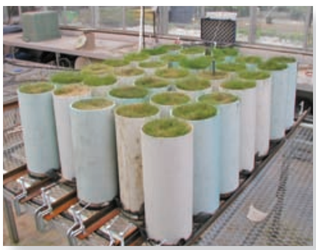
Water retention of sand-based root zones with organic and inorganic amendments

Adding certain organic or inorganic amendments to sand root zones can improve root-zone performance.



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Sand-based root zones are well suited for putting greens because they maintain air-filled pore space, resist compaction and provide excellent drainage (7). However, these root zones have relatively poor nutrient and water-holding capabilities (5) and have typically been amended with peat to improve water and nutrient retention. Because peat is a limited resource and naturally decomposes over time, inorganic amendments may offer an alternative to peat moss for use in sand-based root zones (8). Past research has shown that several commercially available inorganic soil amendments incorporated at a rate of 20% by volume decrease ammonium leaching by 27% to 88% when compared to unamended sand (1). Although some inorganic amendments increase the total water-holding capacity of a root zone, they may have little effect on plant-available water (2).

A 1993 USGA publication reported that the average cost of peat was approximately $30/cubic yard, whereas the average cost of inorganic amendments was around $200/cubic yard (3). Additional research on putting green root-zone amendments would allow superintendents to make better-informed decisions using a cost-benefit approach to selecting such materials. The objectives of the following research were: to determine the physical properties, including water-holding capacity, of sand root zones (meeting USGA specifications) modified with various amendments, and to determine the effect of amendments on the grow-in rate and dry-down characteristics of creeping bentgrass established in the amended root zones.

Materials and methods

Physical properties study

Moist sand:amendment root zones were mixed at the appropriate ratio (Table 1) and then each was packed into three replicate brass cylinders (3.2 inches tall × 3.0 inches in diameter [8 centimeters × 7.5 centimeters]), brought to field capacity, and then compacted with a hammer to simulate field conditions.

Saturated hydraulic conductivity was evaluated using a permeameter, which maintained a constant head of water on the root-zone treatments for four hours, after which percolation water was collected for 10 minutes. The volume of water collected for each root zone was used to calculate its saturated hydraulic conductivity (6). Water retention and pore-size distribution were evaluated using a tension table to simulate field capacity and a pressure chamber apparatus to simulate near-wilting-point conditions. The available water-holding capacity for each root zone was calculated as the difference between water retention at field capacity and water retention near wilting point.

Establishment/dry-down study

Each amended root-zone treatment (Table 1) was packed into three replicate lysimeters to create root zones meeting USGA recommendations (6). The lysimeters were constructed using PVC

The root-zone amendments used in this research are (from left to right): sphagnum peat, zeolite, calcined clay, diatomaceous earth and reed sedge peat. **Photos by D. Karcher**

pipes that were 16 inches tall × 6 inches in diameter (41 centimeters × 15 centimeters), with screens attached to one end to provide adequate drainage while retaining the root zones.

The lysimeters were seeded at a rate of 2 pounds/1,000 square feet (10 grams/square meter) with L-93 creeping bentgrass (*Agrostis stolonifera*). Milorganite fertilizer (6-2-0) was applied at 34.4 pounds/1,000 square feet (168 grams/square meter) to dilute and more evenly distribute the seed. The lysimeters were irrigated three times daily via overhead irrigation during establishment and once daily thereafter. Following germination, turf cover was evaluated twice weekly using digital image analysis techniques (4). Lysimeters were mowed at 0.5 inch (1.2 centimeters) three times per week. Once the lysimeters were completely established, each was saturated by soaking in a 5-gallon (18.9-liter) bucket full of water for approximately one hour, and then subjected to a dry-down period in which irrigation was completely withheld.

Turf establishment and green cover during the dry-down period were evaluated twice weekly using digital image analysis techniques (4). Images were collected twice weekly. Turf-wilt symptoms were evaluated three times per week during the dry-down period using a visual rating scale of 1-9, where 1 is no wilt, and 9 is severe wilt. The establishment/dry-down study was replicated twice, referred to in the results as Run 1 and Run 2.

Results and discussion

Physical properties study

Saturated hydraulic conductivity. The USGA recommends saturated hydraulic conductivity (K_{sat}) of 6 inches (15 centimeters)/hour or greater (7). All root-zone treatments tested in this study met USGA recommendations. Among treatments, diatomaceous earth (80:20) had significantly lower values for saturated hydraulic conductivity, and sphagnum peat (80:20) had significantly higher values (Figure 1). As the amendment ratio increased from 90:10 to 80:20, diatomaceous earth decreased saturated hydraulic conductivity, whereas sphagnum peat increased it.

Bulk density. Compared to the sand control, all amendments decreased bulk density (data not shown). Bulk density was lowest for diatomaceous earth and sphagnum peat and highest for reed sedge peat. As the ratio increased from 90:10 to 80:20, bulk density significantly decreased. The USGA does not publish recommendations for bulk density.

Amendments

Root zone	Ratio	Amendment source
Sand (Control)	100:00	
Sand: peat	90:10	Dakota reed sedge peat
Sand: peat	80:20	
Sand: peat	90:10	sphagnum peat
Sand: peat	80:20	
Sand: zeolite	90:10	Clinolite
Sand: zeolite	80:20	
Sand: calcined clay	90:10	Profile
Sand: calcined clay	80:20	
Sand: diatomaceous earth	90:10	prescription soil amendment
Sand: diatomaceous earth	80:20	

Table 1. Amendments investigated along with ratios and amendment source.

Total porosity. The USGA recommends total porosity of 35% to 55% (7). All root-zone mixes in this study (including the sand control) met USGA recommendations (Figure 2). Reed sedge peat had the lowest total pore space and diatomaceous earth had the highest. As the ratio increased from 90:10 to 80:20, total porosity increased because of the higher relative porosity of the amendments.

Air-filled porosity. The USGA recommends air-filled porosity of 15% to 30% (7). All root-zone mixes in this study (including the sand control) met USGA recommendations (data not shown). Reed sedge peat had the lowest amount of air-filled pore space, and zeolite had the highest. As the sand:amendment ratio increased from 90:10 to 80:20, air-filled porosity also increased, indicating that the amendments had more air-filled pore space than the root-zone sand.

Capillary porosity. The USGA recommends capillary porosity of 15% to 25% (7). All root-zone mixes in this study, *except* for the sand control, met USGA recommendations (data not shown). Reed sedge peat had the highest capillary porosity, and zeolite had the lowest. The sand: amendment ratio did not significantly affect capillary porosity.

Plant-available water. Even though the amount of water held increased as the sand:amendment ratio increased from 90:10 to 80:20, the percent of plant-available water did not increase (Figure 3). The sand control held the least amount of water at wilting point. Reed sedge peat was the only amendment that had significantly more plant-available water than the sand control. At wilting point, diatomaceous earth held a large amount of water that probably would not be available to plants. These results suggest that although inorganic amendments increase internal pore space and water retention, these products may hold water very tightly (because of greater surface area and the very strong adhesive and cohesive forces associated with their microscopic pores) and not increase water uptake of turf roots.

Conclusions

All root zones met USGA recommendations except for capillary porosity in the sand control. Reed sedge peat was the only amendment that significantly increased plant-available water compared to the sand control.

Greenhouse study

Turf establishment. For Run 1, none of the inorganic amendments had significantly faster establishment than either reed sedge (80:20) or sphagnum peat (80:20), in terms of percent green turf cover following germination (data not shown). Diatomaceous earth (80:20) performed significantly better than the other inorganic amendments and the sand control by reaching 50% green turf cover within eight days after seeding; the next inorganic amendment, zeolite (80:20), took nine days to reach 50% green turf cover. Calcined clay (90:10) reached 50% green turf cover in 14 days. All the amendments at the 80:20 ratio performed significantly better than the sand control. The inorganic amendment treatment that was slowest to establish at the 80:20 ratio was calcined clay, which reached 50% green turf cover within 10 days, whereas the sand control reached 50%

Saturated hydraulic conductivity

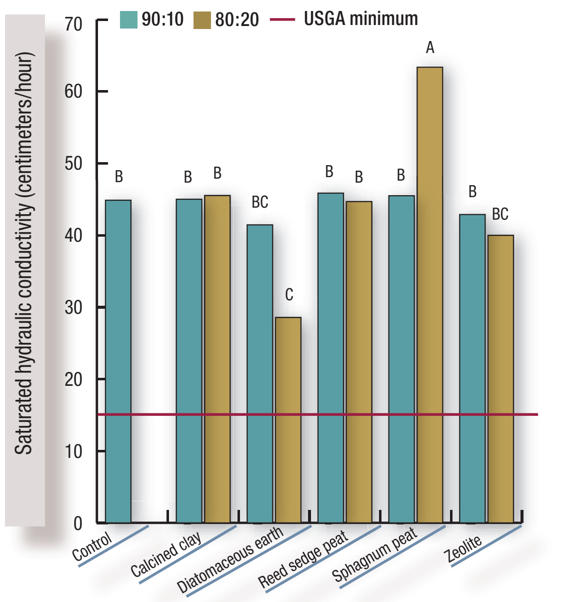

Figure 1. Saturated hydraulic conductivity (centimeters/hour) of a sand control and five root-zone amendments investigated at two different ratios. Bars that do not share a letter are significantly different.

Total porosity

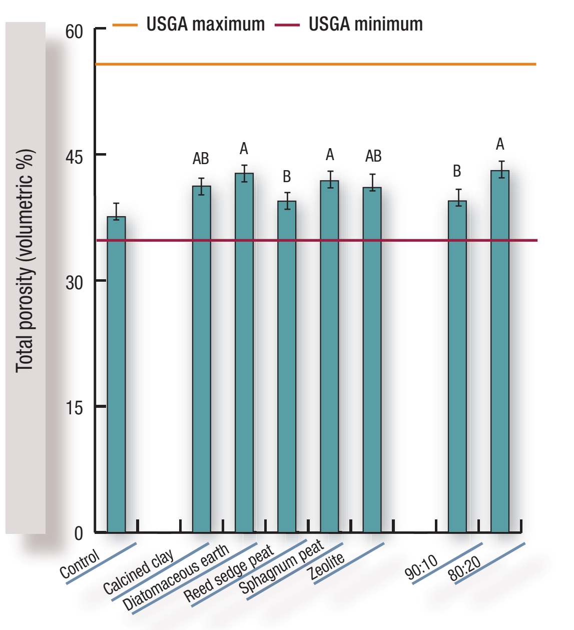

Figure 2. Total porosity (volumetric %) of a sand control and five root-zone amendments compared at varying ratios. Within groups, bars that do not share a letter are significantly different.

Irrigation was withheld to determine which root zones retained the most plant-available water.

green turf cover within 12 days. There were two peat treatments, reed sedge (80:20) and sphagnum peat (80:20), in the top four amendments that reached 50% green turf cover within 10 days; no inorganic amendments performed significantly better than these peats.

For Run 2, the data for percent green cover during establishment were similar to the data for Run 1 (Figure 4). On average, the inorganic amendments at the 80:20 ratio reached 100% green turf cover before the inorganic amendments at the 90:10 ratio, but there were no significant differences among treatments. Diatomaceous earth (80:20) performed significantly better than the other inorganic amendments except for calcined clay (80:20) by reaching 50% green turf cover within 14 days. Diatomaceous earth (80:20), sphagnum peat (80:20), the sand control, and calcined clay (80:20) performed the best of all the treatments, but no treatment was significantly better than the others. There was no consistent trend in amendment performance.

Green cover during dry-down. During the dry-down period for Run 1, diatomaceous earth (80:20) performed significantly better than all the other amendments, including the sand control, except for reed sedge (90:10) and sphagnum peat (80:20) (Figure 5). In addition, diatomaceous earth (90:10) and zeolite (80:20) retained significantly more green cover than the sand control. For Run 2, there were no significant differences among treatments (data not shown).

Wilt ratings. For Run 1, on days when root-zone treatment significantly affected wilt ratings, the sand control consistently had the most wilt. Diatomaceous earth (80:20) had the lowest wilt ratings over the course of the dry-down period, but did not perform significantly better than the reed sedge (90:10) or sphagnum peat (80:20). Reed sedge peat (90:10) was one of the better treatments, but at the 80:20 ratio, it did not perform significantly better than the sand control. Zeolite (90:10) was among the four root zones with the least wilt during the dry-down period. On average, the inorganic amendments were not significantly different from the organic amendments, with regard to wilt ratings.

For Run 2, on the days when treatments significantly affected wilt ratings, the sand control and diatomaceous earth (80:20) had the most severe wilt (data not shown). Reed sedge peat (80:20) was one of the better treatments over the course of the dry-down period, but it did not perform significantly better than the sphagnum peat (90:10)

Available water content

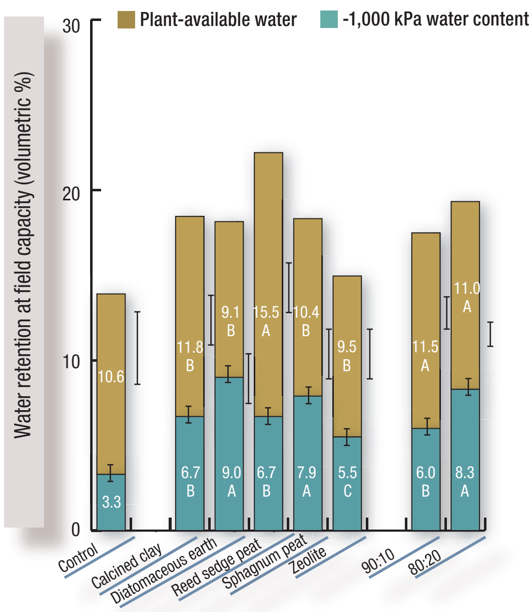

Figure 3. Available water content (volumetric %) of a sand control and five root-zone amendments compared at varying ratios. Within evaluations and groups, bars that do not share a letter are significantly different. (-1,000 kilopascals = -145 pounds/square inch)

50% cover after germination

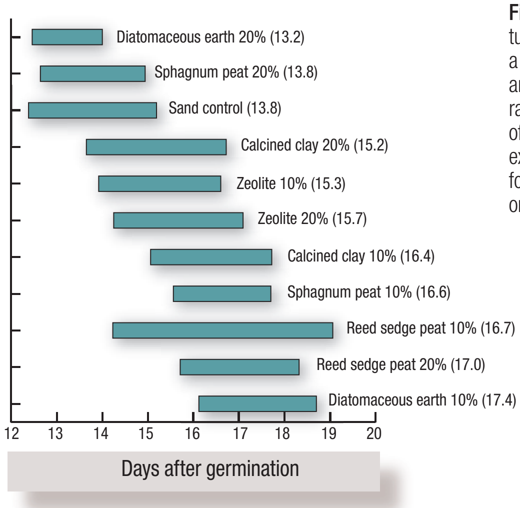

Figure 4. Days until 50% green turf cover following germination on a sand control and five root-zone amendments compared at varying ratios. Bars represent the range of days during which the turf is expected to reach 50% green cover for each root-zone treatment, based on statistical analysis (Run 2).

50% cover vs. dry-down

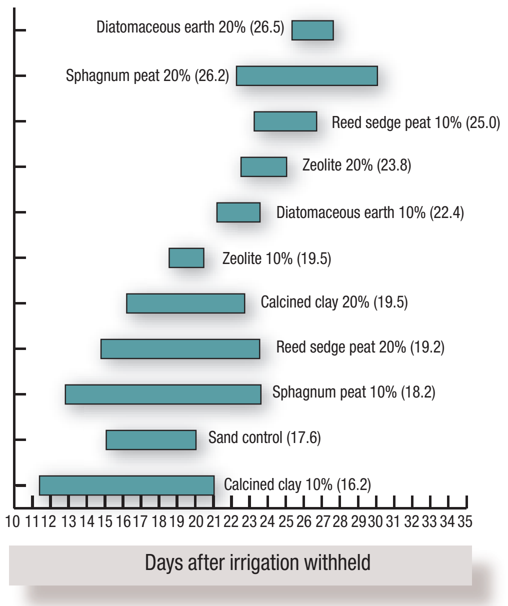

Figure 5. Days until 50% green turf cover during a dry-down period for five root-zone amendments compared at varying ratios and a sand control. Bars represent the range of days during which the turf is expected to reach 50% green cover for each root-zone treatment, based on statistical analysis (Run 1).

The research says

➔ All root-zone treatments met USGA recommendations except for capillary porosity in the sand control.

➔ In the laboratory, reed sedge peat was the only amendment that significantly increased plant-available water compared to the sand control.

➔ Increasing amendment ratios from 10% to 20% enhanced germination, but the difference was significant in only one of two trials.

➔ Diatomaceous earth enhanced establishment rate, green cover during dry-down and resistance to wilt, but using it for putting green construction would greatly increase costs. Long-term studies must be conducted to determine whether this product has long-term benefits compared to traditional peats.

➔ This experiment was performed in a controlled setting that favored turf growth. The results might be different if this experiment were performed under field conditions that included foot traffic, mowing stress and greater environmental variability.

or diatomaceous earth (90:10). On average, no inorganic amendment treatments performed significantly better than the organic amendments.

Conclusions

For Run 1, increasing the amendment ratio from 10% to 20% significantly enhanced germination. Diatomaceous earth (20%), reed sedge (10%) and sphagnum (20%) peat had the least amount of wilt and maintained green cover the longest during dry-down. For Run 2, increasing the amendment ratio from 10% to 20% enhanced germination, but there was not a significant difference among amendment ratios overall. Diatomaceous earth (10%), reed sedge (20%) and sphagnum (10%) peat had the least amount of wilt and maintained green cover the longest during dry-down.

It is apparent from these studies that root-zone performance is inherently variable as results were somewhat inconsistent between Run 1 and Run 2. In addition, it should be noted that these results were obtained in a greenhouse environment (high relative humidity) and that results would likely vary in a field situation.

Overall conclusions

Diatomaceous earth enhanced establishment rate, green cover during dry-down, and resistance to wilt, but did not perform consistently better than organic peat treatments. Diatomaceous earth, if used in a putting green construction situation, could increase construction costs by approximately $86,000 (3). Long-term studies must be conducted to determine whether diatomaceous earth has long-term benefits compared to traditional peats. Replacing peats with inorganic amendments during putting green construction may not be economically prudent.

This experiment was performed in a controlled setting that favored turf growth. The results might be different if this same experiment were performed under field conditions that included foot traffic, mowing stress and greater environmental variability.

Acknowledgments

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