MOISTURE RELATIONS AND BENTGRASS ROOTING IN SIMULATED GOLF GREENS

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The Green Section of the USGA has meticulously set forth specifications for construction of golf greens. The primary purpose of specifications for the root zone mix is to provide maximum compaction resistance while ensuring high water infiltration rates and adequate moisture holding capacity and aeration.

For many reasons, golf course architects and superintendents deviate from the USGA golf green specifications. The purposes of this study were to characterize the moisture relations of simulated golf greens of various compositions and to note associated effects on bentgrass root development.

METHODS

The simulated golf greens were established in six-inch diameter PVC pipes previously drilled to allow for moisture measurement (Fig. 1). The greens materials listed in Table 1 were combined as shown in Table 2. In all but column 6, the green mixes were underlain by 1.5 inches of very coarse sand. All greens contained four inches of pea gravel overlying a perforated plate at the bottom of each column. All mixes were compacted to a uniform bulk density of 1.4g/cc and no subsidence was observed over the duration of the study.

Fig. 1. Jeff measuring soil moisture with the time domain reflectometer.

The newly constructed greens were subjected to three wetting-drainage cycles before infiltration rates were measured. The greens were then allowed to drain for 24 hours and the moisture content measured at six different vertical distances with a Time Domain Reflectometer (Fig. 1).

Each golf green was then seeded to Penncross creeping bentgrass. Nitrogen at the rate of 1.0 lb/M was applied as 19-25-5 at the time of seeding. A second pound of N was applied three weeks later as 22-0-16. One month later the grass showed N stress and 0.5 lb. N was applied as a urea solution.

Once established, the bentgrass was clipped every other day at a ½-inch height. The greens received 0.2-inch water daily. On three separate occasions 0.5 inch "rain" was applied to each green, leachate collected for two hours and analyzed for N, P and K content. Phosphate concentrations were consistently below detection limits.

Infiltration rates of the greens were determined again 11 weeks after grass establishment. As had been done previously, the columns were allowed to drain for 24 hours and moisture measured at different soil depths. Irrigation was then suspended for two days, at which time the bentgrass was showing signs of moisture stress. The moisture contents of the greens were then measured for the third and final time.

After one week of daily watering, rectangular metal frames measuring 1.5 x 4 x 24 inches were driven into the columns a depth of 12 to 13 inches. These were extracted from the greens and the covers replaced by pin boards. The sand was then carefully washed away. The isolated plants with intact root systems were then photographed (Fig. 2).

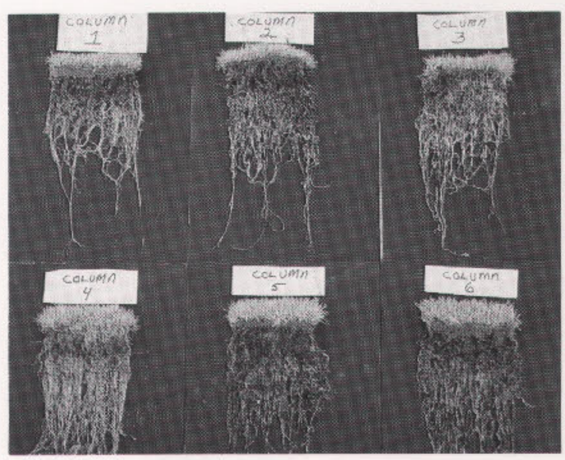


Fig. 2. Root development in the simulated golf greens.

RESULTS

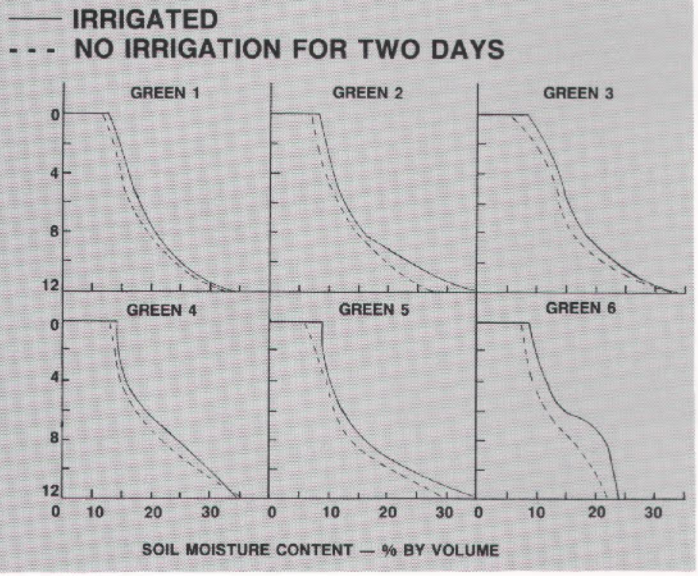
The initial infiltration rates of the golf greens prior to grass establishment ranged from 3.1 to 36.2 inches per hour (Table 3). This very wide range was achieved simply by varying the peat source. Incorporating peat to a depth of 5.5 inches only or leaving out the very coarse sand layer reduced the initial infiltration rates by 77 percent or more (greens 2 vs. 5 and 6). Shifting from the 80:20 mix (green 2) to the 80:10:10 mix reduced the infiltration rate by only 22 percent.

The anticipation was that as bentgrass roots filled in the larger pores, water infiltration rates would decrease. This did occur, but not in all the greens. Where it occurred (greens 1, 2, 4 and 5), the infiltration rates declined 42 to 75 percent. Infiltration rates on greens 3 and 6 actually increased by 47 to 63 percent after the bentgrass was established. Thus, in those greens whose infiltration rates were initially very low, grass root penetration somehow enhanced water infiltration.

The moisture profiles of the six greens are shown in Figure 3. At first glance, only green 6, the one without the very coarse sand layer, appears to have a distinctively different moisture profile. Placing the sand-peat mix directly over the pea gravel rather than over very coarse sand apparently produced a more pronounced perched water table. This is to be expected given the differences in pore sizes in the very coarse sand and pea gravel.

Differences in the golf green moisture profiles when fully wet or after a two-day dry-down period are difficult to detect visually (Fig. 3). Therefore, areas under the soil moisture curves were integrated graphically to reveal relative

Figure 3. Simulated Golf Green Moisture Profiles



differences in moisture retention and the percentages of water lost during two days of evapotranspiration. The results of these integrations reveal a general trend of increasing moisture retention with increasing degree of peat decomposition (greens 1, 2, 3 in Table 4). Incorporating the peat in just the top 5.5 inches of sand reduced total water retention by only four percent (greens 2 vs. 5). Leaving out the very coarse sand layer modified the shape of the moisture retention curve (Fig. 3) but did not notably alter the total amount of moisture retained (green 6 Table 4).

The amount of water lost via evapotranspiration over a two-day period varied considerably from one green to another (Table 4). These differences likely reflect the combination of two factors: (1) the amount of water retained in the grass rooting zone; and (2) the tension with which the water was held. Without quantitative measures of roots at different depths in the various golf greens, it cannot be deduced which of these two factors was more important. It was noted, however, that in green 5 where peat was incorporated to a depth of only 5.5 inches, bentgrass roots virtually did not penetrate the pure sand (Fig. 2).

Indications from the data in Table 4 are that the decomposed sphagnum (green 2) held water in a more readily available state than did the Manitoba sphagnum (green 1) or the Iowa peat (green 3). Substituting silt loam soil

Table 1. Putting Green Component Materials

Material	Characteristics	
Sand: Waupaca Materials, Inc.; pH 7.3		
	Sieve Analysis	
	Size fraction	**%**
	V. coarse	0.7
	Coarse	17.6
	Medium	74.4
	Fine	6.9
	V. fine	0.4

Peats		**Ash Content**	
Source and type	**pH**	**Total**	**Acid insoluble**
		%	
Manitoba Sphagnum	3.6	8.40	6.58
Decomposed Sphagnum	5.8	16.0	11.9
Iowa	5.0	32.8	29.1

Soil Hockheim silt loam					
	Mechanical analysis				
	pH	**O.M**	**Sand**	**Silt**	**Clay**
			%		
	6.2	4.5	22	70	8

for some of the decomposed sphagnum reduced evapotranspiration loss of water (green 2 vs. 4) while incorporating this peat to only a 5.5-inch depth or leaving out the very coarse sand layer did not greatly alter water availability.

Nitrogen and potassium leaching losses from the greens varied two- to 20-fold (Table 5). Interpretation of these leaching losses are difficult because the different peats and the soil obviously contributed different amounts of N and K. However, because the same peat was used in greens 2, 5, and 6, some comparisons are possible. These comparisons show that shallow incorporation of peat increased N leaching but reduced K leaching. Leaving out the very coarse sand layer dramatically reduced leaching loss of N. But potassium loss did not change significantly, which leads to the suggestion that denitrification was responsible for the very low leaching loss from green 6.

Table 2. Putting Green Constructions.

Green Number	Construction
1	80:20 Sand: Manitoba sphagnum over 1.5 inches very coarse sand
2	80:20 Sand: decomposed sphagnum over 1.5 inches v. coarse sand
3	80:20 Sand: Iowa peat over 1.5 inches v. coarse sand
4	80:10:10 Sand: decomposed sphagnum: soil over 1.5 inches v. coarse sand
5	80:20 Sand: decomposed sphagnum to a 5.5-inch depth, then 6.5 inches pure sand over 1.5 inches v. coarse sand
6	80:20 Sand: decomposed sphagnum without the v. coarse sand layer

Table 3. Putting Green Water Infiltration Rates

Green Number	Infiltration rate	
	Initial	After 10 weeks
	inches/hr	
1	19.9	11.6
2	36.2	9.8
3	3.1	5.0
4	28.1	16.3
5	8.4	2.1
6	4.7	6.9

Table 4. Relative Amounts of Water Retained In The Top 12 Inches of Various Golf Greens And Water Use By Bentgrass in a 2-Day Period

Green Number	Relative amount of water retained	Loss over Two Days
1	87	6.7
2	94	15.6
3	100	9.6
4	99	9.7
5	90	15.5
6	96	17.2

Table 5. Nitrogen And Potassium Loss By Leaching

Green Number	Nitrogen	Potassium
	mg/column	
1	4.27	0.87
2	3.01	1.18
3	11.2	1.42
4	10.1	1.22
5	7.21	0.65
6	0.56	1.06

CONCLUSIONS

None of the simulated greens used in this study were replicated. While this means caution must be used in interpreting the results, some generalizations are possible. These are:

1. Choice of peat, depth of incorporation and whether or not a very coarse sand layer is used can markedly affect water infiltration rates in golf greens.
2. The declines in water infiltration rates of new greens over time is not entirely due to compaction. Grass root blockage of larger pores also appears to be involved.
3. The amount of water retained by golf greens is not greatly affected by peat source, depth of peat incorporation, use of an appropriate silt loam soil, or elimination of the very coarse sand layer.
4. The plant availability of water does, however, seem to vary substantially with the composition of the greens mix.
5. Although not quantified in this study, incorporation of peat into the top few inches of sand rather than throughout the 12-inch sand layer did appear to restrict bentgrass rooting depth.
6. Nitrogen and potassium leaching losses are influenced by depth of peat incorporation and, in the case of N, by elimination of the very coarse sand layer.

Editor's Note: Jeff Bahr will graduate at the end of this semester in mid-May. An outstanding student and recipient of a GCSAA, a NOR-AM, a WGCSA and a WTA scholarship during his undergraduate years, Jeff will be Pat Norton's Assistant Superintendent at Cedar Creek.

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