z
Cultivar			
Bison	350	646	461
Buffalawn	360	519	366
Plains	346	589	401
Prairie	295	605	330
Sharps Improved	294	357	370
Texoka	276	572	485
Top Gun	320	453	337
315	384	846	397
378	372	815	401
609	353	640	449
Experimental line			
AZ-143	413	904	425
Highlight 4	363	632	406
Highlight 15	285	381	419
Highlight 25	375	606	457
NE84-436	306	591	401
NE84-45-3	261	392	271
NTDG-1	433	740	355
NTDG-2	313	429	322
NTDG-3	328	620	301
NTDG-4	377	643	304
NTDG-5	337	726	322
Rutgers	379	467	443
$LSD_{0.05}$^{y}	76	299	110

^{z}Shoot weight is the cumulative total of all weekly clippings.
^{y}Means separated using Fisher's protected LSD procedure at $P \leq 0.05$.

complete-block design with six replications.

Maximum root depth was monitored weekly by marking on the bottom side of the polyethylene tube face. Roots of all entries within a replication were taken for analysis when roots of one entry in that replication reached the bottom of the polyethylene tube. The six replications were harvested for analysis over 4 weeks, the final replication being taken on 25 Jan. 1992. Shoots were clipped weekly at 50 mm throughout the experiments, dried at 70C, and pooled for total shoot clipping dry weights.

At root harvest, the three longest roots (three maximum root depths) were marked on each polyethylene tube face and recorded. Rooting depth is reported as average maximum root depth (AMRD = total length of three longest roots/3). Each tube was then slit with a razor, leaving the intact sand column laying horizontally on a wire-mesh trough. Sand was gently washed away, leaving the root profile in its original configuration on the screen. The root profile was cut into 100-mm sections from the sand–plug interface (0 mm), each root section tied together with thread immediately below the cut, placed in weak (≈3 g·liter^{-1}) thymol solution (preservative), and refrigerated until analysis.

Root counts per 100-mm depth were determined by counting the number of severed roots at each 100-mm root section interface with a stereo microscope. Each 100-mm root section was then thoroughly blotted dry and weighed to determine root weight distribution with depth. Total root fresh weight is the sum of the weights of each root section.

A second, identical experiment was initiated 28 Mar. 1992. The six replications were taken over 3 weeks, the final replication taken on 15 Aug. 1992. No significant experiment × treatment interaction was found by analysis of variance (ANOVA), and Pearson product moment correlation between the two experiments was highly significant, so data are reported as an average of two experiments. Data were analyzed by ANOVA procedure (SAS Institute, 1985), and entry means separated using Fisher's protected LSD. Treatment means were correlated using Pearson product moment correlation.

Results and Discussion

Average maximum root depth ranged from 433 mm for NTDG-1 to 261 for NE84-45-3 (Table 1). Grasses within the top 20% for AMRD, in decreasing order, were NTDG-1, AZ-143, '315', Rutgers, NTDG-4, Highlight 25, '378' (NE85-378), Highlight 4, 'Buffalawn', '609' (NE84-609), 'Bison', and 'Plains'.

Root count was correlated with AMRD at each depth, the best correlation being at middle depths, 200 to 400 mm (Table 2). Grasses with the most roots at the lower root profile depth of 400 mm, in decreasing order, were AZ-143, Highlight 25, '609', NTDG-1, NTDG-5, '315', Highlight 4, and NTDG-4 (Table 3). Of these, only AZ-143 and NTDG-1 had an average of one or more roots at 500 mm.

Total root weight ranged from 904 mg for AZ-143 to 357 mg for 'Sharps Improved' (Table 1). Grasses within the top 20% for total root weight, in decreasing order, were AZ-143, '315', '378', NTDG-1, and NTDG-5. Total root weight was highly correlated with AMRD, and with root count at 0- through 400-mm depths (Table 2). Total root weight was significantly, though less strongly, correlated with root count at the 500-mm depth.

Root weights per 100-mm vertical root profile section differed significantly at all depths (Table 4). Grasses with highest root weights at the lower root profile depth of 400 to 500 mm, in decreasing order, were NTDG-1, AZ-143, NTDG-5, NTDG-4, Highlight 25, '609', and Rutgers. Root counts and weights across all vertical root profile sections were correlated ($R = 0.81$).

Cumulative shoot dry weights ranged from 486 mg for 'Texoka' to 272 mg for NE84-45-3 (Table 1). Shoot dry weight was correlated with AMRD, but not with total root weight. In contrast, shoot dry weight was correlated with rooting depth and total root weight in zoysiagrass (Marcum et al., 1995). In that study, both rooting characteristics, but not shoot dry weight, were good predictors of drought resistance. Shoot dry weight also was correlated with root counts at 0- through 400-mm depths, but not at the 500-mm depth, the strongest correlations being at depths of 0 to 200 mm. The association of shoot dry weight and root count at shallow depths may be related to shoot count. 'Texoka' had the highest shoot dry weight, but low AMRD and total root weight. However, root counts were high at shallow depths of 0 and 100 mm.

Deeply rooted grasses (having large AMRD values) generally also had high total root weights, and many roots and high root weights in lower root profile sections (300 to 500 mm). The best-performing grasses overall, having the largest values noted, were AZ-143, NTDG-1, and '315'. Rutgers and Highlight 25 had large AMRD and root counts at lower root profile depths, but low total root weights.

Assessing root growth via flexible plastic tubes in a glasshouse is an efficient method for screening many plant materials for several reasons. The technique 1) is less expensive than field coring or excavation techniques; 2)

Table 2. Correlation coefficients (r) for average maximum root depth (AMRD), total root weight, root counts at increasing 100-mm depths, and cumulative shoot clipping dry weight of buffalograsses grown in a sand medium under glasshouse conditions.

Root characteristic and depth (mm)	Total root wt	Root counts/depth (mm) 0	100	200	300	400	500	Shoot wt
AMRD	0.59***	0.20**	0.30***	0.58***	0.65***	0.53***	0.39***	0.28***
Weight		0.43***	0.53***	0.70***	0.69***	0.47***	0.18**	0.11
Count at 0			0.56***	0.30***	0.23**	0.14*	0.08	0.37***
100				0.52***	0.32***	0.22**	0.03	0.39***
200					0.71***	0.42***	0.16**	0.31***
300						0.60***	0.24**	0.17**
400							0.36***	0.14*
500								–0.03

*, **, ***Correlation coefficients significantly different from 0 at $P \leq 0.05$, 0.01, or 0.0001, respectively.

Table 3. Root counts at successive 100-mm vertical profile depths of 22 buffalograss entries grown on a sand medium in flexible plastic tubes in a glasshouse.

Entry	Root counts at each 100-mm root section 0	100	200	300	400	500
Cultivar						
Bison	21.3	14.4	12.8	6.4	1.4	0.0
Buffalawn	29.7	19.5	19.4	11.1	1.4	0.6
Plains	20.3	16.6	14.3	7.4	1.4	0.1
Prairie	29.6	32.3	11.0	3.1	0.0	0.0
Sharps Improved	18.6	14.0	7.9	2.4	0.2	0.0
Texoka	35.3	22.0	10.0	3.1	0.1	0.0
Top Gun	22.9	15.3	10.5	4.8	0.9	0.0
315	40.1	24.0	15.5	12.9	3.7	0.0
378	26.6	20.4	16.8	7.5	2.4	0.0
609	22.7	19.8	15.7	10.4	4.4	0.0
Experimental line						
AZ-143	29.0	20.9	19.1	17.3	7.4	1.1
Highlight 4	17.7	16.9	12.9	9.7	3.7	0.2
Highlight 15	19.1	17.4	9.2	8.4	2.7	0.0
Highlight 25	17.4	11.9	14.1	10.2	4.9	0.0
NE84-436	26.2	18.0	10.9	3.5	1.1	0.0
NE84-45-3	27.2	14.6	4.6	2.5	1.5	0.0
NTDG-1	19.8	17.2	17.7	9.4	4.4	1.0
NTDG-2	22.1	12.4	11.1	3.9	1.0	0.1
NTDG-3	22.7	14.7	9.9	8.2	1.8	0.0
NTDG-4	20.9	16.5	10.6	6.5	3.5	0.2
NTDG-5	28.6	19.3	11.5	7.1	3.9	0.2
Rutgers	23.5	21.4	14.4	7.0	2.2	0.7
$LSD_{0.05}$[z]	8.4	8.0	7.9	7.2	4.6	0.7

[z]Means separated using Fisher's protected LSD procedure at $P \leq 0.05$.

Table 4. Root fresh weight of successive 100-mm vertical root profile sections of 22 buffalograss entries grown on a sand medium in flexible plastic tubes in a glasshouse.

	Root wt (mg)/vertical section (mm)					
Entry	0–100	100–200	200–300	300–400	400–500	500–600
Cultivar						
Bison	283	196	115	46	6	0
Buffalawn	217	135	105	50	11	1
Plains	267	164	103	45	10	1
Prairie	349	190	54	11	0	0
Sharps Improved	194	107	44	10	2	0
Texoka	374	132	52	13	0	0
Top Gun	218	146	66	18	5	0
315	390	211	146	86	13	0
378	384	210	158	56	6	0
609	257	171	141	56	15	0
Experimental line						
AZ-143	319	237	177	135	34	2
Highlight 4	236	170	127	88	10	0
Highlight 15	169	106	64	35	7	0
Highlight 25	222	156	138	72	17	0
NE84-436	333	163	73	21	1	0
NE84-45-3	254	93	28	13	4	0
NTDG-1	251	218	149	85	34	3
NTDG-2	216	116	75	18	4	0
NTDG-3	293	161	104	54	8	0
NTDG-4	313	141	117	53	19	0
NTDG-5	350	181	107	65	19	1
Rutgers	176	138	102	36	14	2
$LSD_{0.05}$[z]	131	90	74	52	21	2

[z]Means separated using Fisher's protected LSD procedure at $P \leq 0.05$.

reduces variability due to localized changes in field soil temperature, texture, and water content; and 3) allows nondestructive monitoring of root extension through time.

Differences in root depth, total root weight, and root weights and counts at increasing root profile depths (root distribution) were found among 22 buffalograss genotypes grown in flexible plastic tubes. Deep rooting under water-limiting conditions in the field was associated with drought resistance in corn (*Zea mays* L.) (Lorens et al., 1987) and wheat (Narayan, 1991), while total root volume was associated with drought resistance in rice (Zuno-Altoveros et al., 1990). Differences in root mass distribution with depth, but not shoot dry weight, were associated with bermudagrass quality (relative percentage of green leaves) in a greenhouse experiment where irrigation depth was gradually lowered through time (Hays et al., 1991). Rooting characteristics of creeping bentgrasses grown in flexible plastic tubes in a glasshouse were heritable (Lehman and Engelke, 1991), suggesting that this technique might be used as a screening procedure in selecting turfgrasses having the superior rooting characteristics necessary for improved drought resistance.

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