Accepted for publication 21 July 2008. Published 6 October 2008.

Humic Substances Effect on Moisture Retention and Phosphorus Uptake in Intermountain West Putting Greens

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Van Dyke, A., Johnson, P. G., and Grossl, P. R. 2008. Humic substances effect on moisture retention and phosphorus uptake in intermountain west putting greens. Online. Applied Turfgrass Science doi:10.1094/ATS-2008-1006-01-RS.

Abstract

Humic substances are often used as an amendment in 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 uptake, and chlorophyll content of creeping bentgrass (*Agrostis stolonifera* L.). Three irrigation levels — 80%, 70%, and 60% — of reference evapotranspiration (ET_o) were imposed on the turf at the research putting green. 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, and no differences were observed for chlorophyll content of the turf with any humic substance treatment. While they may provide other benefits, humic substances may not provide superintendents with benefits of reducing water or P fertilizer on putting greens.

Turf Management and 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. Plus, sand root zones 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 to 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, they 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 (9).

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 (17). These fractions represent an operationally defined heterogeneous mixture of organic materials (12) that are characterized as being yellow or black in color, of high molecular weight, and refractory (1). 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 (5).

Humic substances have caused hormone-like effects on plant growth and metabolism (3). Growth responses may also result from increased nutrient availability (15), including bioavailability of phosphorus (6), increased tissue levels of iron (4), zinc (4), and manganese (11). However, less growth effects from humic substances have been reported on creeping bentgrass when adequately supplied with nutrients (5).

Humic substances increased photosynthesis in creeping bentgrass (11,20) and root mass (11) and length (5) in controlled studies. However, similar responses have not been observed in the field (8). 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 confounding effects of 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, with claimed benefits including 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. This study tested organic acids, including a pure humic acid and commercial humic substance products, on established putting greens to test their effects on (i) increased water retention, and (ii) uptake of phosphorus by creeping bentgrass in sand putting greens.

Testing Effects of Humic Substances on Putting Greens

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 substance, 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 root zones 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. The Talons Cove putting green was built to California style specifications. The Country Club and Birch Creek greens were native soil push-up green with sand topdressing applied. In all locations, the putting green turf was predominantly creeping bentgrass (*Agrostis stolonifera* L.) with varying percentages of annual bluegrass (*Poa annua* L.) (Table 1). Cultural practices at all of the locations were considered typical for the Intermountain West region of the United States. Details of the management are outlined in (Table 1). 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.

Table 1. Site characteristics and turf management practices at the golf course and research putting green locations.

		Birch Creek 2006	The Country Club 2006	Talons Cove 2006	Research putting green 2006	Research putting green 2007
Turf	Type	Penncross	Many old bent-grasses	L-93 and South-shore	Dominant blend	Dominant blend
	Bent: P. annua[v]	50:50	60:40	99:1	80:20	80:20
Soil	Type	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand
	Root zone mix[w]	100:0	80:20	100:0	90:10	90:10
	pH	7.65	7.50	7.81	7.52	7.52
	ECe (dS/m)	0.4	0.8	0.8	0.3	0.3
Manage-ment	Mowing height[x] (mm)	3 to 3.5	2 to 3	3 to 3.3	3 to 3.5	3 to 3.5
	Fertilizer[y]	6/10/06: 10-2-4, N at 183 kg/ha, & weekly foliar applied nutrients (rate not known)	Weekly foliar applied nutrients, N at 12 to 24 kg/ha	6/19/06: 5-16-22, K at 96 kg/ha	Weekly foliar applied nutrients, N at 5 kg/ha	Weekly foliar applied nutrients, N 5 kg/ha
	Verti-cutting	3-4× /mo	2-3× /mo	2-3× /mo	1-2× /mo	1-2× /mo
	Top-dressing	3× /mo	2-3× /mo	1× /mo	1-2× /mo	1-2× /mo
	Wetting agent	Revolution	No	Cascade	Cascade	Cascade
	Fungicide	Heritage & Daconil alternated every 2 weeks	No	No	No	No
	Insecticide	Talstar	No	No	No	No
	Irrigation days[z]	39	91	63	80% ETo: 29 70% ETo: 25 60% ETo: 23	80% ETo: 25 70% ETo: 23 60% ETo: 22
	Syringing	Daily	As needed	As needed	As needed	As needed

[v] Ratio of bentgrass to annual bluegrass.

[w] Ratio of sand to organic matter in the root zone mix.

[x] Mowing height was gradually lowered during the summer evaluation period at all locations.

[y] Weekly foliar fertilization at the USU site was not done in July 2007.

[z] Number of irrigations that occurred during the 91 day evaluation period (June 1 to August 31).

Experimental design. Both experiments were laid out as a split-split-plot design. The experiment with the golf courses had location as the whole-plot factor, organic treatment the sub-plot factor, and observation date the sub-sub-plot factor. The experiment at the research putting green had irrigation level as the whole-plot factor, organic treatment the sub-plot factor, and observation date the sub-sub-plot factor. Individual organic treatment plots measured 1.5 × 1.5 ft with three replications. At the research putting green only, each block of organic treatments was centered in a 10.7 × 10.7 m plot irrigation block where different irrigation levels were applied. Irrigation treatments were randomized in a Latin square consisting of 80%, 70% and 60% of reference evapotranspiration (ET_o) replaced (2). The ET percentages imposed on the turf corresponded to watering approximately every 2 to 3 days for 80%, every 3 to 4 days for 70%, and every 4 to 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 confounding factors of 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 usually applied just prior to, or when the turf began to wilt.

Treatments. The plots were treated with reagent grade organic acids, four commercial humic substance products and evaluated against a water-only control. These treatments included citric acid monohydrate (Mallinckrodt Chemicals, Phillipsburg, NJ), gallo-tannic acid (J. T. Baker Chemical Co., Phillipsburg, NJ), and leonardite humic acid (Sigma-Aldrich Inc., St. Louis, MO). The commercial products included three humic acid products, H-85 (Redox Chemicals Inc., Burley, ID), Focus, and Launch (PBI Gordon Corp., Kansas City, MO), and a fulvic acid product (Horizon Ag Products, Modesto, CA). 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, except the fulvic acid, which did not have a recommended application rate (Table 2). The rates of application for the fulvic acid and organic acid treatments were normalized to equal carbon rates between these products. The application rate of the pure humic acid treatment applied the same amount of leonardite humic acid as the H-85 product treatment. Three separate applications were done on 7 June, 5 July, and 3 August 2006 at Birch Creek golf course, and 1 June, 6 July, and 2 August 2006 at the Salt Lake Country Club and Talons Cove golf courses. Applications at the research putting green were done on 5 June, 5 July, and 4 August 2006, and 1 June, 2 July, and 1 August 2007. All treatments were applied with approximately 2,290 liters/ha of water and made using a CO_2 backpack sprayer at 276 kPa.

Table 2. Organic acid and humic substance products application amount and ingredients.

Treatment	Amount[x]	Analysis	Additional Ingredients	Recommended Rate[y]
Control	—	—	—	n/a
Citric acid	3.7 g		None	n/a
Tannic acid	2.3 g		None	n/a
Humic acid	2.1 g		None	n/a
H-85	4.2 g	0-0-15	Leonardite humic acid: 49.8%	2-6 oz/1000 ft² every 2-6 weeks
Focus	5.9 ml	0-0-6 with 1.4% Iron	Leonardite humic acid: 35.4% Sea Plant Extract: 4.8% Surfactant: 1.4%	7.5 fl. oz/1000 ft² at 30 day intervals
Launch	11.02 ml	0-0-1 with 0.36% iron	Manure extract: 74% Leonardite humic acid: 9% Sea plant extract: 1% Surfactant: 0.36%	15 fl. oz/1000 ft² at 30 day intervals
Fulvic acid	30 ml	n/a	n/a	n/a

[x] Amount applied to each individual treated plot area (5 ft × 5 ft).

[y] Recommended application rate according to the product label.

Evaluation of treatments. Moisture content of the root zones 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 assembled 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). The water content measurement was averaged over the length of the probe. A 15-cm probe was used at the research putting green site and Talons Cove golf course, but a 10-cm probe was needed at the Birch Creek and Salt Lake Country Club golf courses because of a shallow sand layer. At the research putting green site 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 1 m 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 (13). Chlorophyll measurements were taken at three random locations within in each plot and averaged to get the plot mean. Measurements were taken between 11:00 am and 13:00 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. In order to get enough tissue for a sample the green was not mowed for approximately one week. 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, tissue from all treatments was not collected. Only tissue from the control and pure humic acid treatments were collected. Tissue was also collected prior to the experiment in each year to provide a baseline of tissue elemental concentrations.

Statistical analysis. The volumetric water content and chlorophyll data were analyzed for differences using the PROC MIXED repeated measures analysis (SAS Institute Inc., Cary, NC) and means compared using Fisher's protected LSD. Analysis of the golf course data was done separately, and each year of data at the research putting green was analyzed separately. The tissue phosphorus was analyzed for differences using the PROC MIXED analysis (SAS) and means compared using Fisher's protected LSD.

Influence on Soil Moisture

Overall, no differences in soil volumetric water content were observed for any treatment in either experiment. The location × date interaction was highly significant at the golf course sites in 2006, and the irrigation × date interaction was highly significant at the research putting green in both years. Likewise, location and date at the golf course sites in 2006, and at the research putting green in both years were highly significant. These significant effects were caused by taking soil moisture readings at different times after irrigation events and different management practices at each location (Table 1). The golf course sites had different irrigation practices that ranged from watering every day to watering every 3 to 4 days.

Even though the organic treatment effect was not significant in the golf course experiment ($P = 0.47$) or the research putting green experiment in 2006 ($P = 0.16$), mean separation of soil volumetric 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 3). 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 4). 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 creeping bentgrass (18). Turf irrigated with humic acid resulted in faster drying of the soil and more frequent irrigations than the control treatment. 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 (19).

Table 3. 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.

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.

Influence on Chlorophyll Content

Overall, little or no differences in the color index of the turf as measured by the chlorophyll meter were observed for any treatment in either experiment. The location × date interaction was highly significant at the golf course sites in 2006, and the irrigation × date interaction was highly significant at the research putting green in both years. Likewise, location and date at the golf course sites in 2006, and at the research putting green in both years were highly significant. These significant effects were caused by chlorophyll readings being taken on different days after an irrigation event, as well as different management practices, variety of creeping bentgrass, and amount of annual bluegrass at each location (Table 1).

Even though the organic treatment effect was not significant in the golf course experiment ($P = 0.23$) or research putting green experiment in 2006 ($P = 0.37$), 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 3). 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 4).

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. Due to the lack of irrigation level differences for chlorophyll meter readings at the research putting green in 2006 ($P = 0.83$) and 2007 ($P = 0.99$), it appears that irrigating approximately every 4 to 5 days may be a way to reduce water without sacrificing turf quality. 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.

Table 4. 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.

Treatment	**Volumetric water content**[y] (%)		**Chlorophyll content**[z] (color index)	
	2006	**2007**	**2006**	**2007**
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.

Influence on Phosphorus Uptake

Phosphorus (P) uptake as measured by leaf tissue concentration was significantly influenced by the treatments in 2006 (P = 0.04), but not in 2007 (P = 0.09) (Table 5). However, this result was contrary to previous research (6). In 2006, tissue levels of P were significantly higher for the control plots (0.43%), compared to the humic acid-treated plots (0.41%). In 2007, the control plots had a higher tissue P concentration than the humic acid-treated plots, although differences were not significant (Table 5). There was no increase in tissue concentration reported in creeping bentgrass when grown in sand (11,18) or solution (5) when humic acid was foliarly applied, but tissue levels were increased when humic acid was incorporated into sand (5).

Table 5. Effect of humic acid application on tissue nutrient concentration of creeping bentgrass at the USU research putting green in 2006 and 2007 ('06 and '07).

Treat-ment	P		K		Ca		Mg		S		Fe		Cu	Zn	Mn	Na
	'06	'07	'06	'07	'06	'07	'06	'07	'06	'07	'06	'07	'07			
	(%)										(mg/kg)					
Control	0.43a[x]	0.43a	1.4a	1.2a	0.74a	0.75a	0.26a	0.29a	0.32a	0.31a	234a	523a	9.6a	30a	31a	55a
Humic acid	0.41b	0.42a	1.5a	1.1a	0.69a	0.68a	0.26a	0.28a	0.29b	0.29a	214a	421a	9.5a	27a	27a	51a

[x] Means within same column with same letter are not different significantly P = 0.05.

Turfgrass plants, including creeping bentgrass, are efficient at the uptake of P, and capable of obtaining adequate amounts of P even at low levels (7). The differences in uptake observed here may have been influenced by the distribution of roots in the soil. Based on results from a greenhouse experiment (18), possible hydrophobic properties of the humic substances present near the soil surface (10,14) may have facilitated the movement of water into the subsurface, and root growth may have followed water distribution. Fewer roots in the upper rootzone would not have accessed available P when fertilizers were surface applied.

Other nutrient levels in plant tissue were affected by the application of humic substances in this study including sulfur (S), which was significantly lower for the humic acid treatment in 2006 (P = 0.002) (Table 5). In a greenhouse study, high tissue concentrations of Na were observed with the application of the pure humic acid product (18). This was most likely due to high Na levels still present in the product after the sodium hydroxide extraction process from its source material. High Na may not be present in all humic substances applied to turf, but increased levels have been found in some commercial products (16).

Conclusion

Overall, the humic substances used in these experiments did not have any substantial effect on the water holding capacity in sand putting greens, or the tissue concentration of P in creeping bentgrass. In fact, humic acid-treated turf had lower levels of tissue P than the control, but the differences were small, and may not be substantial from a turf management standpoint. The humic substances contributed to lower soil moisture retention than the control, and decreased the amount of water held in the soil, as the volumetric water content for humic acid and fulvic acid-treated plots were approximately 1% lower than the control. While this difference was statistically significant, in practical application the effect on water holding capacity may not warrant a change in management practices. This effect may be important if soil water is frequently allowed to approach the wilting point or if there are cumulative effects over time.

Acknowledgments

The authors would like to thank the Center for Water Efficient Landscaping, Utah Agricultural Experiment Station and the United States Golf Association for their financial support of this project. We would also like to thank the superintendents at the golf course locations: Chad Daniels, Ross O'Fee, and Ryan Huntington. Approved as journal paper number 7991 by the Utah Agricultural Experiment Station, 4810 Old Main Hill, Utah State University, Logan, UT 84322-4810.

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