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A Utah State University study tested organic acids, including a pure humic acid, and commercial humic substance products on established putting greens to test their effects on water retention and uptake of nutrients by creeping bentgrass grown on sand-based rootzones. Humic substances did not increase moisture retention in putting green soils as pure humic acid significantly decreased soil volumetric water content compared to the control.

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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 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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Humic Substances Effect on Moisture Retention, Nutrition, and Color of Intermountain West Putting Greens

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SUMMARY

Humic substances are often applied to putting greens to improve turf health, but little is known regarding their effects on soil moisture retention. Commercial humic substance products and pure organic acids were applied to three golf course putting greens in Utah in 2006 and the Utah State University research putting green in 2006 and 2007. These treatments were evaluated for effects on soil volumetric water content, phosphorus (P) uptake, and chlorophyll content of creeping bentgrass. Three irrigation levels, 80%, 70% and 60% of reference evapotranspiration (ET_o) were imposed on the turf at the research putting green. Results indicate:

- Humic substances did not increase moisture retention in putting green soils as pure humic acid significantly decreased soil volumetric water content compared to the control. Both humic acid- and fulvic acid-treated plots had lower soil moisture content readings than the control at a depth of 10 to 15 cm during the growing season.
- Uptake of P by creeping bentgrass was significantly decreased with the application of humic acid.
- No differences were observed for chlorophyll content of the turf with any humic substance treatment suggesting turf color is not enhanced when using humic substances.

Creeping bentgrass (*Agrostis stolonifera* L.) is the predominant cool-season grass grown and managed on putting greens in the Intermountain West region of the United States. While adapted to golf course conditions, both the climate and calcareous soils of the region can impose difficult growing conditions for this and other turfgrass species. The large transpiration gradient created by warm temperatures and low humidity during the summer can create stressful conditions for bentgrass growth.

Sand rootzones have low water-holding capacity that requires frequent irrigation. The calcareous sand commonly used in the Intermountain West has a relatively high pH (~ 7.5-8.5), making phosphorus and some micronutrients less available to the turf. In addition to these challenges, many golf course superintendents are expected to reduce water use, especially during droughts, and minimize fertilizer use while still maintaining high quality turf. Thus, supertintendents are always seeking ways to be more efficient with their management practices while improving turf health.

In order to meet these challenging demands, one management practice that is often implemented is the use of natural organic products such as those containing humic substances. However, many questions exist regarding their effectiveness and what exactly these products can do for putting green turf (8). Humic substances are a component of soil humus, which can be divided into fractions of fulvic acid, humic acid, and humin depending on their solubility as a function of pH (13). Humic substances have been studied and used on a variety of agricultural crops for years, but only in the last twenty years have they been studied on turfgrass systems. Of the humic substances that have been studied, humic acid is the most common, but results with creeping bentgrass have been highly variable (4).

Humic substance treatments were foliarly applied to creeping bentgrass greens and made with a back pack sprayer.

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Humic substances have been shown to increase photosynthesis (9, 17) and root mass (9) and length (4) of creeping bentgrass in controlled studies. However, similar responses have not been observed in the field (7). The lack of responses on turf when using humic substances in the field may be attributed to the difficulty in isolating the effects of nutrients and other ingredients often included in humic substance products and the variability and uncontrolled nature of field conditions.

Regardless of the inconsistencies that have been reported, products containing humic substances are common in the turf industry. Claimed benefits include the ability to increase soil moisture and nutrient availability. While positive growth effects of humic substances on creeping bentgrass have been well documented, scientific literature on improved moisture retention in putting greens has not. Our study tested organic acids, including a pure humic acid, and commercial humic substance products on established putting greens to test their effects on water retention and uptake of nutrients by creeping bentgrass grown on sand-based rootzones.

Putting Green Experiments with Humic Substances

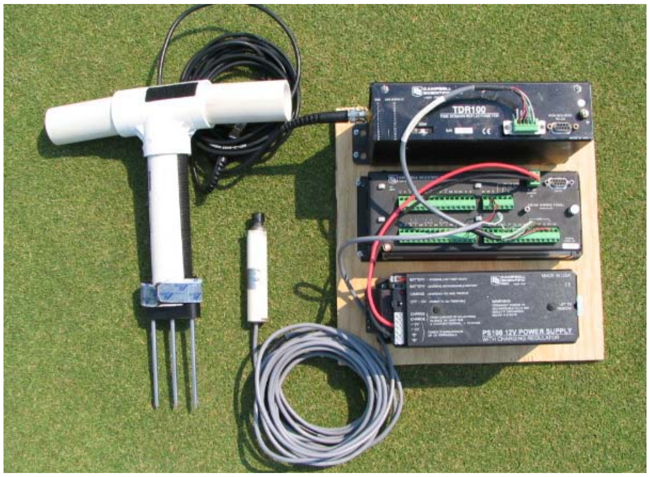
Two experiments were conducted. One involved three golf courses in Utah and the other at a research putting green at Utah State University. Organic acids, including a pure humic acid, and commercial humic products were applied to established creeping bentgrass putting greens. Evaluations were done during the summer growing season (June, July, and August) of 2006 and 2007 at the research putting green at Utah State University, and in 2006 at the three golf courses in Utah. The research sites for this experiment were the Utah State University Greenville Research Farm in North Logan, Birch Creek Golf Course in Smithfield, The Country Club in Salt Lake City, and Talons Cove Golf Course in Saratoga Springs.

At the golf courses, plots were laid out on practice putting greens. The rootzones consisted of primarily calcareous sands. None of the putting greens were built to USGA recommendations, with the research putting green being the closest of all the sites. At the research putting green, the sand mix contained higher percentages of fine (14%) and very fine (9%) sand particles than USGA recommendations allow. The Talons Cove putting green was built to California-style recommendations. The Country Club and Birch Creek greens were native soil push-up greens with sand topdressing applied.

In all locations, the putting green turf was predominantly creeping bentgrass with varying percentages of annual bluegrass (*Poa annua* L.). Cultural practices at all locations were considered typical for the Intermountain West region of the United States, but varied at each site. At the three golf courses, the putting greens were used extensively by golfers, but no traffic was applied on the research putting green at Utah State University.

Materials and Methods

Individual organic treatment plots measured 5 ft. by 5 ft. with three replications. At the research putting green only, each block of organic treatments was centered in a 35 ft. by 35 ft. irrigation block where different irrigation levels were applied. Irrigation treatments consisted of 80%, 70%, and 60% of reference evapotranspiration (ET_o) replaced (1). The ET percentages imposed



Time-domain reflectometry (TDR) device and datalogger used to measure and store volumetric water content of putting green soils.

on the turf corresponded to watering approximately every 2-3 days for 80%, every 3-4 days for 70%, and every 4-5 days for 60%, depending on the weather conditions. Evapotranspiration replacement percentages were determined by a Weather Reach controller (Irrisoft Inc., Logan, UT).

The irrigation blocks and individual treatment plots were not re-randomized in 2007 at the research putting green to reduce any possible residual effects from these products occurring in the soil over time. The experimental design, except for irrigation levels, was the same at each golf course. Irrigation treatments were not possible at the golf courses, but irrigation was reduced to stress the turf at the superintendents' discretion.

Treatments and Application Techniques

The plots were treated with reagent-grade organic acids, four commercial humic substance products and evaluated against a water-only control. These treatments included the organic acids citric acid (4 oz. / 1000 ft^2), tannic acid (3.2 oz. / 1000 ft^2), and leonardite humic acid (2.8 oz / 1000 ft^2). The commercial products included three humic acid products, H-85 (6 oz. / 1000 ft^2), Focus (7.5 oz. / 1000 ft^2) and Launch (15 oz. / 1000 ft^2), and a fulvic acid (40 oz. / 1000 ft^2). The commercial humic substance products were selected because of humic substance content, particularly humic acid, and availability to turf managers in the Intermountain West.

Applications were made at recommended label rates for the commercial products, and the rates of application for the fulvic acid and organic acid treatments were normalized to equal carbon rates among these products. Three separate applications were done approximately 30 days apart, according to the label, on June 7, July 5, and August 3, 2006 at Birch Creek golf course, and June 1, July 6, and August 2, 2006 at the Salt Lake Country Club and Talons Cove golf courses. Applications at the research putting green were done on June 5, July 5, and August 4 in 2006, and June 1, July 2, and August 1 in 2007. All treat-

The portable TDR device made measuring rootzone moisture content of individual plots quick and efficient.


A chlorophyll meter was used to measure color effects of the treatments on the putting green turf.

ments were applied with approximately 605 GPA of water and made using a CO_2 backpack sprayer at 40 psi.

Evaluation of Treatments

Moisture content of the rootzones was monitored weekly throughout the summer growing period using a hand-held time-domain reflectometry (TDR) probe. The TDR 100 (Campbell Scientific, Logan, UT) device was connected to a CR10X datalogger (Campbell Scientific, Logan, UT) and a power supply that was designed to be portable in the field. The TDR probe was assembled and calibrated for determining volumetric water content for this application using Win TDR software (Utah State University, Logan, UT), and the water content measurement was averaged over the length of the probe. A 6-inch (15-cm) probe was used at the research putting green and Talons Cove golf course, but a 4-inch (10-cm) probe was needed at the Birch Creek and Salt Lake Country Club golf courses because of their shallow sand layers.

At the research putting green only, measurements were taken daily for two weeks at the end of July and again in August in both years. This was done to track soil water content more accurately when the different irrigation levels were being applied. Turf color was also measured using a CM1000 chlorophyll meter (Spectrum Technologies, Inc., Plainfield, IL) at approximately 3 ft. off the ground on the same days soil volumetric water content was measured. The chlorophyll index measured by this meter has been highly correlated with visual color ratings (10).

Treatment	Volumetric water content^y	Chlorophyll content^z
	(%)	(color index)
Control	17.6 a^x	226 ab
Citric acid	17.4 ab	230 a
H-85	17.1 ab	226 ab
Focus	17.0 ab	226 ab
Fulvic acid	16.9 ab	226 ab
Tannic acid	16.8 ab	227 ab
Launch	16.8 ab	223 b
Humic acid	16.0 b	228 a

^{x}Means within same column with same letter are not different significantly P=0.05.

^{y}Volumetric water content measured with a TDR probe.

^{z}Chlorophyll content measured with a CM-1000 chlorophyll meter.

Table 1. Effect of organic acid and humic substance products on volumetric water content of soil and chlorophyll content (color) of creeping bentgrass at golf course locations in 2006.

Chlorophyll measurements were taken at three random locations within in each plot and averaged to get plot means. Measurements were taken between 1100 am and 1300 pm MDT.

Leaf tissue was collected in 2006 and 2007 to evaluate nutrient uptake effects of the treatments. This was only possible at the research putting green site due to greater control over the management practices. Leaf tissue was collected with a walking greens mower at the end of August and analyzed (USU Analytical Laboratories, Logan, UT) for elemental content, most notably for phosphorus. Due to cost constraints, only tissue from the pure humic acid treated plots and the control were collected. Leaf tissue was also collected prior to the experiment in each year to provide a baseline of tissue elemental concentrations.

	Volumetric Water Content^y		Chlorophyll Content^z	
Treatment	2006	2007	2006	2007
	(%)		(color index)	
Launch	12.2 a^x	11.8 a	173 ab	179 a
Control	12.1 ab	11.8 a	177 a	178 a
Citric acid	11.9 abc	11.6 a	174 ab	175 a
H-85	11.9 abc	11.4 a	172 b	177 a
Focus	11.9 abc	11.5 a	176 ab	178 a
Tannic acid	11.8 abc	11.5 a	172 b	177 a
Humic acid	11.7 bc	11.2 a	174 ab	178 a
Fulvic acid	11.6 c	11.2 a	173 ab	177 a

^{x}Means within same column with same letter are not different significantly P=0.05.

^{y}Volumetric water content measured with a TDR probe.

^{z}Chlorophyll content measured with a CM-1000 chlorophyll meter.

Table 2. Effect of organic acid and humic substance products on volumetric water content of soil and chlorophyll content (color) of creeping bentgrass at the USU research putting green in 2006 and 2007.

Humic substances did not influence the color of creeping bentgrass as no visual differences were observed between individual plots.

Results

Putting Green Soil Moisture Retention

Overall, no differences in soil volumetric water content were observed for any treatment in either experiment. Even though the organic treatment effect was not significant in the golf course experiment or the research putting green experiment in 2006, when means were compared, water content readings indicated some differences. The soil volumetric water content for the humic acid-treated plots was significantly lower than the control plots at the golf courses (Table 1).

At the research putting green in 2006, the soil volumetric water content for plots treated with humic acid and fulvic acid were significantly lower than the Launch-treated plots, and the fulvic acid-treated plots were significantly lower than the control plots (Table 2). Throughout the experiments, the control plots had one of the highest volumetric water content means, while the humic acid- and fulvic acid-treated plots usually had one of the lowest.

We also observed a decrease in soil moisture retention in a greenhouse experiment where humic acid was applied to simulated USGA putting greens. Turf irrigated with humic acid resulted in faster drying of the soil and more frequent irrigations than the control treatment (15). Previous research has shown that humic substances may have the potential to reduce soil moisture by adsorbing to and enhancing the water repellency of surface soil layers (16).

Chlorophyll Content

Overall, little or no differences in the color of the turf as measured by the chlorophyll meter were observed for any treatment in either experiment. Even though the organic treatment effect was not significant in the golf course experiment or research putting green experiment in 2006, mean separation of chlorophyll meter readings indicated some differences. The citric acid- and humic acid-treated plots were significantly higher than the Launch-treated plots at the golf courses (Table 1). At the research putting green, chlorophyll meter readings for the control and tannic acid treated plots were significantly higher than the H-85-treated plots in 2006 (Table 2).

Nutrient Uptake

Phosphorus uptake as measured by leaf tissue concentration was significantly influenced

Treatment	P 2006	P 2007	K 2006	K 2007	Ca 2006	Ca 2007	Mg 2006	Mg 2007	S 2006	S 2007	Fe 2006	Fe 2007	Cu 2007	Zn 2007	Mn 2007	Na 2007
	%										mg/kg					
Control	0.43 a†	0.43 a	1.4 a	1.2 a	0.74 a	0.75 a	0.26 a	0.29 a	0.32 a	0.31 a	234 a	523 a	9.6 a	30 a	31 a	55 a
Humic acid	0.41 b	0.42 a	1.5 a	1.1 a	0.69 a	0.68 a	0.26 a	0.28 a	0.29 b	0.29 a	214 a	421 a	9.5 a	27 a	27 a	51 a

†Means within same column with same letter are not different significantly P=0.05.

Table 3. Effect of humic acid application on tissue nutrient concentration of creeping bentgrass at the USU research putting green in 2006 and 2007.

by the treatments in 2006, but not in 2007 (Table 3). In 2006, tissue levels of P were significantly higher for the control plots compared to the humic acid-treated plots, and this result was contrary to previous research (5). There was no increase in P tissue concentration reported in creeping bentgrass when grown in sand (9, 15) or solution (4) when humic acid was foliarly applied, but tissue levels were increased when humic acid was incorporated into sand (4). Turfgrass plants, including creeping bentgrass, are efficient at the uptake of P, and capable of obtaining adequate amounts of P at soil levels above 3 mg P kg^{-1} (6). Few differences of other nutrient levels in plant tissue were detected by the application of humic acid in our study.

Sulfur (S) was significantly lower for the humic acid treatment compared to the control in 2006, but all other nutrients concentrations were not significantly influenced by the treatments (Table 3). Although not an essential nutrient, sodium (Na) levels present in humic substance products after the sodium hydroxide extraction process can be a concern for turf managers by contributing to poor soil structure and reduced water infiltration. No differences in tissue concentration of Na were observed in our study, and high Na may not be present in all humic substances applied to turf, but other research has found increased levels in some commercial products (12).

The differences in P uptake observed here may have been influenced by the distribution of roots in the soil. Based on results from a controlled greenhouse experiment (15), possible hydrophobic properties of the humic substances present near the soil surface (11, 14) may have contributed to preferential flow, or fingering, in the rootzone (3, 2) and facilitated the movement of water into the subsurface. Consequently, root growth may have followed water distribution. Fewer roots in the upper rootzone would not have accessed available P when fertilizers were surface applied.

Conclusions

Overall, the humic substances used in our experiments did not have any substantial effect on the water-holding capacity in sand putting greens. The humic substances contributed to lower soil moisture retention than the control, as the volumetric water content for humic acid-treated plots were approximately 1% lower than the control. Perhaps, the adsorption of humic substances to the surfaces of sand particles in putting greens contributed to increased water repellency, thus lowering the water-holding capacity of the humic acid- and fulvic acid-treated plots. This effect may be important if soil water is frequently allowed to approach the wilting point or if there are cumulative effects over time. Humic acid-treated turf had lower levels of tissue P than the control, and while these differences were statistically significant, in practical application the effects on water-holding capacity and P nutrition may not warrant a change in management practices.

We used the chlorophyll meter in the place of quality ratings in the plots for this study since these instruments have been shown effective for this purpose (10). No differences were observed for any of the humic substances used in our experiments. It was interesting to note that one significant finding of this study was the potential to irrigate creeping bentgrass at 60% ET_o during the summer months (June through August) in the Intermountain West with no reduction in turf quality.

From the results of our study, it appears that irrigating approximately every 4 to 5 days may be a way to reduce water without sacrificing turf quality on Intermountain West putting greens. However, this result was obtained on a putting green that did not receive the level of traffic that would be experienced at a typical golf course. While they may provide other benefits, humic substances may not provide superintendents with improved turf quality, a reduction of water use, or the need for P fertilizer on putting greens.

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