Using Humus on Golf Course Fairways to Alleviate Soil Salinity Problems

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Summary. Increased use of recycled water along with inherent soil salinity problems on golf courses make salinity an important issue for golf course management. The objective of this study was to investigate if using humus on golf fairways by topdressing or spraying can alleviate soil salinity problems and improve turf quality. The study was conducted from 2015 to 2017 at Aurora, CO, and Medora, ND. Treatments included an untreated control, topdressing (sand, sand + peat), and spraying of humic acid. Our results showed that the application of humus increased the soil microbial biomass and improved turf quality on fairways either with a soil salinity problem or irrigated with recycled water. The effects on turfgrass health and turf quality were dependent on the rates of humus applied. Humic acid at 3 gal/acre was equivalent to topdressing sand + peat (80/20 v/v) and consistently showed improved turf quality over the untreated control. Soil properties also were affected by the application of humus. Soil pH, electrical conductivity (EC), bulk density, water infiltration, and microbial biomass may have had an indirect contribution to turf quality.

Based on a national survey, golf courses in the United States used 2.3 million acre-ft of irrigation water per year during 2004–05, with 12% of all golf facilities using recycled water as one of the water sources (Throssell et al., 2009). Recycled water usage increased from 14.7% in 2005 to ≈25% in 2013 of all water used on golf courses (Gelernter et al., 2015). Most recycled water has elevated salt levels (Harivandi, 2007; Marcum, 2006). Golf courses that are developed on saline soils or where the major water sources contain high salt levels also experience salinity problems. Salts cause physiological stress on turfgrasses (Slavens et al., 2009) and have negative effects on soil properties including structure, water movement, and nutrient availability (Murphy, 2015; Qian and Mecham, 2005). Therefore, increased use of recycled water along with inherent soil salinity problems on many golf courses make salinity an important issue in golf course management.

Soil salinity causes soil organic matter (OM) flocculation, which leads to OM loss due to wind erosion and leaching (Artiola and Walworth, 2009; Kida et al., 2017; Martinez et al., 2002; Wong et al., 2010). Salinity not only accelerates the decrease of soil OM but also increases the accumulation of harmful trace elements in plants (Ondrasek et al., 2012), inhibits the microbial activity in soils (Setia et al., 2014), and delays the decomposition of soil organic residues (Peinemann et al., 2005). Soil properties deteriorate as OM diminishes (Wong et al., 2010) because soil OM is important for nutrient recycling, cation exchange capacity, water holding, and structure stability. When dealing with soil salinity problems in land management, different practices are taken to improve soil OM quality and quantity. Examples of such include reclamation with grasses (Akhter et al., 2004), addition of glucose (Elmajdoub et al., 2014) or plant residues (Hasbullah and Marschner, 2015; Wong et al., 2009), and incorporation of compost to soil (Wright et al., 2008).

Salinity is more problematic on fairways than on putting greens and tee boxes on a golf course because greens and tees are usually constructed with sand-based root zones and drainage systems, which allow for efficient leaching of salts. Fairways, which contribute to the largest playing surface on a golf course, are usually maintained on native soils with limited drainage. Because of the relative large area, topdressing, and aeration may not be affordable on fairways even though the practices are shown to be beneficial (Klingenberg et al., 2013). The objective of this study was to test if application of humus on golf course fairways by topdressing or spray can alleviate soil salinity problem and improve turf quality.

Materials and methods

The study was conducted from 2015 to 2017 on two golf courses. During 2015 and 2016, the study was on the 17th fairway of the Valley Country Club (VCC) in Aurora, CO. The fairway was covered predominantly with kentucky bluegrass (*Poa pratensis*), with negligible amounts of annual bluegrass (*Poa annua*), and perennial ryegrass (*Lolium perenne*) and was aerated (solid tine of 3/4-inch diameter and 6 inches deep) in Apr. 2015. For both 2015 and 2016, the fairway received 1 lb/1000 ft^2 nitrogen (N) from urea stabilized with dicyandiamide and N-(n-butyl) thiophosphoric triamide (UMaxx; J.R. Simplot Co., Boise, ID) in April, 0.5 lb/1000 ft^2 N from ammonium sulfate monthly from June to

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
1,233.4819	acre-ft	m^3	0.0008
0.3048	ft	m	3.2808
9.3540	gal/acre	L·ha^{-1}	0.1069
2.54	inch(es)	cm	0.3937
48.8243	lb/1,000 ft^2	kg·ha^{-1}	0.0205
1.1209	lb/acre	kg·ha^{-1}	0.8922
1	mmho/cm	dS·m^{-1}	1
28.3495	oz	g	0.0353
1.7300	oz/inch^3	g·cm^{-3}	0.5780
1	ppm	mg·kg^{-1}	1

October, and 200 lb/acre langbeinite in April and August. The langbeinite contained 22% potassium (K), 22% sulfur (S), and 11% magnesium (Mg). No pesticides were applied during the 2-year period of study. The turfgrass was mowed at 0.65 inch. Recycled water from a local water treatment plant was used for irrigation (Table 1). The VCC hosts about 29,000 rounds of play per year.

During 2016 and 2017, the study was on the first fairway of the Bully Pulpit Golf Course (BPGC) in Medora, ND. The fairway was covered predominantly with kentucky bluegrass with less than 5% of perennial ryegrass and fine-leafed fescues (*Festuca* sp.). Fertilization was 2.0 lb/1000 ft^2 N annually using 20N–0.9P–16.6K in three applications; May at 0.75 lb/1000 ft^2, July at 0.5 lb/1000 ft^2, and September at 0.75 lb/1000 ft^2. Gypsum, containing 20% calcium (Ca), was applied at 750 lb/1000 ft^2 monthly from May to September. A selective herbicide containing 2,4-D, mecoprop, and dicamba (Three-Way; LESCO, Roswell, GA) was applied in late May at the labeled rate. The mowing height of the fairway was 0.65 inch. Well water was pumped to a pond before being used for turfgrass irrigation (Table 1). The BPGC hosts about 17,000 rounds of play per year.

Initial soil and water samples were taken from two study sites at the end of April or the beginning of May and were analyzed by commercial laboratories (Table 1). The two study sites followed the same research protocol. Treatments included topdressing with sand, sand + reed sedge peat (90/10 v/v), sand + reed sedge peat (80/20 v/v), and sprayable humic substance (REV; Dakota Peat, Grand Forks, ND) at 1 and 3 gal/acre, and an untreated control. The reed sedge peat contained >90% OM. The sprayable humic substance was a suspension with particle sizes smaller than 100 μm, and containing 21.2% humic acid and 0.8% fulvic acid based on dry weight. Each treatment plot measured 20 × 50 ft. The treatments were arranged in a randomized complete block design with three replications. The sand at the VCC site had an EC of 0.65 $dS \cdot m^{-1}$ and a composition of 8.2% very coarse, 35.3% coarse, 44.3% medium, 11.9% fine, 0.1% very fine, and 0.2% silt and clay. The sand at the BPGC site had an EC of 1.2 $dS \cdot m^{-1}$ and a composition of 3.8% very coarse, 20.8% coarse, 42.0% medium, 29.4% fine, 3.7% very fine, and 0.3% silt and clay. Treatments were applied in the first week of May, July, and September each year. Topdressing was applied at 1/8-inch depth. Humus was sprayed at a spray volume of 30 gal/acre.

Soil properties and turf quality were evaluated on day 15 or 16 of each month, from May to September in each year. Soil pH was tested in a 1:1 soil/deionized water (v/v). Soil EC was determined in a 1:5 soil/deionized water (v/v) extract. Soil OM was determined using loss-on-ignition method (Ben-Dor and Banin, 1989). Soil bulk density was determined from each plot using an undisturbed soil sampler (A-145; ELE Intl., Loveland, CO) at the 2.9- to 8.9-cm depth below the turf surface to avoid sampling the thatch and mat layer which was less compacted. Soil samples were oven-dried at 105 °C for 24 h before the determination of dry bulk density. Water infiltration rate was measured using the falling-head, double-ring method with the diameter of inner and outer rings being 10 and 15 cm, respectively. Two sub samples were taken from each plot. Water infiltration rate was recorded when the change was less than 5% over 5-min periods following the principles of Bouwer (1986). Soil microbial biomass carbon (MBC) was determined by fumigation-extraction (Anderson and Ingram, 1993). Briefly, 5 g of soil was extracted with 0.5 M potassium sulfate in 1:4 ratio (v/v) for both nonfumigated and chloroform-fumigated samples. Dissolved organic carbon in the extracts was determined by titration with 0.033 M acidified ferrous ammonium sulfate after dichromate digestion of the extraction. The MBC concentration was calculated from the difference between the fumigated and nonfumigated samples and multiplying the difference by 2.64 (Vance et al., 1987).

Turf visual quality was evaluated using a 1 to 9 scale (National Turfgrass Evaluation Program, 2000), where 9 is the best, 6 is the minimum acceptable, and 1 is completely dead turf. The turfgrass was scanned at 1 m above the ground with a handheld data collection and mapping unit (model 505

Table 1. Soil and water analysis at two golf course fairways in 2015 and 2016 before the application of humus.

	EC ($dS \cdot m^{-1}$)[z]	pH	OM (%)[y]	Soil minerals (ppm)[x]												
				Carbonate	Bicarbonate	Available phosphorus	Available potassium	Sodium	Calcium	Magnesium	Sulfur	Copper	Manganese	Zinc	Iron	Boron
Valley Country Club, Aurora, CO																
Soil	0.93	7.8	6.3	2.2	—	9	212	148	2,816	274	60	0.75	2.7	11.46	31.3	2.69
Water	1.08	7.8	—	3.0	277.4	—	14.1	89	100	13.5	154.2	<0.02	0.026	0.07	0.01	0.16
Bully Pulpit Golf Course, Medora, ND																
Soil	3.37	7.6	4.2	2.0	—	10	287	660	3,686	405	271	2.7	7.1	8.3	40.4	1.1
Water	2.47	8.3	—	2.4	209.6	0.007	11.4	409	52.2	63.1	372.4	—	0.01	—	0.09	0.46

[z]EC = electrical conductivity; 1 $dS \cdot m^{-1}$ = 1 mmho/cm.
[y]OM = organic matter.
[x]1 ppm = 1 $mg \cdot kg^{-1}$.

Greenseeker; Trimble, Hamilton, IN), which collects near-infrared light (NIR) at 770 nm and red light (Red) at 660 nm. Turfgrass normalized vegetation index (NDVI) was calculated from the spectrum radiance data using the following formula: NDVI = (NIR – Red)/(NIR + Red).

Data were analyzed separately for two locations but within one location the data were combined for 2 years because of homogenous variation. The data homogeneity was tested by the HOVTEST option in the GLM procedure of SAS (version 9.3; SAS Institute, Cary, NC). Treatment means were separated using the Tukey's honestly significant difference test at the 0.05 *P* level.

Results and discussion

TURF QUALITY. At the VCC site, monthly turf quality was consistently higher for the humic acid treatment at 3 gal/acre as compared with the untreated control (Table 2). Treatments containing either peat or humic acid showed better turf quality than the untreated control in all months except May. Topdressing with straight sand improved turf quality over the control only in September. Treatments containing 20% peat or humic acid at 3 gal/acre resulted in higher NDVI values than the untreated control, for all months except May, which is consistent with turf quality data. A previous study also showed that NDVI is a good indicator of stress levels in turfgrass and is strongly correlated with turf visual quality (Gao and Li, 2012).

At the BPGC site, monthly turf quality was consistently higher for the humic acid treatment at 3 gal/acre as compared with sand topdressing or untreated control (Table 3). There were no differences in turf quality between the two rates of peat in topdressing except in August and September. Similarly, turf quality was not different between the two rates of humic acid except in September. The NDVI results also indicated that topdressing with sand + peat or spraying humic acid was more beneficial than untreated control or topdressing with sand only. The differentiations between the rates of peat and between the rates of humic acid were more noticeable for NDVI than for turf quality (Table 3). The light spectrum–based NDVI is indicative of leaf chlorophyll content because the index is reflective of light use efficiency by leaves, which is strongly correlated with leaf chlorophyll content (Ciganda et al., 2009).

At both study sites, application of humic acid at 3 gal/acre caused either equivalent or better turf quality than topdressing sand + peat (80/20 v/v), although the latter provided more OM to the fairways as calculated from the dry weight. Therefore, the treatment differences were not only caused by the absolute amount of OM but also by the components in the OM as well as the application methods.

SOIL PROPERTY. At the VCC site, soil pH was lower than the control when the higher rate of peat or humic acid was used (Table 4). The soil EC responded differently to the

Table 2. Turf quality as affected by topdressing and humus application on a golf course fairway in Aurora, CO, during 2015 and 2016.

	Visual quality (1 to 9 scale)[z]					NDVI[y]				
Treatment	May	June	July	August	September	May	June	July	August	September
Control	5.5 b[x]	6.0 c	5.9 d	5.9 c	6.0 d	0.64 c	0.74 b	0.76 c	0.73 c	0.77 c
Sand	5.5 b	6.2 bc	6.0 d	6.0 c	6.5 c	0.66 bc	0.75 b	0.75 c	0.73 c	0.78 c
Sand + peat (90/10 by v/v)	5.7 ab	6.5 b	6.5 c	7.0 b	7.2 b	0.68 bc	0.75 b	0.78 bc	0.76 bc	0.84 ab
Sand + peat (80/20 v/v)	5.7 ab	6.7 b	7.0 b	7.2 ab	8.2 a	0.68 bc	0.80 a	0.83 ab	0.86 a	0.89 a
Humic acid (1 gal/acre)[w]	5.7 ab	6.7 b	7.0 b	6.8 b	7.0 b	0.72 ab	0.79 ab	0.82 abc	0.80 b	0.82 bc
Humic acid (3 gal/acre)	6.0 a	7.2 a	7.5 a	7.6 a	8.1 a	0.73 a	0.83 a	0.84 a	0.85 a	0.88 a

[z]Turf visual quality was evaluated using a 1 to 9 scale (National Turfgrass Evaluation Program, 2000), where 9 is the best, 6 is minimum acceptable, and 1 is completely dead turf.
[y]Turfgrass normalized vegetation index (NDVI) using the formula: NDVI = (NIR – Red)/(NIR + Red), where near-infrared light (NIR) was at 770 nm and red light (Red) was at 660 nm.
[x]Means within a column followed by the same letter are not significantly different at $P = 0.05$ based on Tukey's honestly significant difference test.
[w]1 gal/acre = 9.3540 $L \cdot ha^{-1}$.

Table 3. Turf quality as affected by topdressing and humus application on a golf course fairway in Medora, ND during 2016 and 2017.

	Visual quality (1 to 9 scale)[z]					NDVI[y]				
Treatment	May	June	July	August	September	May	June	July	August	September
Control	5.0 c[x]	5.4 c	5.6 b	5.8 c	6.0 d	0.50 c	0.54 c	0.65 b	0.68 c	0.70 c
Sand	5.2 c	5.6 c	5.8 b	6.1 c	6.4 c	0.52 c	0.56 c	0.68 b	0.72 c	0.79 b
Sand + peat (90/10 v/v)	6.0 ab	6.5 ab	6.7 a	6.8 b	7.2 b	0.56 b	0.66 b	0.76 a	0.79 b	0.80 b
Sand + peat (80/20 v/v)	6.4 a	6.8 a	7.1 a	7.6 a	7.8 a	0.61 a	0.72 a	0.78 a	0.83 a	0.84 a
Humic acid (1 gal/acre)[w]	5.9 b	6.2 b	6.8 a	7.0 b	7.2 b	0.59 ab	0.68 ab	0.77 a	0.78 b	0.77 b
Humic acid (3 gal/acre)	6.0 ab	6.5 ab	7.0 a	7.4 ab	7.7 a	0.62 a	0.70 ab	0.79 a	0.84 a	0.85 a

[z]Turf visual quality was evaluated using a 1 to 9 scale (National Turfgrass Evaluation Program, 2000), where 9 is the best, 6 is minimum acceptable, and 1 is completely dead turf.
[y]Turfgrass normalized vegetation index (NDVI) using the formula: NDVI = (NIR – Red)/(NIR + Red), where near-infrared light (NIR) was at 770 nm and red light (Red) was at 660 nm.
[x]Means within a column followed by the same letter are not significantly different at $P = 0.05$ based on Tukey's honestly significant difference test.
[w]1 gal/acre = 9.3540 $L \cdot ha^{-1}$.

application of treatments in different months. In May and July, only topdressing with peat resulted in lower EC than the control, which could have been due to higher infiltration rates in those treatments. Topdressing with sand only did not lower the soil EC despite the higher infiltration rates because of the high salt content in sand. The higher water infiltration rates were accompanied by lower soil bulk density (Table 4). In September, the soil had a lower EC than the control as a result of topdressing and the use of humic acid at 3 lb/acre.

At the BPGC site, soil pH was decreased by topdressing with sand + peat (80/20 v/v) or spraying with humic acid as compared with the control (Table 5). The pH change may be the result of more healthy turfgrass. The soil EC was the highest in sand topdressing because of the salt content in the topdressing sand. The increased water infiltration rates in topdressing treatments could be explained by the decrease in soil bulk density. Spraying humic acid did not affect soil EC as compared with the control.

At both study sites, application of humus caused a decrease in pH and increase of soil OM. However, the amount of change at VCC site was very small so that no conclusion can be made as to whether humus application had any direct impact on turf quality despite the statistical significance (Table 4). Because neither study site showed a large change in soil EC due to the application of humus, the contribution of EC to turf quality was not conclusive. There was not a single factor clearly responsible for the change in soil EC because salt content in the topdressing sand, changes of water infiltration rate, and the salinity levels in the irrigation water all played a role (Tables 1, 4, and 5).

Soil MBC was increased over the control due to the application of humus either as peat or as a spray (Tables 4 and 5). Humic acid at 3 gal/acre was equivalent to topdressing sand + peat (80/20 v/v) with respect to the effect on MBC, and both treatments showed higher MBC than the lower rate of humic acid at 1 gal/acre.

Conclusions

Our results showed that the application of humus increased the soil

Table 4. Soil properties as affected by topdressing and humus application on a golf course fairway in Aurora, CO during 2015 and 2016.

Treatment	pH			Electrical conductivity ($dS\cdot m^{-1}$)[z]			Infiltration rate (inches/h)[z]		Bulk density ($g\cdot cm^{-3}$)[z]		Organic matter (%)	MBC ($mg\cdot kg^{-1}$)[y]
	May	July	September	May	July	September	May	September	May	September	September	September
Control	7.70 a[x]	7.78 a	7.73 a	0.96 a	1.52 a	1.17 a	2.63 d	1.51 b	1.52 a	1.57 a	6.4 cd	1,315 c
Sand	7.68 ab	7.77 a	7.70 ab	0.94 ab	1.50 ab	1.09 b	2.82 a	1.77 a	1.52 a	1.58 a	6.3 d	1,324 c
Sand + peat (90/10)	7.66 ab	7.74 ab	7.68 b	0.90 b	1.44 b	1.07 b	2.80 ab	1.79 a	1.51 ab	1.56 a	6.7 b	1,436 a
Sand + peat (80/20)	7.65 b	7.70 b	7.58 c	0.88 b	1.44 b	1.02 c	2.74 bc	1.72 a	1.49 b	1.52 b	7.0 a	1,477 a
Humic acid (1 gal/acre)[z]	7.67 ab	7.72 ab	7.62 bc	0.92 ab	1.48 ab	1.15 a	2.67 cd	1.49 b	1.51 ab	1.58 a	6.5 bcd	1,382 b
Humic acid (3 gal/acre)	7.64 b	7.68 b	7.59 c	0.91 ab	1.47 ab	1.10 b	2.69 cd	1.53 b	1.48 b	1.56 a	6.6 bc	1,454 a

[z] $1\ dS\cdot m^{-1} = 1$ mmho/cm, 1 inch = 2.54 cm, $1\ g\cdot cm^{-3} = 0.5780\ oz/inch^3$, 1 gal/acre = $9.3540\ L\cdot ha^{-1}$.
[y] Soil microbial biomass carbon (MBC); $1\ mg\cdot kg^{-1} = 1$ ppm.
[x] Means within a column followed by the same letter are not significantly different at $P = 0.05$ based on Tukey's honestly significant difference test.

Table 5. Soil properties as affected by topdressing and humus application on a golf course fairway in Medora, ND during 2016 and 2017.

Treatment	pH			Electrical conductivity ($dS\cdot m^{-1}$)[z]			Infiltration rate (inches/h)[z]		Bulk density ($g\cdot cm^{-3}$)[z]		Organic matter (%)	MBC ($mg\cdot kg^{-1}$)[y]
	May	July	September	May	July	September	May	September	May	September	September	September
Control	7.60 a[x]	7.70 a	7.66 a	3.32 b	3.98 cd	4.23 bc	4.40 c	3.43 d	1.43 a	1.44 a	4.3 d	969 c
Sand	7.58 ab	7.69 a	7.63 a	3.41 a	4.26 a	4.48 a	5.60 a	4.72 a	1.38 b	1.39 b	4.3 d	954 c
Sand + peat (90/10 v/v)	7.57 ab	7.67 a	7.55 b	3.38 ab	4.15 b	4.47 a	5.62 a	4.62 b	1.36 c	1.38 b	4.6 bc	1,016 b
Sand + peat (80/20 v/v)	7.42 c	7.50 c	7.38 c	3.36 ab	4.08 bc	4.30 b	5.44 b	4.04 c	1.35 c	1.34 c	4.9 a	1,166 a
Humic acid (1 gal/acre)[z]	7.56 b	7.60 b	7.52 b	3.30 b	3.96 d	4.16 c	4.35 c	3.38 d	1.42 a	1.40 ab	4.4 cd	1,002 b
Humic acid (3 gal/acre)	7.40 c	7.51 c	7.33 c	3.29 b	3.93 d	4.15 c	4.32 c	3.46 d	1.40 ab	1.37 b	4.7 ab	1,184 a

[z] $1\ dS\cdot m^{-1} = 1$ mmho/cm, 1 inch = 2.54 cm, $1\ g\cdot cm^{-3} = 0.5780\ oz/inch^3$, 1 gal/acre = $9.3540\ L\cdot ha^{-1}$.
[y] Soil microbial biomass carbon (MBC); $1\ mg\cdot kg^{-1} = 1$ ppm.
[x] Means within a column followed by the same letter are not significantly different at $P = 0.05$ based on Tukey's honestly significant difference test.

MBC and improved turf quality over the untreated soils on two fairways that had either an inherent soil salinity problem or was irrigated with recycled water with high salt content. The effects on turfgrass health and turf quality were dependent on the rates of humus. Despite the small value, the visual quality improvement over the untreated control at the VCC site was from unacceptable to acceptable value of six for most of the summer. At the BPGC site, application of humic substance improved turfgrass visual quality over the untreated control and sand topdressing alone. Soil microbial activity is critical to soil nutrient availability and is negatively affected by soil salinity. Therefore, maintaining sufficient soil OM is necessary to support the soil microbial activity and soil health over time. Soil properties also were affected by the application of humus and the effects on soil pH, EC, bulk density, and water infiltration were complicated because those factors are correlated. The quality of topdressing sand, especially salt content, was also an important factor for soil EC. Similar results were found at two golf courses with different climate, indicating that the findings may be applicable in areas of wide geological diversity.

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