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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 350 projects at a cost of \$29 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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# Characterizing Soil Organic Matter in Golf Course Putting Greens

Deying Li and Roch Gaussoin

## SUMMARY

Until now there has not been an effective way to quantitatively describe organic matter among turfgrass scientists. Scientists at North Dakota State University and University of Nebraska used infrared (IR) spectroscopy in conjunction with partial least squares analysis as a rapid and inexpensive means to characterize soil organic matter in putting greens. The study's findings include:

- FTIR (Fourier Transform Infrared) spectroscopy can be used for identification of peat and other organic material.
- FTIR spectroscopy at mid-infrared range can be used for characterization of rootzone organic matter.
- FTIR spectroscopy in combination with PLS analysis can be used for quantification of many soil properties such as pH, CEC, organic carbon, etc.

Soil organic matter is one of the most important components in turfgrass rootzones affecting nutrient cycles, air and water movement, thermal properties, and the fate of chemicals used for turf management (11,18,19,29). In turfgrass management, thatch, black layer, localized dry spot, and other problems center on this very basic soil property, i.e. organic matter (1,10, 21).

Golf course superintendent cringe on hearing thatch or organic matter. During the process of rootzone construction, a decision has to be made whether to use organic materials or not. If yes, choices have to be made from all sorts of organic sources (9). During the course of turf management, every single cultural practice has to be carefully considered by superintendents since all turf management measures affects soil organic matter dynamics. Golf courses and other turf areas have also been considered as a sink for car-

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bon sequestration (22). Naturally, everyone in the turf industry has a stake in the soil organic matter issue.

In the past, soil organic matter has been viewed as a black box and all organic matter is treated equal by the loss of ignition method. A great deal of research have been conducted on the effects of organic matter on soil physical properties (5, 17, 18), turfgrass establishment (2, 6, 7, 15, 25), and microbial population (3, 20, 27). Carrow (4) reported that soil organic matter buildup is unavoidable as greens age and recommended remedies by aeration, topdressing, and wetting agents.

Verterlein and Hutt (28) presented a thorough review comparing artificially applied organic matter and soil organic matter. Long-term effects of rootzone mix on organic matter accumulation and physical properties conducted by Gaussoin (8) indicate that over ten years, organic mater and water conductivity tend to stabilize at certain levels. There has not been an effective way to quantitatively describe organic matter among turfgrass scientists. This is especially a



An FTIR spectrometer was used to successfully characterize organic matter in putting greens. The use of this technology is an important step in understanding the complex mix of organic compounds found in turfgrass systems.

Wave number (cm <sup>-1</sup> )	Assignment
3400-3300	O-H stretching
2940-2900	Aliphatic C-H stretching
1725-1720	C=O stretching of COOH
1660-1630	C=O stretching of amide groups (amide I band)
1620-1600	Aromatic C=C
1590-1517	COO-symmetric stretching, N-H deformation, C=N stretching (amide II band 1502)
1460-1450	Aliphatic C-H
1400-1390	OH deformation and C-O stretching of phenolic OH, C-H deformation of CH <sub>2</sub> and CH <sub>3</sub>
1280-1200	C-O stretching and OH deformation of COOH
1170-950	C-O stretching of polysaccharide

**Table 1.** Assignment of the main IR absorption bands of humic substances (after 27)

problem in thatch evaluation when it is diluted with sand.

In order to understand the mechanisms of soil organic matter decomposition and accumulation, attention has been focused on the chemical properties of organic matter and their quantification. Kerek et al. (14) studied microbial biomass within particulate organic matter (POM) of aging golf greens by fractionating it into light and heavy particulate organic matter. They speculate that humus accumulation within particulate POM renders POM and microbial biomass resistant to degradation. Kerek et al. (15) also separated humic acid fraction into calcium-bound (CaHA) and mobile (MHA) fractions and studied labile soil organic matter as a potential nitrogen source. We know very little about the nature of organic molecules, their distribution, and effects on other soil properties.

Another very important aspect of soil organic matter is its contribution to hydrophobicity, a major cause of localized dry spot (LDS). Karnok et al. (13) documented that hydrophobic sand caused by coating with exudates from microbes is a primary cause of LDS in sand-based putting greens. LDS has been recognized for many years (17), in many countries (9, 13, 31, 32) and in different soil types. Topdressing, core aer-

ation, wetting agents, and soil pH adjustment are just a few of the many tools turf managers use to manage LDS. The key to choosing a right practice is a thorough understanding of the soil organic matter and soil microenvironments. Soil organic matter is composed of a very complicated group of materials. Currently, we have not identified the types of organic substances that are the major contributors to LDS.

Characterizing organic matter decomposition is very important. Quantitative information about the organic matter contribution can be obtained by <sup>14</sup>C activity measurement. Chemical structures characteristic of recently formed organic matter (thatch) can be identified using <sup>13</sup>C cross polarization magic angle spinning nuclear magnetic resonance (CPMASNMR) spectroscopy (24). However, those methods are time-consuming and expensive. The objective of this study was to use infrared (IR) spectroscopy in conjunction with partial least squares analysis as a rapid and inexpensive means to characterize soil organic matter in putting greens.

### Choice of Methodology

Near-infrared (NIR) spectroscopy in combination with multivariate data analysis has been

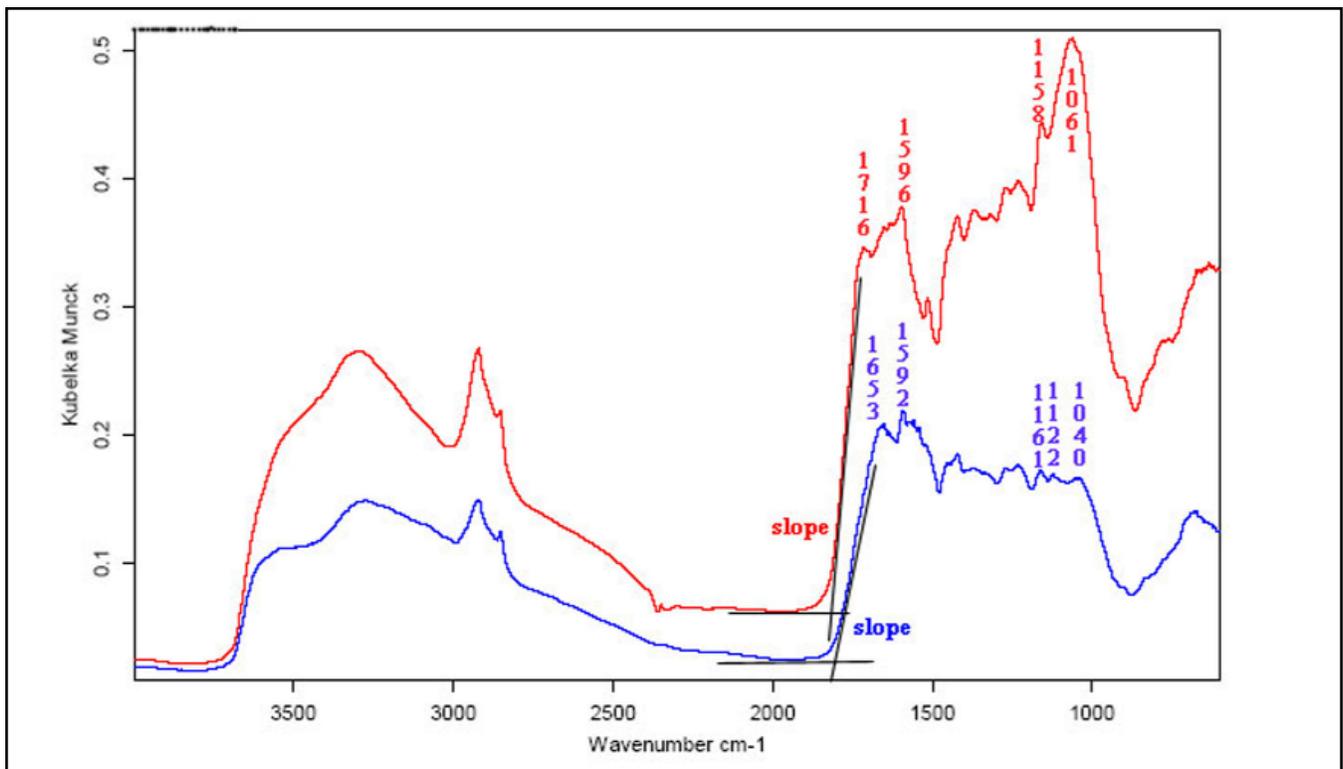


Figure 1. Typical spectrum of peat organic matter in the mid-infrared range

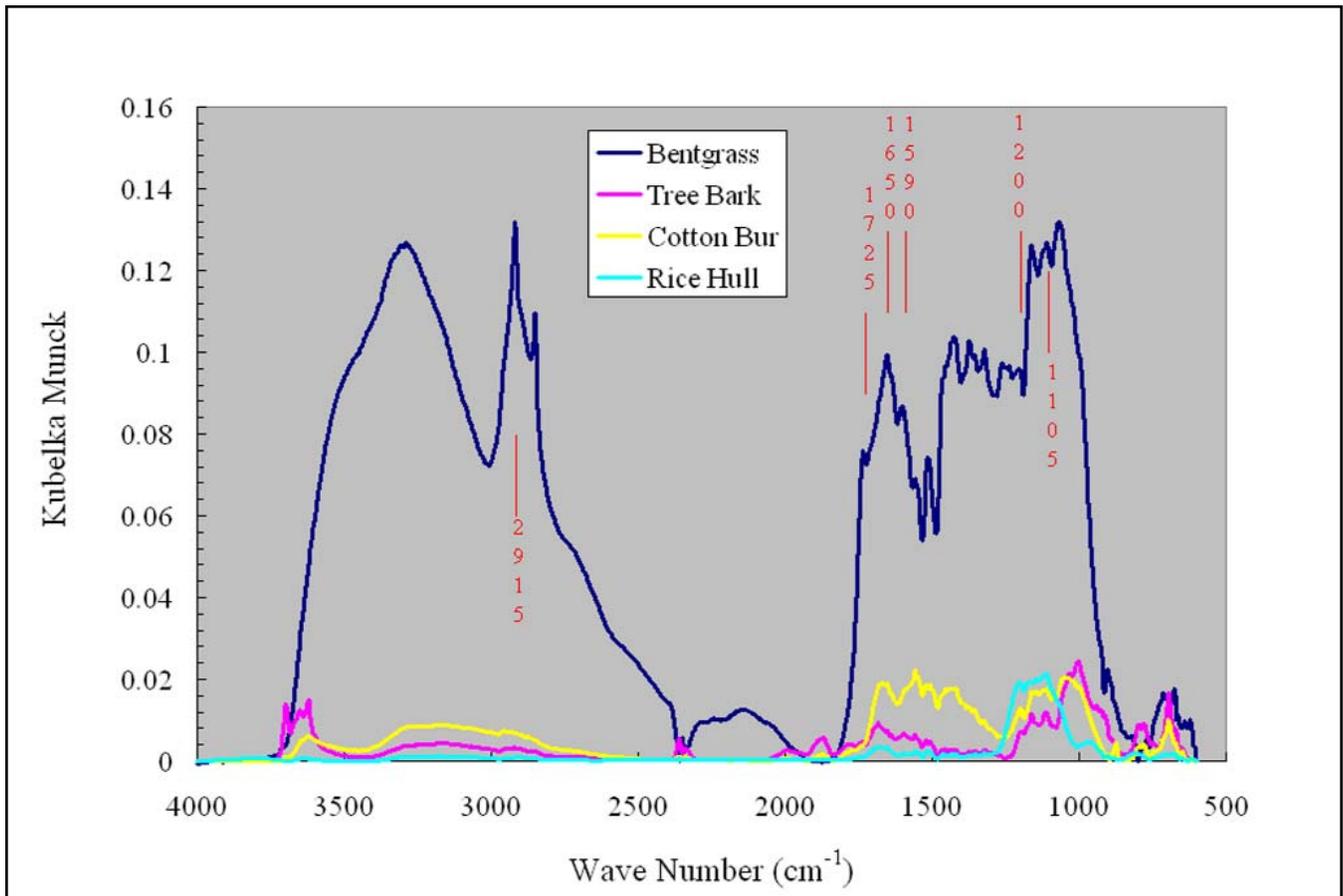


Figure 2. Mid-infrared spectrum of creeping bentgrass, tree bark, cotton bur, and rice hulls

Organic Material	Organic Component			
	Cellulose	Lignin	Hemicelluloses	Others
	-----% (dry weight)-----			
Bentgrass	49.2	2	10.8	38
Rice Hull	42.2	4	23.6	30
Tree Bark	51.1	10	28.8	10
Cotton Bur	45.5	1	10.2	43

**Table 2.** Components of non-decomposed organic materials

used to determine the composition of a wide variety of organic materials and soils, including total N and organic C. The mid-infrared (2,500-25,000 nm) has mainly been for research and qualitative analysis involving spectral interpretation.

The advantage of mid-infrared spectroscopy is that the spectrum is not limited to OH, NH, and CH and overlapping bands as in NIR. Using mid-infrared diffuse reflectance Fourier transform (DRIFT) spectroscopy and "as is" samples can provide accurate analyses (24). Table 1 is a list of commonly assigned peaks in the mid-infrared range for various molecular bonds. A typical spectrum for peat organic matter is shown in Figure 1, where:

(a) The slope of peak  $1720 \pm 5 \text{ cm}^{-1}$  or  $1652 \pm 5 \text{ cm}^{-1}$  (if peak at  $1720 \pm 5 \text{ cm}^{-1}$  is absent) is used as a parameter of peat decomposing. Higher slope indicate less decomposition, and

(b) the ratio between the peak  $1592 \pm 10 \text{ cm}^{-1}$  and  $1050 \pm 15 \text{ cm}^{-1}$  is used as an a parameter of decomposing peat. Higher ratios indicate more decomposition.

To test the sensitivity of the DRIFT meth-

ods for recent organic materials, bentgrass shoots, tree bark, cotton burs, and rice hulls were air-dried, ground to pass a 40-mesh sieve, and ground with potassium bromide (KBr) to be tested using mid-infrared FTIR spectroscopy. Accordingly, the peak identification information can be used to characterize different fresh organic materials as in Figure 2.

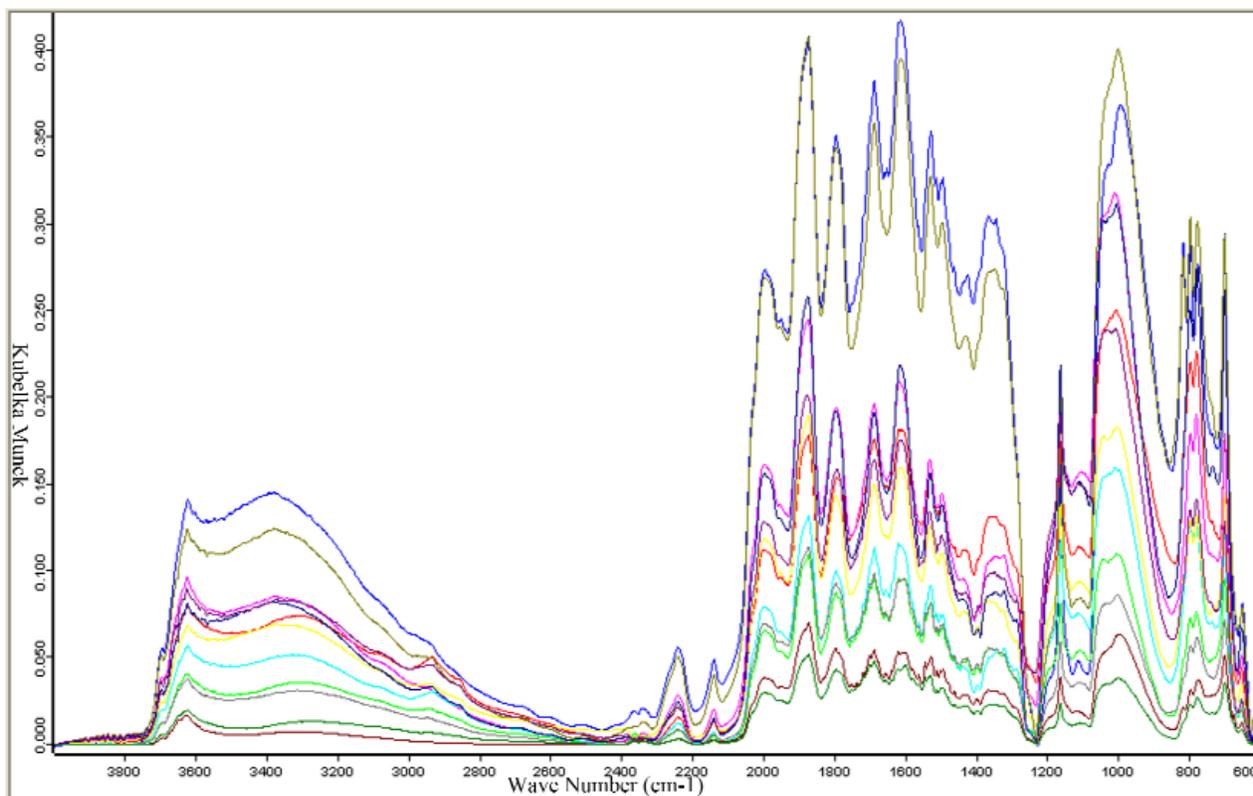
Wet chemistry tests for quantification of total cellulose, hemicelluloses, lignin, water-soluble carbohydrates, and water-insoluble carbohydrates were conducted. The results (Table 2) indicate that the DRIFT methods for mid-infrared FTIR spectroscopy provided accurate and detailed information about these four different sources of organic matter.

### Soil Sampling and Preparation

Soil samples were taken from test putting greens using a 4-inch diameter cup cutter to the depth of 6 inches. Six samples represent 8-, 9-, 10-, and 12-year-old greens built according to USGA recommendations for putting green construction. Samples were divided into 12 layers of

Extracted Factor	Model Effects		Dependent Variables	
	Current	Total	Current	Total
1	56.9047	56.9047	20.44	20.44
2	29.1391	86.0438	30.1701	50.6101
3	2.9203	88.9641	19.5051	70.1152
4	4.9605	93.9246	3.1706	73.2859
5	1.7963	95.7209	3.76	77.0458

**Table 3.** Statistical summary of PLS results of the 72 putting green samples of different ages and at different depths.



**Figure 3.** Mid-infrared FTIR spectra of 12 half-inch layers of a 6-inch deep putting green rootzone sample demonstrate peak height, shape, and peak number differences.

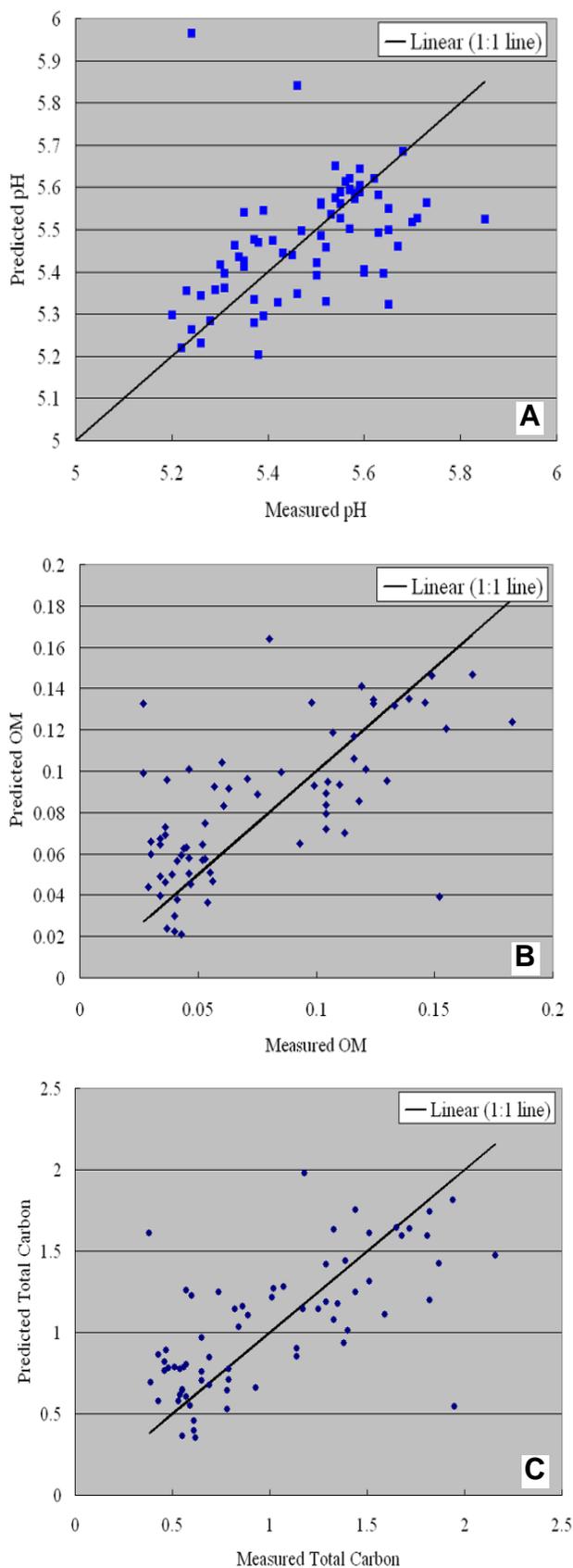
0.5-inch thickness each. The samples were then air-dried and ground with a hammer mill to pass a 100-mesh sieve. Total N, total organic C, and pH were analyzed using a Leco CHN 1000 analyzer and pH meter, respectively. Meanwhile, the samples were diluted with KBr at 1:1 ratio (by weight) and further ground with an agate mortar and pestle before used for DRIFT in the range of 4000 to 600  $\text{cm}^{-1}$  (2,500-25,000 nm) wave numbers at a resolution of 4  $\text{cm}^{-1}$  and 64 co-added scans per spectrum. The equipment was a Bruker Optic Tensor 27 with a germanium-coated KBr beam splitter, a high density globar source, and a liquid nitrogen cooled wide-band mercury-cadmium-telluride (MCT) detector.

Absorbance spectra were transformed to  $\log(1/\text{reflectance})$  for statistical analysis. All points were subjected to pretreatment (mean centering, variance scaling, and baseline correction) before multivariate analysis using SAS PLS procedures.

## Results and Conclusion

FTIR spectrum of one sample at different depth is shown in Figure 3. Multivariate analysis showed that five minimum factors extracted with  $P > 0.1$ . The five factors accounted for 95.7% of the model variation and 77% of the response variation (Table 3). The model was further tested by testing the data set. Half of the data set was used for the establishment and cross-verification of the model, and the other half was used for testing the prediction ability. Figure 4 exhibits the prediction of pH, OM, and total carbon from the model.

In summary, FTIR spectroscopy, in combination with peak identification and multivariate analysis, can be used for characterization of organic matter in terms of their degree of decomposition, pH, CEC, biological activity, total C, total N, as well as many other important properties.



**Figure 4.** Comparisons of predicted and measured pH (A), organic matter content (B), and total carbon (C).

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