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Rootzone mixes low in initial moisture content of the rootzone mix immediately prior to initiation of the test method in the laboratory tend to have higher saturated hydraulic conductivity than those which have a high moisture content at the time of analysis. In 2000, a research project was initiated by the USGA Green Section to further investigate the impact of antecedent moisture on the SHC method.

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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 $21 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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Variation in Saturated Hydraulic Conductivity: The Effect of Antecedent Moisture Content

Robert O. Miller

SUMMARY

Researchers at Colorado State University have studied inter-lab variability in testing for saturated hydraulic conductivity (SHC) in samples of putting green rootzones. In 2000, a research project was initiated to investigate the impact of antecedent moisture on SHC. Antecedent moisture is the inherent initial moisture content of the rootzone mix immediately prior to initiation of the test method in the laboratory. Results of the study include:

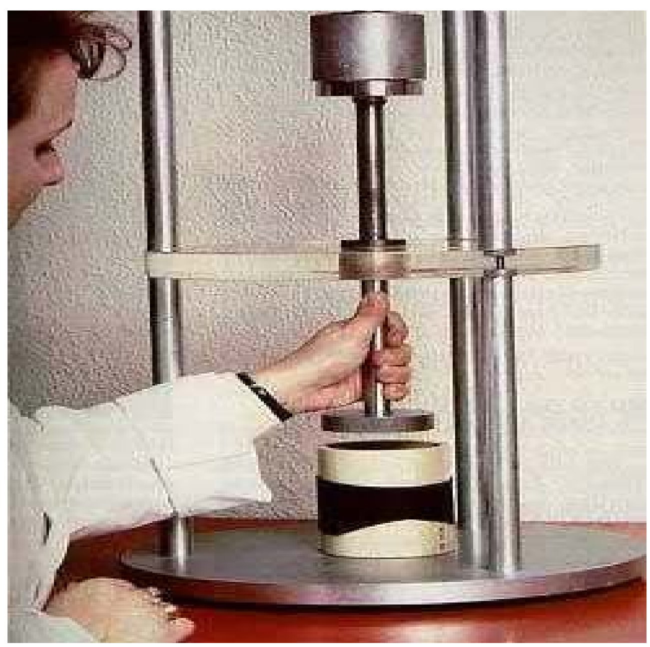
- Data provided by several cooperating laboratories indicated rootzone mixes low in antecedent moisture tend to have higher SHC rates than those which have a high moisture content at the time of analysis. Antecedent moisture had little impact on either capillary porosity, air-fill porosity, or bulk density across the range of antecedent moisture evaluated.
- In 2002, , the USGA Green Section Putting Green Committee (PUG) program revised ASTM method F1874-97, to include an antecedent moisture equilibration step to the method. All USGA-PT rootzone samples were to be equilibrated to a moisture content of 8.0% ± 0.5% (by weight) prior to analysis for SHC.
- Results from the 2002 USGA-PT program show that the addition of the antecedent moisture step to the SHC method has resulted in decrease in inter-lab variation in the SHC results over a previous year.

The saturated hydraulic conductivity (SHC) test (ASTM method F1874-97) is one of the fundamental laboratory tests used to assess the suitability of a rootzone materials for the construction of golf greens. Architects, contractors, sand suppliers and golf clubs often rely on this test as a key factor of the acceptability of a specific rootzone mix for use in putting greens.

The method was developed by Dr. Marvin Ferguson at Texas A&M University in the 1960s and was last revised in 1997. Results of the USGA Laboratory Proficiency Testing program (USGA-PT) over the past five years , however, have indicated inter-lab variability (consistency of analysis results between testing laboratories) of 25% or more in the SHC method for rootzone mixes evaluated between 1997 and 2001.

One of the factors identified that contributes to SHC laboratory variation was first reported in 1999 by Dr. James Murphy of Rutgers University, New Brunswick, New Jersey as antecedent moisture. This is the inherent initial moisture content of the rootzone mix immediately prior to initiation of the test method in the laboratory. Preliminary results indicated rootzone mixes low in antecedent moisture tend to have higher SHC rates than those which have a high moisture content at the time of analysis. Similar observations have been reported by testing laboratories and sand suppliers.

In 2000, a research project was initiated by



Quanitifying saturated hydraulic conductivty for packed rootzone mixes provide a measurement of how fast water will drain from putting green rootzones. Research is showing that this value is dependent upon the moisture level of the rootzone mix immediately prior to when the lab procedure is conducted.

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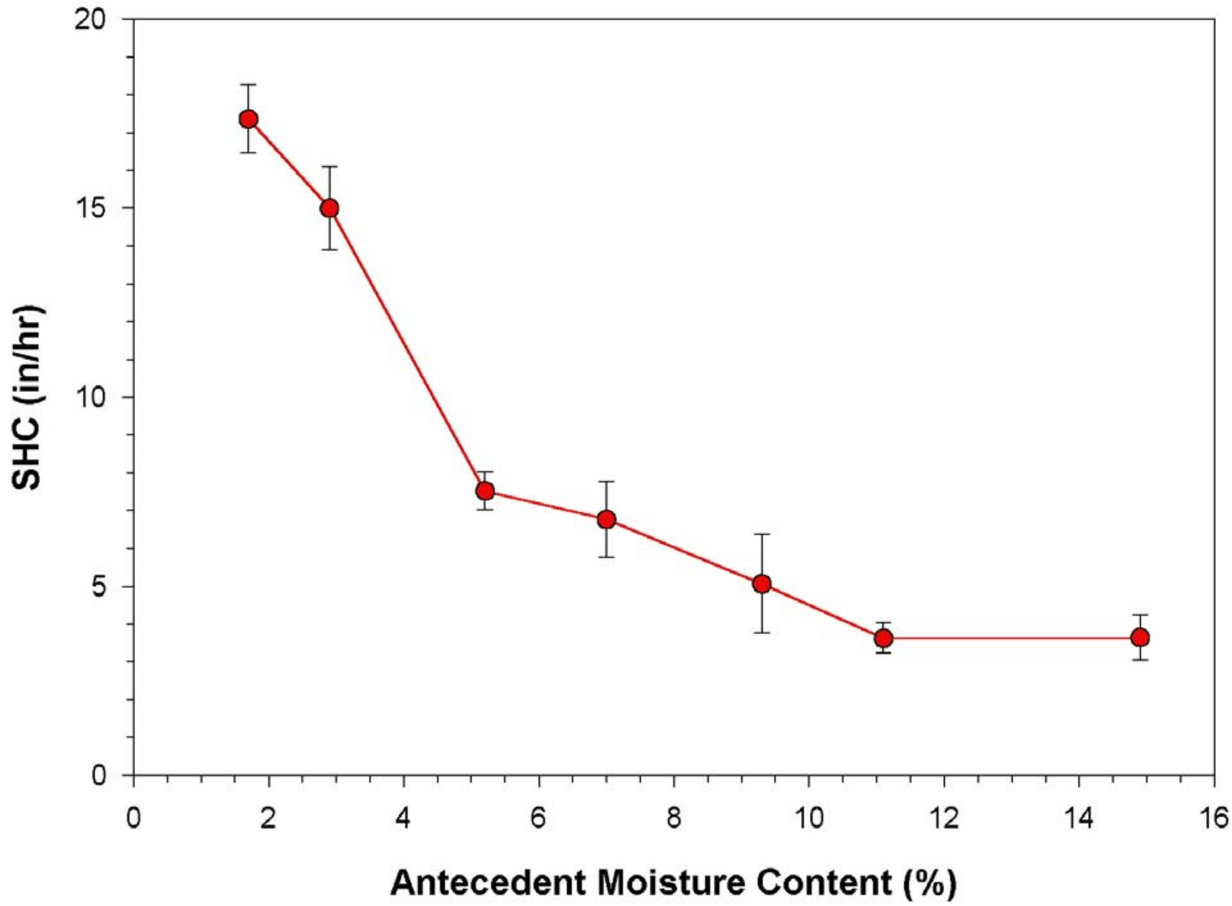

Figure 1. The influence of antecedent moisture on saturated hydraulic conductivity (SHC) on Hall-Irwin rootzone mix. (Data provided by Ann Murray, European Turfgrass Labaoratory, Stirling, Scotland)

the USGA Green Section to further investigate the impact of antecedent moisture on the SHC method. The focus of this research was to evaluate a range of antecedent moisture contents on SHC rates and porosity values. Data provided by Ann Murray, of European Turf Grass Laboratories of Stirling Scotland on a sand material supplied by the Hall Irwin company of Brighton, Colorado indicated that as the antecedent moisture content of the rootzone mix increased from 2% to 14%, there is initially a rapid decrease in SHC to 6% moisture followed by a more gradual decrease with higher antecedent moisture values (Figure 1).

Similar results were reported by Diane Rindt of Dakota Analytical Inc., of East Grand Forks Minnesota on a Colorado sand material (Figure 2) and Duane Otto of Turf Diagnostics and Design, Olathe Kansas; on a rootzone material supplied by TXI, of Austin, Texas (Figure 3).

Research results provided by Powell Gaines, of Tifton Soil Testing, Tifton Georgia, using a Golf Agronomics rootzone material from Florida indicated there was an initial rapid decrease in initial SHC values with an antecedent moisture content increasing from 2 to 9% followed by gradual decrease thereafter (Table 1). There was little impact on either capillary porosity, air-fill porosity, or bulk density across the range of antecedent moisture evaluated. Similar results were reported for a Scotish rootzone mix reported provided by Ann Murray of European Turf Grass Laboratory (Table 2).

The actual phenomena which antecedent moisture influences SHC, is not well understood, but is believed to be related to the inter cohesion of fine and coarse grain sand particles as function

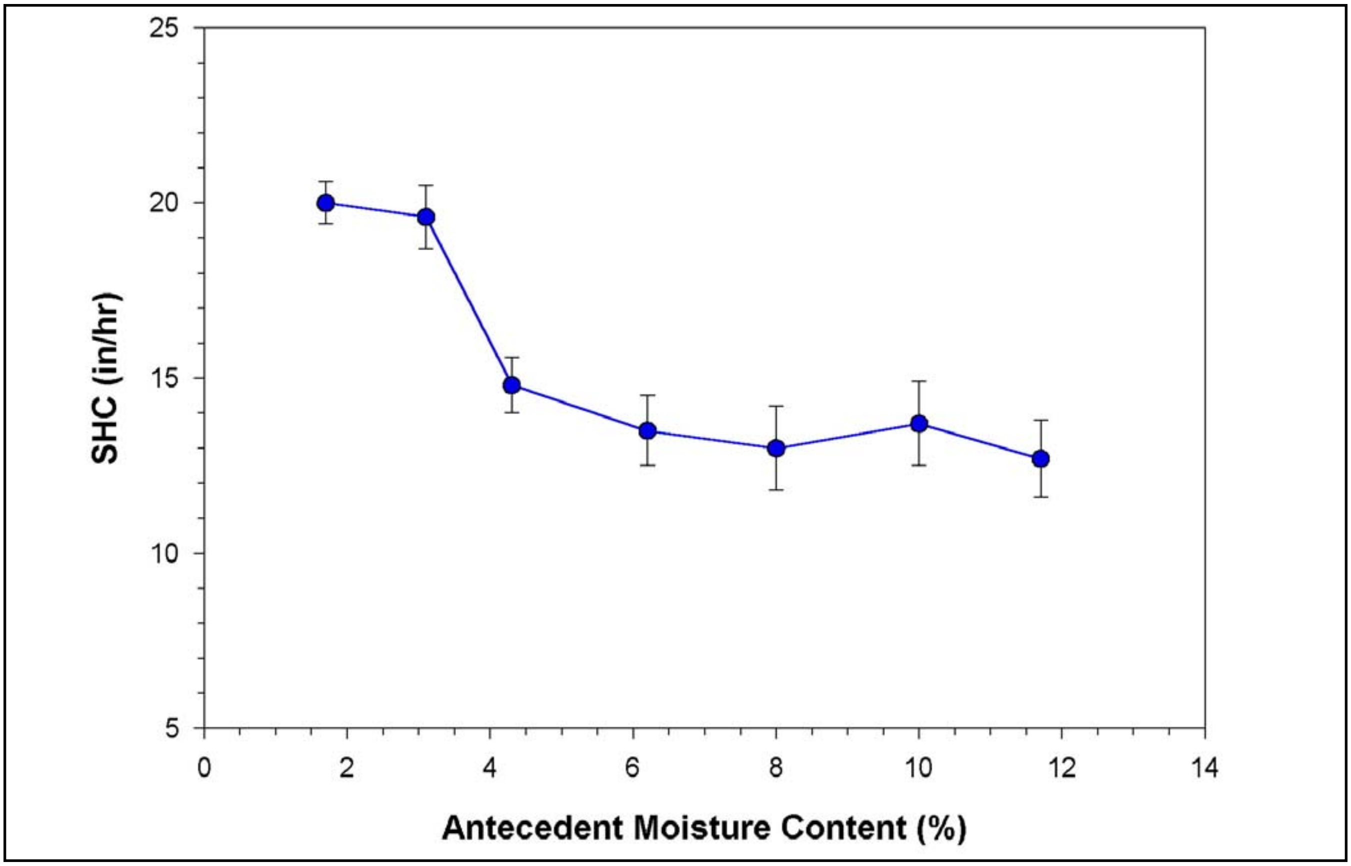

Figure 2. The influence of anecedent moisture on saturated hydraulic conductivity (SHC) on a TXI rootzone mix. (Data provided by Diana Rindl, Dakota Analytical Inc.,

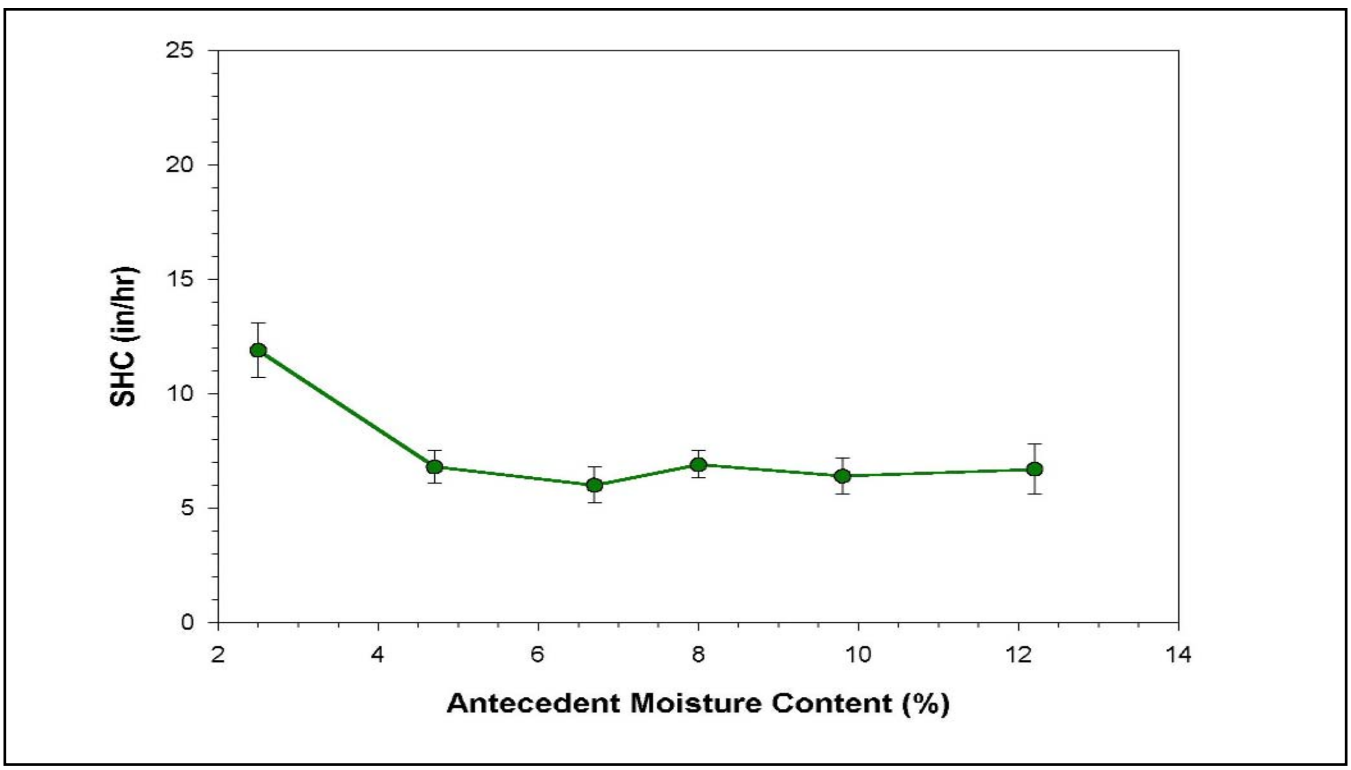

Figure 3. The influence of antecedent moisture on saturated hydraulic conductivity (SHC) on a Colorado rootzone mix. (Data provided by Duane Otto, Turf Diagnostic and Design, Olathe, KS.)

Antecedent Initial Moisture (%)	SHC (in/hr)	Capillary Moisture (%)	Air-filled Porosity (%)	Bulk Density (g/cm³)
2.7	15.7	13.5	24.6	1.62
9.7	12.1	14.8	24.0	1.61
11.3	11.7	14.4	24.7	1.62
13.9	10.5	14.7	24.9	1.60
16.1	9.3	15.4	25.1	1.58

Table 1. Impact of initial root zone mix moisture on SHC, capillary moisture, air filled pores and bulk density for a Golf Agronomics sand. Data provided by Powell Gaines, Tifton Soil Testing, Tifton Georgia.

Antecedent Initial Moisture (%)	SHC (in/hr)	Capillary Moisture (%)	Air-filled Porosity (%)	Bulk Density (g/cm³)
1.7	17.3	21.9	15.5	1.66
2.9	15.1	18.8	19.7	1.63
5.2	7.5	18.7	20.5	1.61
7.0	6.7	18.9	20.7	1.60
9.3	5.1	18.9	20.7	1.60
11.3	3.6	18.8	21.6	1.58
14.1	3.6	19.0	21.8	1.57

Table 2. Impact of initial root zone mix moisture on SHC, capillary moisture, air filled pores and bulk density for a Hall Irwin sand. Data provided by Ann Murray of European Turf Grass Laboratories of Stirling Scotland.

Rootzone Material	SHC (in/hr)		
	Median	MAD	RMD(%)[1]
1999-I	19.1	3.4	17.8
1999-II	18.7	4.5	24.0
1999-III	10.9	2.3	21.1
2002-VIII	14.9	1.9	12.7
2002-IX	10.1	0.86	8.5
2002-X	26.3	1.9	7.2

[1] RMD is calculation: (MAD/Median) x 100.

Table 3. Statistical performance of the SHC method for three root zone mixes in the 1999 and 2002 USGA-PT Program. Results based on twelve participating laboratories.

of increasing thickness of water films associated with moisture. Using the current method ASTM F1874-97 for SHC, low antecedent moisture leads to a lack of cohesion of sand particles and results in a greater proportion of air-filled macro-pores (those which hold water at tensions less than 30 cm), and greater macropore conductivity. High antecedent moisture levels lead to more cohesion, a decrease in air-filled macropores, and less connectivity. This results in slowed saturated water flow and low SHC percolation rates. The physics of this process are not understood within the context of the current SHC method, but clearly it affects all rootzone materials independent of the sand fraction composition or the source of the material.

Based on these research, in 2002 the USGA Green Section Putting Green Committee

(PUG) program revised ASTM method F1874-97 to include an antecedent moisture equilibration step to the method. All USGA-PT rootzone samples were to be equilibrated to a moisture content of 8.0% ± 0.5% (by weight) prior to analysis for SHC. The moisture content typifies a zone of little or no influence of moisture on SHC rates across a range of rootzone mix materials.

Results from the 2002 USGA-PT program clearly show that the addition of the antecedent moisture step to the SHC method has resulted in decrease in inter-lab variation in the SHC results over a previous year (Table 3). Based on twelve rootzone materials, the variability in SHC results decreased from 17-24% in 1999 to 7-12% in the 2002 USGA-PT Program. Although this method change has resulted in an overall downward shift in the effective SHC rate, the percentage drop depends on the rootzone mix.

This method change has resulted in three significant improvements in the SHC method: (1) a more accurate test result, (both within and between laboratories); (2) a more conservative SHC test which is less likely to approve a marginal rootzone mix; and (3) a method less affected by pre-analysis manipulation. As the revision to the method has no impact on porosity values or bulk density, there are no changes needed in the current guidelines for USGA acceptable rootzone materials.

Acknowledgments

Special thanks to Ann Murray of European Turf Grass Laboratories of Stirling Scotland, Duane Otto of Turf Diagnostics and Design, Olathe Kansas; Powell Gaines, of Tifton Soil Testing, Tifton Georgia; and Diana Rindt of Dakota Analytical Inc, East Grand Forks, Minnesota for their assistance in performing research for this project. Also thanks to the USGA Green Section for supporting this project and those laboratories enrolled in the USGA-PT Program.

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