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Several organic and inorganic amendments were at Rutgers University for their ability to enhance establishment and performance of creeping bentgrass when grown on sand-based media .

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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 290 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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Creeping Bentgrass Establishment on Sand-based Rootzones Varying in Amendment

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SUMMARY

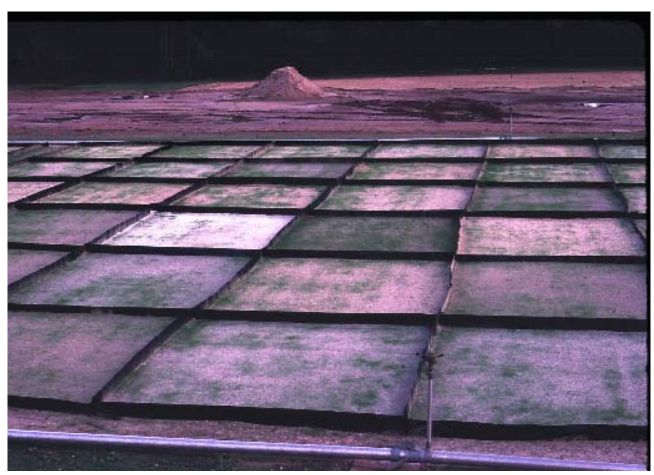
Creeping bentgrass turf responded during grow-in to varying rootzone mixes in a study conducted at Rutgers University. Among the study's findings:

- The most consistent and best performing turf over the first year of establishment was observed on organic amended plots at higher amendment rates including 20% compost, 20% sphagnum peat, 10% reed sedge peat and 20% Irish peat mixes; these mixes had capillary porosity greater than 25%, which exceeds the USGA upper limit.
- The 20% loam had water retention capacity similar to the 20% sphagnum and 10% reed sedge mixes. Turf performance suggested that compaction (low air-filled porosity and K_{sat}) was producing some stress on the 20% loam plots, yet these plots were not failing.
- Mixes with higher CEC also improved turf performance during grow-in. Low water retention potential in a mix with high CEC (high relative to sand-based mixes) offset this advantage as irrigation and fertilization objectives shift away from establishment toward a maintenance goal.
- Adequate turf establishment was observed on most mixes with inorganic amendments (exception Greenschoice). However, more consistent and higher levels of turf performance were observed on rootzones amended with organic amendments.
- Sand amended with a kaolin-cellulose recycled paper product (Kaofin) produced highly variable turf performance, yet the longer term turf response was very positive. Thus, the product could have potential if problems at early establishment can be overcome.
- Longer term studies of turf responses to these rootzone mixes is needed to verify the persistence of responses, especially considering that some of the better turf responses occurred on mixes having unacceptable indexes based on current evaluation criteria.

Sand is commonly used to construct putting green rootzones and is often amended with organic amendments, such as peat, or soil containing silt and clay to improve physical and nutrient properties for turf. Goals of amending sand include improving plant-soil relationships, altering the growing conditions on or beneath the playing surface, and minimizing soil and turf management problems (20).

Materials other than peat that have been studied for amending sand include slag, calcined clay, expanded perlite and composted soil (19), clinoptilolite zeolite (12, 14), rice hulls, sawdust, calcined clay and vermiculite (15), bark (2), perlite (2, 10), green waste, wood chips, pulp, sewage and plant residue and fibers (9) , and finer-textured soils (3, 4, 7, 17, 18). Much of these previous reports emphasized physical properties of rootzone mixtures with some information provided on turfgrass response.

Few field studies have assessed the effects of physical properties of sand-based rootzones while avoiding the confounding effects of varying nutrition and specific surface on turf establishment (18, 19, 20). Amending sand may alter nutritional properties of rootzones as well depending on properties of the amendment and amount added, and the properties of the material being



In a comprehensive field and lab study, Rutgers University scientists compared various inorganic organic amendments for their abilities to enhance creeping bentgrass establishment on sand-based rootzones.

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Sand	Fine Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Silt and Clay
	------------------------------------- % by weight ------------------------------------						
Medium Sand	1.9	7.7	24.9	45.5	16.4	3.1	0.5
Finer Sand	1.8	1.8	7.7	45.7	36.2	5.2	0.6

Table 1. Size distribution of the two sands used to construct field plots. Medium sand was used to construct the sand-based plots except for one (i.e., finer sand mixed with compost at 20% by volume).

amended as well as uniformity of mixing (20).

It is important to have a rapid and thorough establishment of turfgrass on newly constructed rootzones as it can affect the initial generation of revenue and use of a golf course. The objective of this field study was to examine the effects of rootzones varying in amendment type and/or rate, and consequently physical and nutritional properties, on the establishment of creeping bentgrass turf.

Field Plot Construction and Management

Rootzone plots were constructed using techniques described by Murphy et al. (18). All rootzone plots were constructed over a subgrade with a 1.4% slope. Subsurface drainage was modeled after USGA construction guidelines (26) and used a 4-inch gravel blanket, except for two rootzone treatments which were built directly on the subgrade. Plots were separated vertically by polyethylene plastic to prevent lateral air and water flow between rootzone plots. Field plots of rootzone mixes, 12 inches deep, were constructed in two layers. Each 6-inch layer was compacted with a vibratory plate compactor to simulate compaction caused by heavy equipment during construction; the upper surface of the first (lower) layer was scarified after compaction before placement of the second layer.

Three general classes of amendment materials were used (loam, organic, and inorganic) to construct the rootzones at various volume ratios. A commercially available medium sized sand meeting USGA guidelines for sand size was used as the major component for rootzones except the 100% loam and 20% compost treatments. The 20% compost treatment used a sand considered too fine based on USGA guidelines. The 100% loam and 20% compost treatments were included for the purpose of comparison (i.e., relatively extreme rootzone properties). Rootzone treatments are described in Table 2.

Mixes were assessed for organic matter by loss on ignition at 360 °C, and physical properties were determined in 2-inch i.d. by 3-inch high cores (American Society for Testing and Materials, F1647-99; American Society for Testing and Materials, F1815-97). The 100% loam was not tested due to the difficulties of handling and processing in the methods listed above. Saturated water conductivity was determined under constant head from a 0.5-h flow after 4-h of equilibration flow (17).

Plots were fertilized with 10-10-10 and 12-24-14 (N-P_2O_5-K_2O) fertilizers each at an N rate of 1 pound per 1000 ft^2 (total 2 pounds per 1000 ft^2 of N) before seeding with 'L-93' creeping bentgrass at 1 pound per 1000 ft^2. Fourteen post-planting fertilizations were made to all plots except 100% loam and 20% compost during 1998, which applied a total of 5.1, 2.5 and 2.8 pounds per 1000 ft^2 of N, P_2O_5, and K_2O, respectively. The 100% loam and 20% compost plots received 13 post-planting fertilization that amounted to 4.7,

Amendment	Material Description	Amendment Mixes (% by volume)
None	Medium sized sand	0
Loam	Loam mixed with medium sand	
	Sand Silt Clay (% by weight)	
	98.2 1.0 0.7	2.5
	96.8 2.2 1.0	5
	88.9 8.3 2.8	20
Loam over subgrade	Rootzones constructed 12 inches deep over subgrade with drainage pipe (i.e., no gravel layer)	
	Sand Silt Clay (% by weight)	
	96.8 2.2 1.0	5
	5.8 48.7 15.5	100
Organic Amendments		
Sphagnum Peat	Sphagnum peat from Sun Gro, Canada	5, 10, 20
Reed Sedge Peat	Reed sedge peat from Dakota Peat, ND	5, 10
Irish Peat	Sphagnum peat from Ireland	10, 20
Kaofin	Granulated recycled paper manufacturing by-product containing cellulose and kaolin from NJ (also containing surfactant).	10
Fertl-soil	Spent mushroom soil compost from PA	5
AllGro Compost	In-vessel composted biosolids from AllGro in NH	10
AllGro Compost with finer sand (AT Sales)‡	Finer sand amended with in-vessel composted biosolids from AllGro, PA	20
Inorganic Amendments		
Isolite	Porous ceramic - diatomaceous earth	10
Axis	Porous ceramic - diatomite	10
Greenschoice	Porous ceramic - clay based	10
Profile	Porous ceramic - clay based	10, 20
ZeoPro	Nutrient charged clinoptilolite zeolite	10
ZeoPro surface 4-inch	Surface 4 inches of rootzone amended with ZeoPro overlying 8 inches of medium sand	10
ZeoPro Plus surface 4-inch	Surface 4 inches of root zone amended with ZeoPro containing micronutrients overlying 8 inches of medium sand	10

‡ Sand used to mix with 20% compost contained a high amount of fine sand based on the USGA guidelines for root zone composition. All other mixes contain medium sand conforming to USGA size guidelines (see Table 1).

Table 2. Description of materials and mixing rates used to amend a medium sized sand and construct root zones 12 inches deep over a 4 inch gravel layer, except where noted.

2.5, and 2.8 pounds per 1000 ft^2 of N, P_2O_5, and K_2O, respectively.

Additionally, a fertilization of 46-0-0 at 0.3 pound per 1000 ft^2 of N was required on the non-amended sand plots to produce sufficient turf growth to survive mowing. Five fertilizations were made to all plots between May 7 and June 1, 1999, which applied a total of 2.1, 0.5 and 1.1 pounds per 1000 ft^2 of N, P_2O_5, and K_2O, respectively. Irrigation was applied to supplement rain-

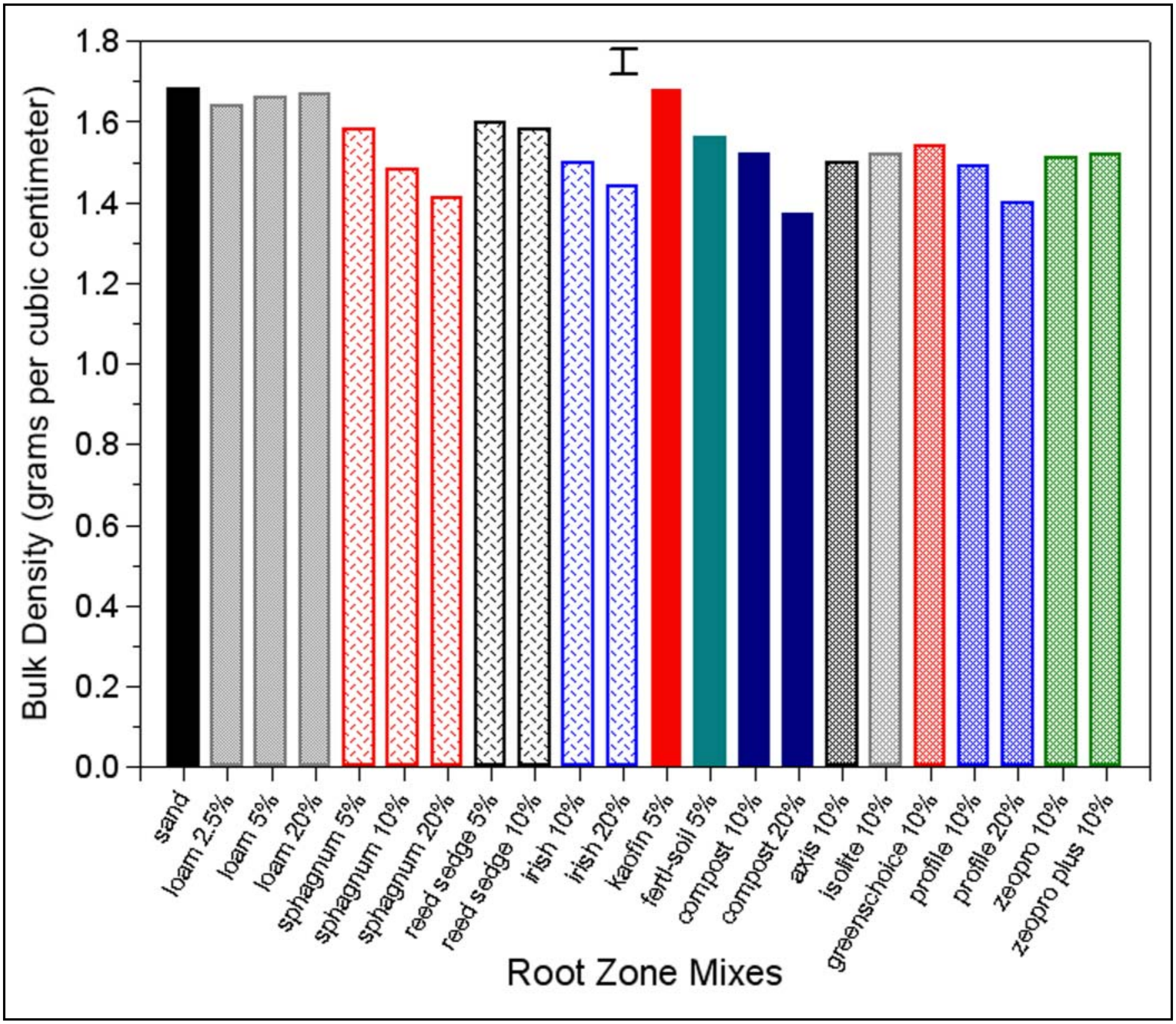

Figure 1. Bulk density of laboratory packed samples of 22 rootzone mixes. Bar represents least significant difference value for comparing means.

fall and mowing was maintained at 0.5-inch until the height was gradually lowered to 0.125-inch by the end of May, 1999. Plots were also top-dressed with their respective rootzone mixes and core cultivated.

Visual ratings of turfgrass establishment and quality were taken, and turf cover for each plot was quantified via line-intersect counting. Samples from the 0- to 4-inch depth were collected in April, 1999 to assess rootzone fertility. Three cores were taken from selected plots in 1999 and sectioned into 3-inch intervals to assess rooting.

Physical Properties of Rootzone Mixes

All the amendments, except loam and Kaofin, lowered bulk density compared to unamended sand (Figure 1). Bulk density decreased as the proportion of peat increased in a mixture. The 20% compost mixed with finer sand had the lowest bulk density among mixes.

Air-filled porosity is a measure of how well aerated a root zone will be at the surface after gravitational drainage of water has ceased. Air-filled porosity is also a measure of the pore space responsible for saturated water conductivity (K_{sat})

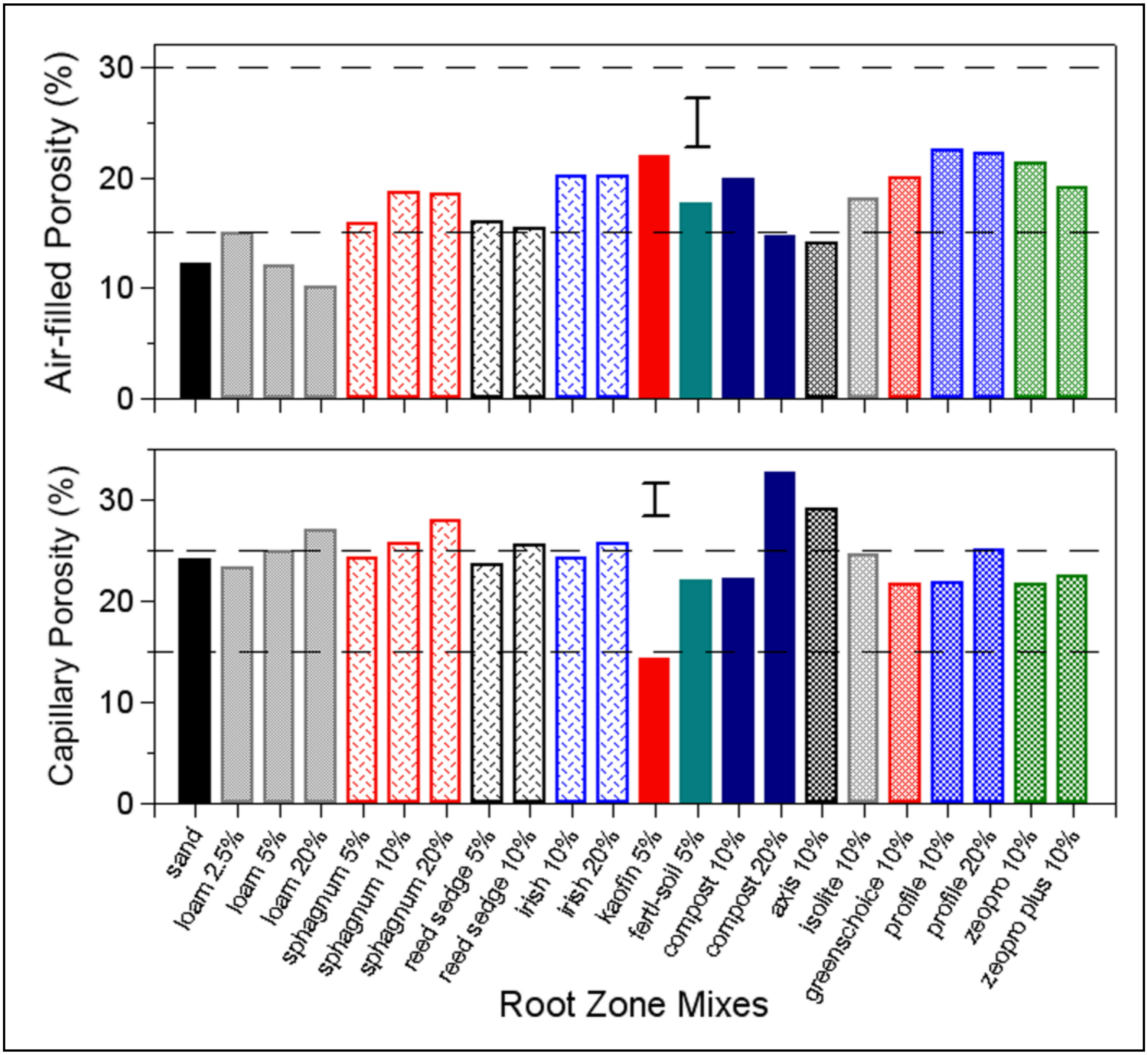

Figure 2. Air-filled and capillary porosity of laboratory packed samples of 22 rootzone mixes. Bar represents least significant difference value for comparing means. Dashed lines delineate upper and lower porosity limits based on USGA guidelines.

as well as the pores through which roots will grow. The USGA guidelines (1993) for air-filled porosity range from a low of 15% to a high of 30% by volume. Mixes that failed to achieve the lower limit for air-filled porosity (15%) included the unamended sand, 5% and 20% loam, 20% compost mixed with finer sand, and the 10% Axis (Figure 2). All other mixes attained acceptable levels of air-filled porosity with the greatest values observed in the Profile, ZeoPro, and Kaofin mixes.

Capillary porosity provides an estimate of the capacity of the rootzone to retain water at the surface against the gravitational pull on water; some refer to this as field capacity. Seven rootzone mixes (20% loam, 10% and 20% sphagnum, 10% reed sedge, 10% Axis, and 20% compost with finer sand) exceeded the upper limit of 25% for capillary porosity based on USGA guidelines (Figure 2). Fourteen out of the remaining 15 mixes had capillary porosity values in the upper third (20 to 25%) of the acceptable range. Only one mix, 10% Kaofin, failed to achieve the minimum capillary porosity of 15%. The Kaofin

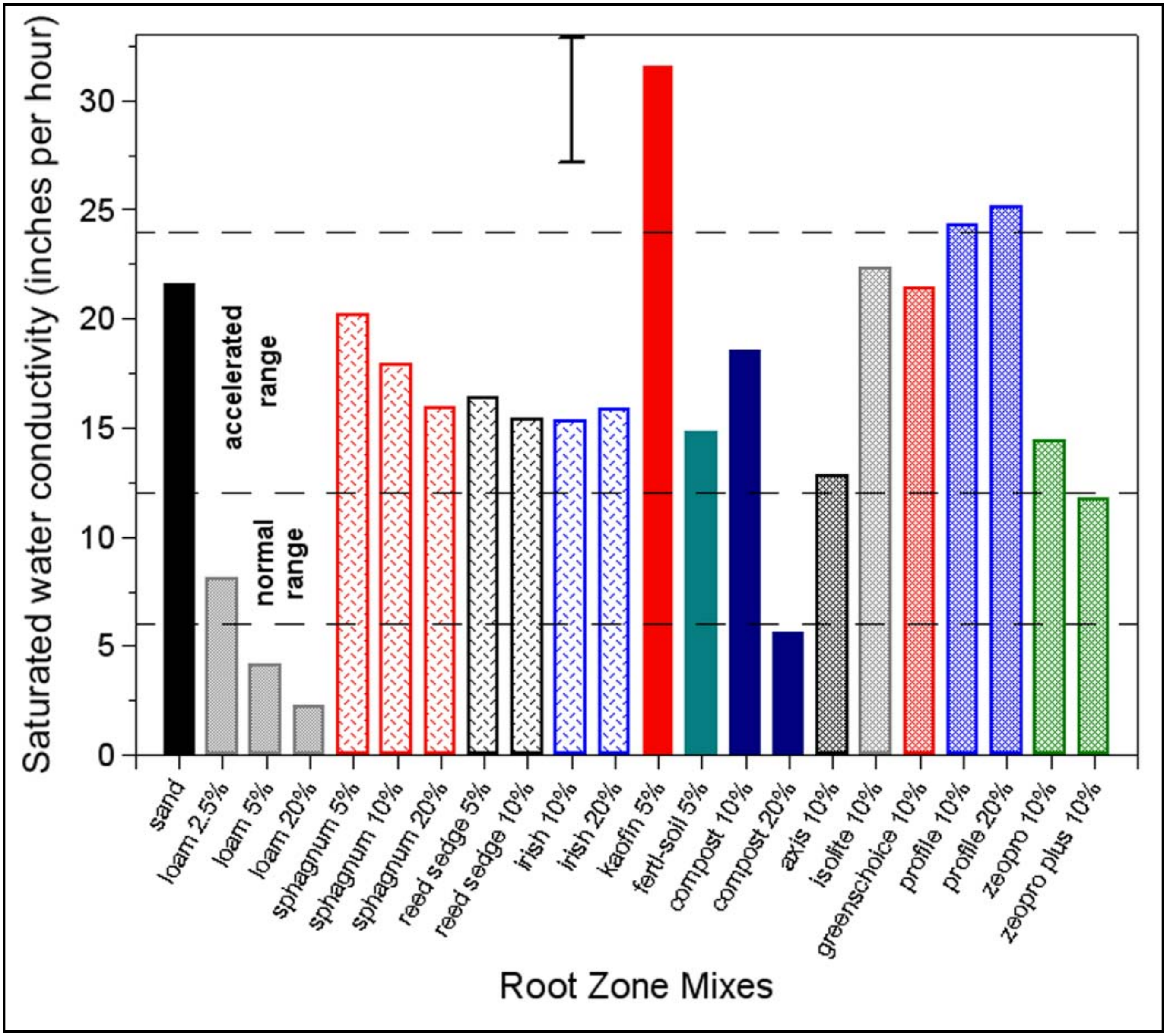

Figure 3. Saturated water conductivity (K_{sat}) of laboratory packed samples of 22 rootzone mixes. Bar represents least significant difference value for comparing means. Dashed lines delineate limits on accelerated and normal ranges of K_{sat} based on 1993 USGA guidelines.

amendment contained a surfactant, which changes the physical behavior of water. This made it difficult to perform laboratory tests with the Kaofin mix; however, the data indicated the impact of the surfactant was to reduce the water holding ability of the mix (capillary porosity).

Saturated hydraulic conductivity (K_{sat}) is a laboratory measure of the ability to conduct water through the mix when it is saturated (or nearly saturated) with water. The K_{sat} of a mix is an indicator of the amount of large pores (air-filled porosity) as well as the degree to which these pores are connected within the mix.

Three mixes (5% and 20% loam and 20% compost with fine sand) had K_{sat} values that did not meet the USGA (1993) minimum threshold of 6 inches per hour (Figure 3). Thirteen of the mixes had K_{sat} categorized by the 1993 guidelines as accelerated (12 to 24 inches per hour). Three mixes (5% Kaofin and 10 and 20% Profile) had K_{sat} values above the accelerated range. Interestingly, many of the mixes with an accelerated K_{sat} had air-filled porosities within the lower third of the acceptable range (15 to 30%) or below

Volume %	Mix amendment	OM†	P	K	Ca	Mg	Cu	Mn	Zn	B
		%	------ pounds per acre --------				------------- ppm --------------			
0	None	0.08	50	33	146	50	0.6	0.9	0.3	1.6
2.5	Loam	0.13	60	38	161	49	0.8	3.6	0.2	2.2
5	Loam	0.16	69	46	169	51	0.7	5.4	0.4	1.6
5	Loam (on subgrade)	0.17	77	43	175	49	0.8	6.0	0.4	1.7
20	Loam	0.39	110	71	365	93	1.5	16.2	0.7	1.4
100	Loam	4.20	411	306	2056	382	7.7	54.3	4.2	1.1
5	Sphagnum Peat	0.24	46	33	221	67	0.8	1.1	0.2	2.1
10	Sphagnum Peat	0.44	37	30	269	69	0.4	0.9	0.2	2.1
20	Sphagnum Peat	0.87	32	31	424	97	0.7	1.1	0.2	2.1
5	Reed sedge Peat	0.36	33	31	261	56	0.5	1.0	0.1	1.9
10	Reed sedge Peat	0.73	28	34	405	70	0.8	0.9	0.1	2.4
10	Irish Peat	0.47	32	32	287	75	0.8	1.1	0.1	2.3
20	Irish Peat	0.89	30	32	465	107	0.6	1.0	0.1	2.2
5	Kaofin	0.56	86	33	1428	42	2.7	1.5	0.3	1.9
5	Fertl-soil	0.27	80	40	332	48	1.8	3.9	0.6	2.0
10	AllGro Compost	0.81	117	44	235	65	4.1	5.9	1.1	1.9
20	AllGro Compost (finer sand)	1.79	439	33	350	41	4.8	4.1	1.7	1.3
10	Axis	0.12	128	65	207	61	0.7	1.5	0.3	1.2
10	Greenschoice	0.08	94	31	124	34	0.5	0.7	0.1	2.0
10	Isolite	0.09	74	35	161	50	0.4	0.9	0.1	1.7
10	Profile	0.08	138	106	655	73	0.7	1.5	0.1	1.2
20	Profile	0.09	128	165	1135	109	0.7	2.6	0.2	0.8
10	ZeoPro	0.35	119	245	484	83	0.9	2.1	0.2	1.4
10	ZeoPro surface 4"	0.28	94	169	385	77	0.4	1.5	0.2	1.4
10	ZeoPro Plus surface 4"	0.24	88	453	372	61	0.3	1.6	0.1	1.2
	$LSD_{0.05}$	0.10	24	18	190	11	0.6	1.1	0.2	0.4

$LSD_{0.05}$, value by which means should differ to consider different at P=0.05.

† OM denotes organic matter content by weight.

Table 3. Nutrient content at the 0- to 4-inch depth zone of rootzone mixes growing creeping bentgrass; sampled April,1999.

the minimum acceptable value (15%). This relationship was unexpected because mixes with very high (accelerated) K_{sat} also should have high air-filled porosity. Recall that air-filled porosity is a measure of the pore space responsible for conducting much of the water under saturated conditions.

Increasing the amendment rate of loam, sphagnum, and reed sedge decreased K_{sat} of the mix. The extremely high K_{sat} of the Kaofin and Profile mixes was due to the large inter-particle pore space (air-filled porosity) created by the narrow and coarse particle size distribution of the amendments. Also, the surfactant within the Kaofin amendment was probably enhancing K_{sat}.

Nutritional Properties of Rootzone Mixes

Organic matter content of the rootzones ranged from 0.08 to 4.20% by weight (Table 3). As expected, organic amendments increased the organic matter content of sand with the 20% compost treatment producing the greatest content. Before planting, pH of rootzone mixes ranged from 6.4 to 7.7 and declined to a range of 5.5 to 6.9, except for the Kaofin mix (7.5), by April

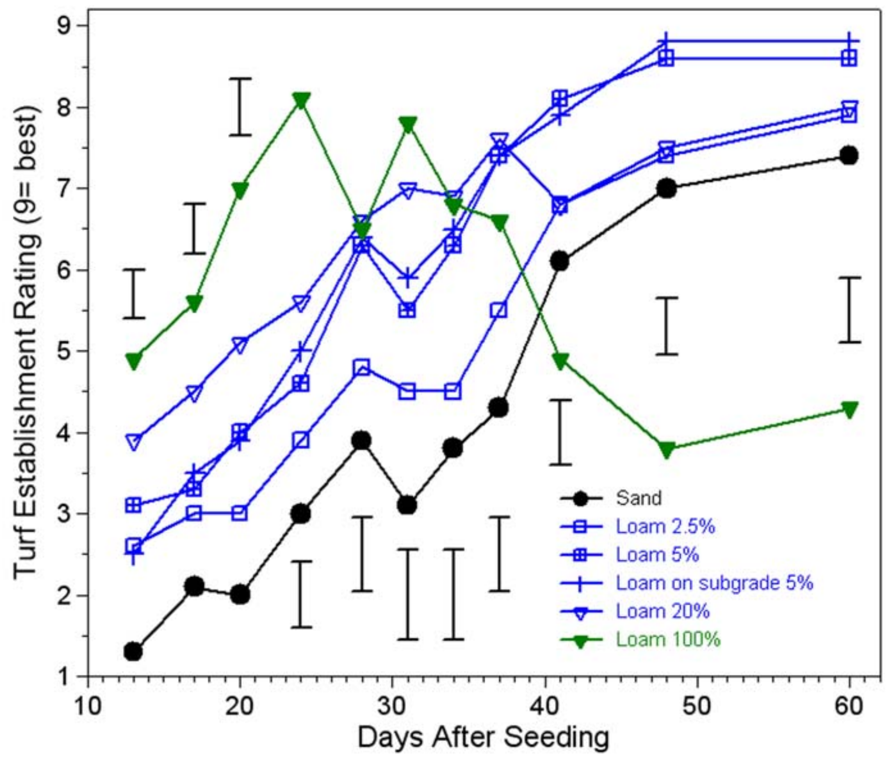

Figure 4. Ratings of turf establishment through 60 days after seeding for unamended sand and loam mixes. Bars represent least significant difference value for comparing means for a given date after seeding.

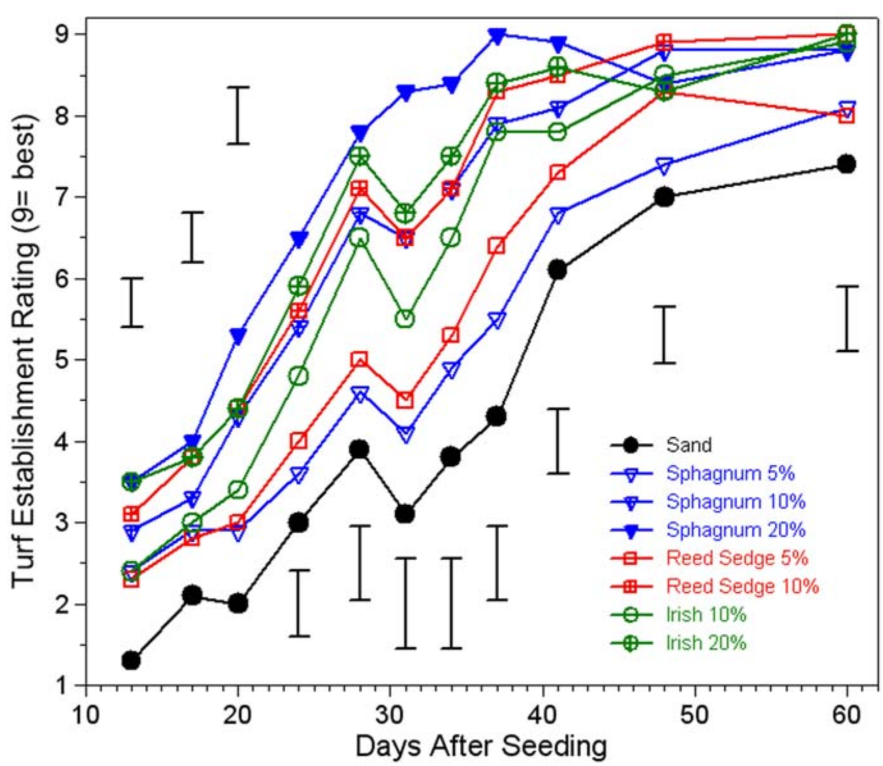

Figure 5. Ratings of turf establishment through 60 days after seeding for unamended sand and peat mixes. Bars represent least significant difference value for comparing means for a given date after seeding.

1999; these are common soil pH values under golf course turf in the northeastern United States. The nutrient content of loam mixes increased as the amendment rate increased for all measured nutrients except B, which decreased slightly (Table 3). The retention of P and K in peat mixes was lower than most other amendment mixes. The 100% loam and 20% compost rootzone had the greatest available P. Calcium and Mg content was greatest in the 100% loam plots, and Profile mixes were notably high in Ca and Mg. The Kaofin mix had a high Ca content. Micronutrients Cu, Mn, and Zn had the greatest increase in mixes containing loam or composted amendments (i.e., AllGro and Fertl-soil).

Turf Establishment Ratings

Bentgrass establishment through 60 days after seeding (DAS) was better on most of the amended rootzone mixes compared to unamended sand (Figures 4, 5, 6, and 7). An acceptable establishment rating (5 or higher) was observed at 13 DAS for 20% compost mixed with finer sand, 17 DAS on 10% ZeoPro and 100% loam mixes, 20 DAS for 20% sphagnum, 20% loam, and 20% Profile mixes, 24 DAS for 10% sphagnum and 10% reed sedge, 20% Irish, and 10% Profile mixes, 28 DAS for 5% reed sedge, 10% Irish, 5% Fertl-soil, and 10% compost mixes, 31 DAS for 5% loam, 37 DAS for 2.5% loam, 5% sphagnum, 10% Isolite mixes, and 41 DAS for unamended sand, 10% Greenschoice, and 10% Kaofin mixes. Note that unamended sand and Kaofin plots received an additional 0.3 pounds per 1000 ft^2 of N at 37 DAS to promote sufficient growth and enable turf to survive mowing, yet these plots remained the slowest to establish.

The 100% loam plots initially established turf very well until mowing was started, and then the turf establishment suffered. The decline in establishment resulted from mower scalping that was caused by lack of firmness (stability) in the soil under frequent irrigation and uneven settling of the loam.

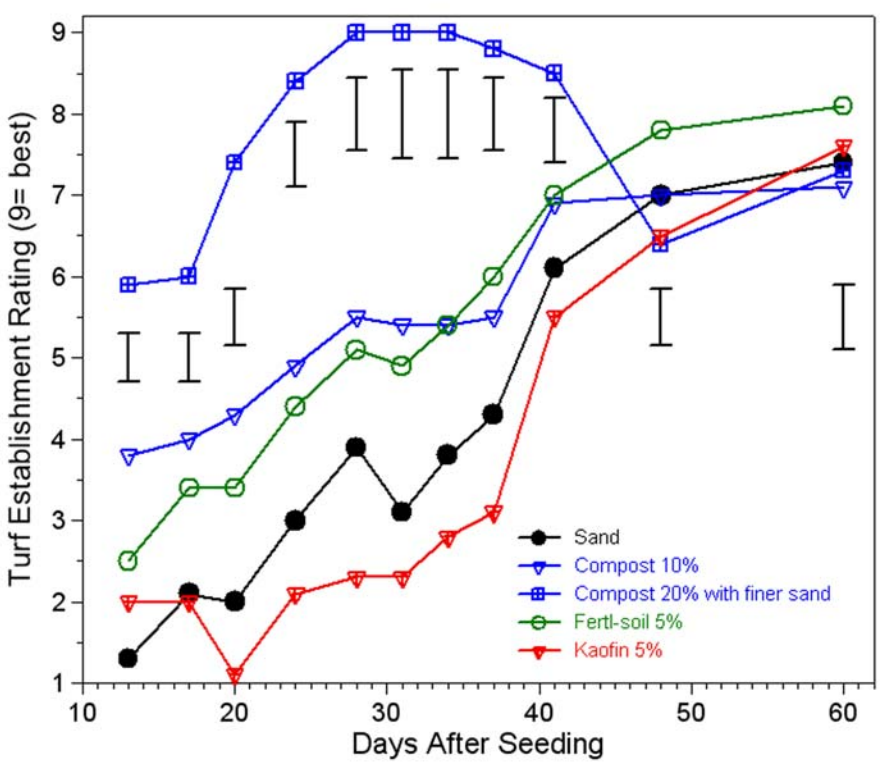

Figure 6. Ratings of turf establishment through 60 days after seeding for unamended sand and organic amendment mixes other than peat. Bars represent least significant difference value for comparing means for a given date after seeding.

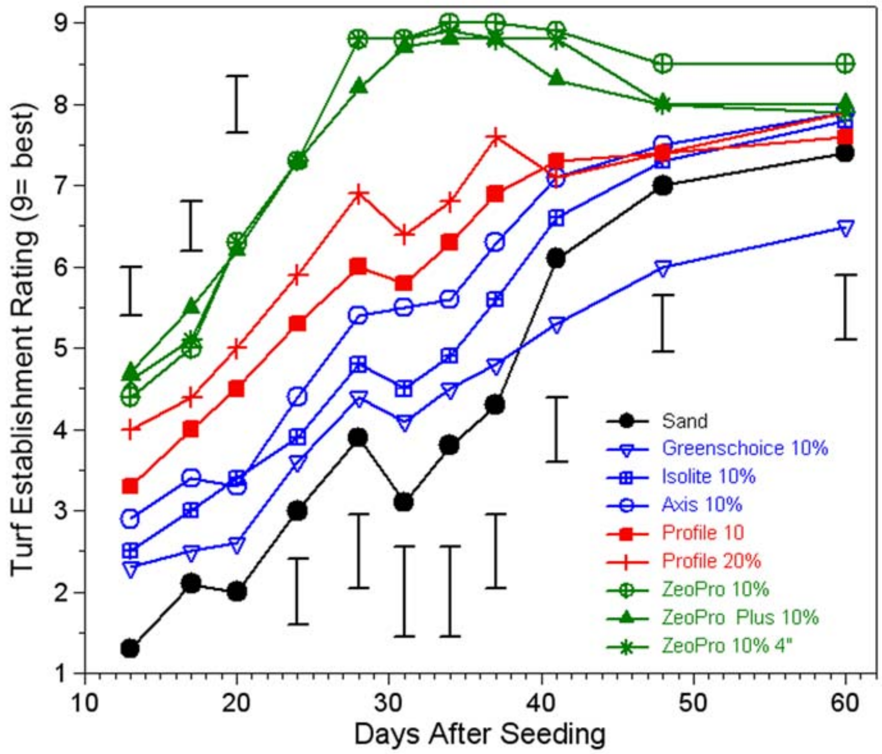

Figure 7. Ratings of turf establishment through 60 days after seeding for unamended sand and inorganic amendment mixes. Bars represent least significant difference value for comparing means for a given date after seeding.

Turf Cover

Turf cover measurements at June 22 and July 8 (22 and 38 DAS, respectively) reflected turf establishment ratings and indicated that the lower amendment rates of loam (2.5% and 5%), sphagnum (5%), reed sedge (5%), and Irish peat (10%) were not as effective in promoting establishment as were greater rates of those amendments. The 20% compost mixed with finer sand and 100% loam plots had the greatest turf cover compared to other mixes.

While the 20% compost mix rapidly developed and maintained excellent turf cover, turf cover on 100% loam plots decreased from 92% to 82% by July 8. Again this decline in turf performance on 100% loam plots was due to mower scalp caused by inadequate surface stability and uneven settling of the rootzone. Amending with 10% Kaofin, 10% Greenschoice, and 2.5% loam did not improve plant cover compared to unamended sand by July 8. Kaofin plots had the least turf cover compared other plots on June 22 and July 8, which reflected the challenges of establishing turf on these plots.

Improved turfgrass establishment was attributed to improved soil physical and nutritional conditions. Bentgrass established most rapidly on the 100% loam (Figure 1), 20% compost (Figure 3), and 10% ZeoPro (Figure 4) plots as would be expected on mixes with a high content of nutrients. The positive turf response to the nutrient-charged ZeoPro amendment was expected (1). Ferguson et al. (11) and Nus and Brauen (15) reported improved creeping bentgrass establishment in field trials using non-charged zeolite.

Increasing amendment rates of loam, sphagnum peat, Irish peat, and reed sedge peat improved the rate of establishment. Most amendments increased CEC, although the level of CEC was less than 4 cmol kg-1, which is considered low (8). The majority of fertilizer N in this trial was in the form of ammonium. Thus, it is probable that the improved turf establishment on mixes with increased CEC was attributable to better nutrient retention, particularly ammonium nitro-

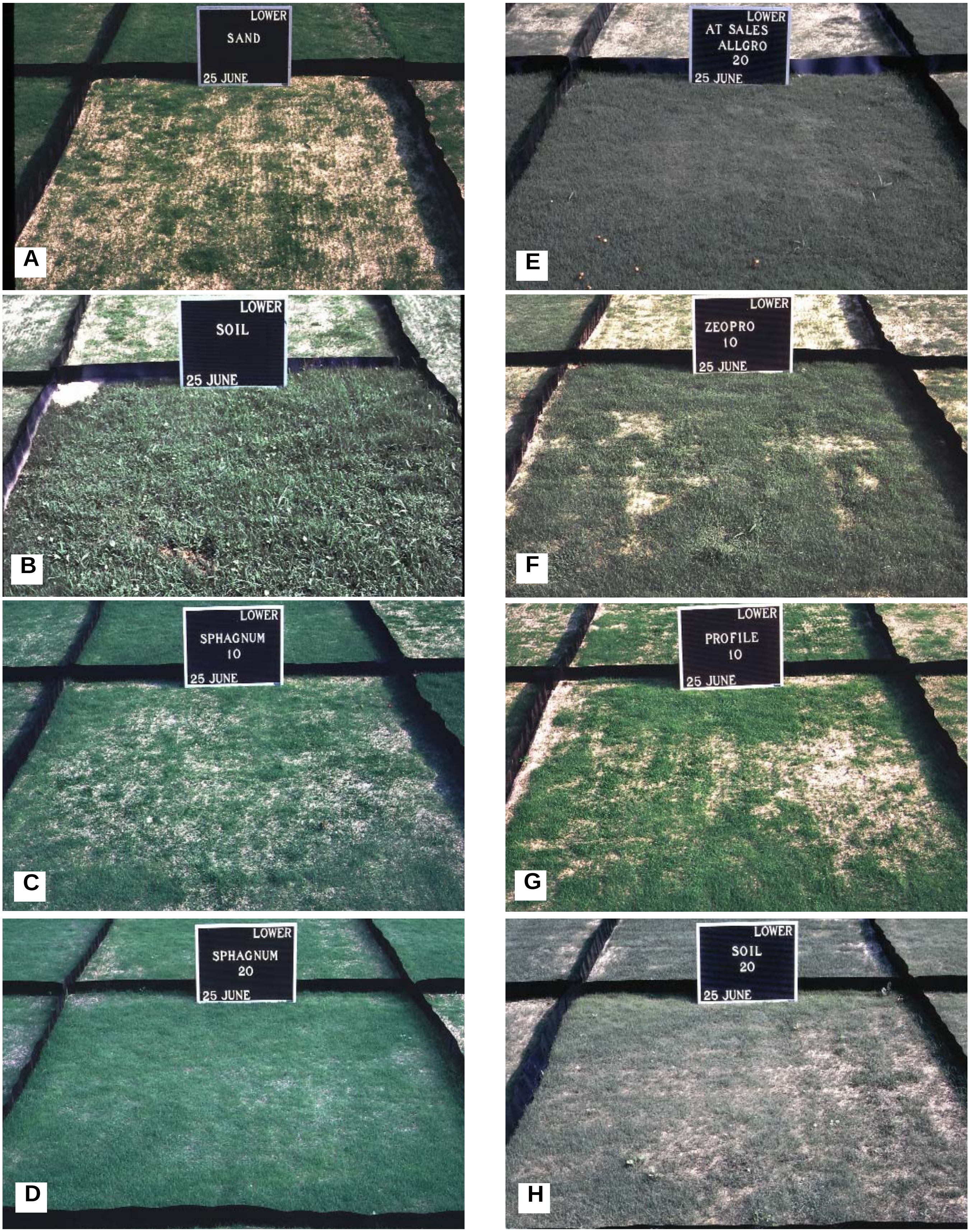

Figure 8. Field images of creeping bentgrass establishment 60 days after seeding on various rootzones including 100% sand (A), 100% soil (B), 10% sphagnum peat-amended sand (C), 20% sphagnum peat-amended sand (D), 20% compost-amended sand (E), 10% Zeopro-amended sand (F), 10% Profile-amended sand (G), and 20% soil-amended sand (H).

gen. Huang and Petrovic (13) and Ferguson and Pepper (11) reported increased ammonium retention in sand amended with non-charged zeolite, and Bigelow *et al.* (6) observed lower ammonium loss in leaching studies with Profile and non-charged zeolite.

Greater water retention (capillary porosity at or above the USGA recommended maximum of 25%) was often associated with rapid turf establishment. Murphy et al. (14) reported better turf establishment on mixes with capillary porosity of 25% (0.25 m^3 m^{-3}) or higher (the mixes in that study were not confounded by differences in nutrient retention). Greenschoice and Kaofin mixes were exceptions compared to other amended sand mixes and exhibited either similar or poorer establishment than unamended sand. These two mixes were very dry despite the light frequent irrigation used during establishment, as evidenced by the low capillary porosity of these mixes, particularly Kaofin.

Turf Quality

Turf quality ratings indicated that many mixes performed at a level that was consistent with observations made at early establishment. However, there were some mixes with dramatic changes in performance. Profile plots, which initially had established turf better than the unamended sand, became similar in turf quality to the unamended sand by October, 1998. Eventually turf quality on the Profile plots was lower than the unamended sand. The ZeoPro plots produced very high turf quality up to October, 1998. However, quality declined to moderate and low acceptable levels by April and May, 1999.

The Kaofin plots, which initially established very slowly (slower than unamended sand), achieved very high turf quality by October, 1998 and maintained that level of quality into May 1999. This change in performance on Kaofin plots was attributed to the surfactant (droughtiness and phytotoxicity) dissipating from the Kaofin amendment, and subsequently turf growth improved. The 10% Greenschoice plots, which initially established at a rate similar or slightly less than the unamended, declined to unacceptable levels of quality by October, 1998. Turf quality on Greenschoice plots was so poor in May, 1999 that the plots nearly failed.

The 5% loam plots (over gravel and over subgrade) produced a moderate level (6.5 to 7.5) of turf quality. However, low acceptable quality levels were observed on 2.5% and 20% loam plots. Thus, turf responses suggested that the 20% loam mix was approaching excessive amounts of the amendment (i.e., silt and clay). As noted previously, surface instability on 100% loam plots continued to negatively impact turf performance from October, 1998 to May, 1999 to the point that quality was unacceptable by April, 1999 and plots could be judged as failing.

The 10% and 20% Profile and 4-inch ZeoPro plots produced relatively low turf quality ratings that were less than the unamended sand in May, 1999. Irrigation was not re-initiated until May 13, 1999. Thus, the improved nutritional characteristics of these mixes that were an asset under the frequent irrigation during seedling establishment were probably negated by the relatively low water availability (capillary porosity) in those plots when irrigation was more limited in 1999. Moreover, the greater ability to retain nutrients, particularly ammonium, probably became less important as fertilization was decreased towards a maintenance level over time and ammonium was depleted from the charged zeolite.

Similarly, low water retention was attributed to the poor turf performance on the 10% Greenschoice plots. Bigelow et al. (5) reported the inability of inorganic amendments to improve available water retention in sand mixes using standard laboratory techniques. In fact, some of their data indicated available water was decreased in sand mixes containing inorganic amendments. Our field data for turf performance on mixes containing inorganic amendments was in agreement with those findings (5).

Rooting Response One Year After Seeding

Roots were observed at all depth zones for all mixes, and the relative differences in total root

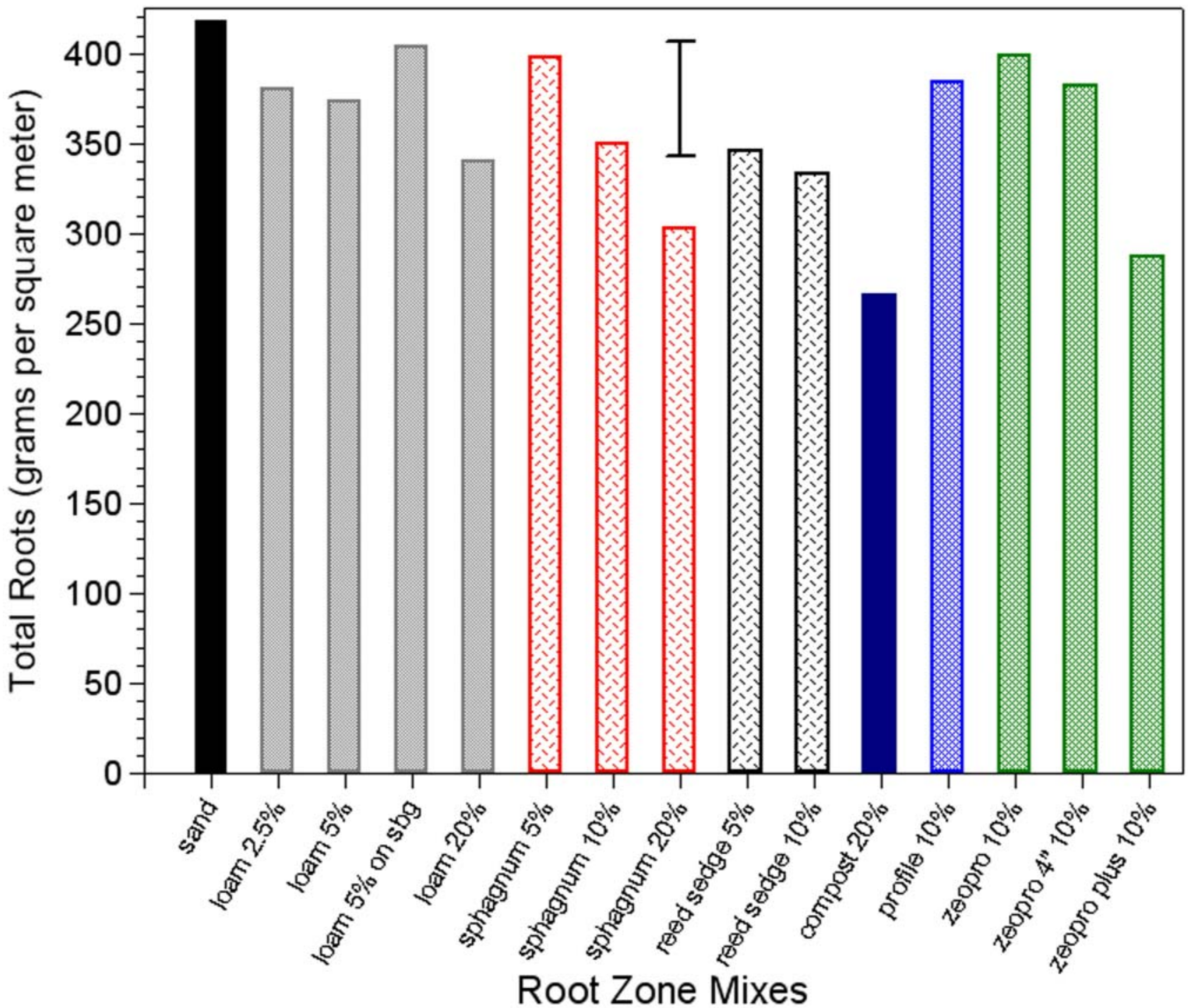

Figure 9. Ratings of turf establishment through 60 days after seeding for unamended sand and inorganic amendment mixes. Bars represent least significant difference value for comparing means for a given date after seeding.

mass (Figure 9) among rootzone mixes were generally evident in root mass assessed at all four 3-inch depth intervals. Greatest total root mass was found in the unamended sand, 2.5% and 5% loam, 5% loam on subgrade, 5% sphagnum, 10% and 20% Profile, and 10% ZeoPro mixes. Higher amendment rates of loam and peat in the rootzone mix decreased the total root mass to the point that the high amendment rates of sphagnum, reed sedge peats and loam had considerably lower total root mass than unamended sand. The lowest total root mass was found in the 20% compost mixed with finer sand and 10% ZeoPro Plus (i.e., containing micronutrients) plots.

Thus, there was a relationship of lower root mass with mixes having greater water storage, yet these mixes also consistently produced high turf quality. Murphy et al. (14) observed that finer-textured and, consequently, wetter sand rootzones resulted in lower root mass at depths below three inches and better turf quality during the first year of establishment. These findings indicate that variation in water availability of sand-based rootzones can be sufficient to impact distribution of dry matter between roots and shoots.

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