Effects of Gypsum on a Wastewater-irrigated Turfgrass Soil

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ABSTRACT

Secondarily treated wastewater is used extensively in the southwestern United States for turfgrass irrigation, but deterioration in soil quality can occur from sodium (Na) delivered by this water. Application of gypsum ($CaSO_4 \cdot 2H_2O$) at 2 240 kg ha^{-1} yr^{-1} is often recommended to control the Na. Research to determine if this rate is effective on effluent-irrigated turfgrass sites is lacking. A 2-yr study was carried out on a golf course fairway (typic torrifluvent soil) with a 10-yr history of effluent irrigation and elevated Na levels (800 mg kg^{-1}). Four rates of gypsum (0, 2 240, 4 480, and 8 960 kg ha^{-1}) were surface applied in November 1986 and 1987. Soil samples were collected every 3 months after treatment (MAT) and analyzed for Ca (total and water-soluble (WSCa)), Mg, K, Na, SO_4^{-2}-S (S), pH, and electrical conductivity (EC). Results showed elevated WSCa and S levels 3 and 6 MAT in both years. The two highest rates resulted in elevated S levels 12 MAT. During both years, gypsum at the two higher rates decreased Na levels within 3 MAT. The lowest application rate did not reduce Na levels until 12 MAT in 1987 and its effects were not as great. Following the second annual application, the 2 240 kg ha^{-1} rate was as effective as the higher rates in reducing Na levels 6 and 12 MAT. Total Ca levels were not affected by gypsum but Mg and K levels did decrease. In both years, a temporary increase in EC and decrease in pH occurred after gypsum treatment. It appears that gypsum at 2 240 kg $ha^{-1}yr^{-1}$ can be as effective as higher application rates in reducing Na in effluent-irrigated turf soil but only after two applications.

INTRODUCTION

Secondarily treated wastewater (effluent) is used in the southwestern United States as a source of turfgrass irrigation water. This water tends to be higher in electrical conductivity (EC), sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), nitrogen (N), phosphorus (P) and bicarbonates than potable irrigation water. These salts tend to accumulate at the soil surface. Soluble salts such as Na can result in a deterioration of soil quality through colloid dispersion. Other constituents of secondary effluent, such as N, P, and K, can serve as plant nutrients and reduce the need for fertilizer amendments. For a discussion of the effects of water quality on turfgrass growth see Butler et al. (4).

The overaccumulation of Na in the soil from effluent is the primary concern of turfgrass managers in the Southwest. Hayes (6) found that turfgrass soil irrigated with effluent for 1.5 yr had three times as much Na as turf soil irrigated with potable water. Most of this change occurred within approximately 3 months of the initiation of effluent irrigation. Calcium sulfate (gypsum) and other sulfur-bearing compounds are useful in reducing the Na content of agronomic soils even when saline irrigation water is used (1,11). The Ca in gypsum ($CaSO_4 \cdot 2H_2O$) replaces Na on the cation exchange sites, which then forms leachable sodium sulfate. However, gypsum can also result in the leaching of magnesium (1,8).

For agronomic crops, gypsum is tilled into the soil or dissolved in and carried into the soil by flood irrigation water. The flooding of large turfgrass areas has essentially been replaced by sprinkler irrigation and permanent turfgrass swards cannot be disrupted by plowing. Therefore, it is recommended that finely ground gypsum be broadcast applied to a turf area and sprinkler irrigated into the soil. Although surface-applied gypsum has shown movement into already disturbed agronomic soils (8, 9) no data is available for surface-applied gypsum on established stands of turf, or for effluent-irrigated turf soils.

The purpose of this two-year study was to determine how different surface-applied gypsum application rates could reduce elevated soil Na levels and influence other chemical properties in a municipal golf course fairway soil with a 10-yr history of effluent-water irrigation.

MATERIALS AND METHODS

The study site was located on the No. 8 fairway of the Silverbell Municipal Golf Course in Tucson, AZ. The site was adjacent to the primary rough and approximately 50 m from the tee and subjected to extensive golf cart traffic. The site had a slope of less than 3%. Except for the gypsum treatments, the study area was maintained the same as the surrounding fairway by municipal workers. The turf was common bermudagrass (Cynodon dactylon L.) kept at a 13 mm height of cut. Clippings were not collected and the turf was fertilized and watered to promote maximum quality and growth as deemed necessary by the golf course supervisor. Average effluent water use at the facility in 1986, 1987, and 1988 for turfgrass irrigation was 0.49 ha m^{-1}. In October of 1986 and 1987 the bermudagrass was overseeded with perennial ryegrass (Lolium perenne L.) to provide a green winter playing surface. Overseeding was done prior to gypsum treatment applications.

Gypsum treatments were equivalent to 0, 2 240, 4 480, and 8 960 kg ha^{-1} yr^{-1} (0, 1, 2 and 4 tons/acre). Plot size was 3 m^2 and the treatments were arranged in a completely randomized block with three replications. The gypsum was a fine grain, high purity material supplied by the Pinal Gypsum Company (Coolidge, AZ). Applications were surface applied in October 1986 and repeated again in October 1987. Normal sprinkler irrigations made by the golf course facility were used to move the gypsum into the soil.

Characteristics of the top 10 cm of this gravelly, alluvial soil (typic torrifluvent) prior to gypsum treatment are shown in Table 1. This soil had a Na and ESP level (ratio of Na to Ca + Mg + Na + K) considered to be very high as a result of effluent irrigation. Water movement into the soil was also very slow.

Soil samples from the treatment plots were collected just prior to treatment application in 1986 and 3, 6 and 12 months after treatment (MAT) in both years. Ten 13 mm (width) by 100 mm (depth) soil samples were collected at random locations in each plot and composited to give a representative sample of that plot.

Exchangeable plus water-soluble Ca, Mg, Na and K were determined using a 1 N ammonium acetate extraction (5) and atomic absorption (AA) spectrometry (7). Water-soluble Ca (WSCa) was determined in a 1:1 soil:water (distilled, deionized) mixture using AA. Sulfate-S (S) was determined turbidimetrically (2) in a 3:1 water:soil extract. Electrical conductivity and pH were determined using a 1:1 soil:water mixture and standard methods (3, 10).

Water infiltration rates in the plots were determined at each soil sampling time by using single ring infiltrometers. Two infiltrometer rings (300 mm dia.) were inserted into each plot to a depth of 100 mm. Enough effluent water was added to each ring to saturate the thatch layer. Then the water was brought to a standing depth of 130 mm. Change in water height was recorded each hour for 3 hours. The average infiltration rate was then calculated.

Characteristics of the effluent irrigation water used in this study over a 2-yr period were described by Hayes (6) (Table 2).

An analysis of variance was used to test for significant differences between treatments. Regression analysis tested for a linear relationship between gypsum treatment level and the soil parameters measured. When linearity was not found, orthogonal contrasts were used to separate treatment means.

RESULTS AND DISCUSSION

In both years, sprinkler irrigation moved the gypsum into the soil within 3 months as indicated by elevated WSCa and S levels (Table 3). For WSCa, this increase was linearly related to the treatment rates for at least the first

6 MAT. Water-soluble Ca levels did not remain elevated 12 MAT during either year. In contrast to WSCa, soil exchangeable plus water-soluble Ca levels were never significantly influenced by gypsum during this study. Calcium levels were very high in this arid soil and apparently masked any additional WSCa coming from the gypsum.

Soil S increased linearly with treatment levels for the first 6 MAT (Table 3). At 12 MAT however, the 2 240 kg ha^{-1} treatment no longer differed from the control. The 4 480 and 8 960 kg ha^{-1} treatments were still significantly higher for S than the other 2 treatments but were not different from each other. Because these results occurred in both years it appears that a 4 480 kg ha^{-1} application is required to maintain elevated S levels if gypsum is to be applied once annually.

Soil Mg was always higher in the control plots except for one sampling time (Table 3). Alawi et al. (1) and Gillman and Sumner (8) reported similar findings where gypsum treatments resulted in increased leachable Mg levels. Potassium levels decreased following the 1987 treatment. This is probably the result of displacement of Mg and K from the soils cation exchange sites as a result of the addition of Ca from gypsum. The loss of Mg from the surface soil might be important in acidic soils with low cation content, but arid soils tend to be well-supplied with Ca, Mg and K. The Mg and K remaining in these gypsum plots was considered to be adequate for plant growth.

Gypsum applications in arid and semiarid regions are for the removal of Na from the root zone. In this study, gypsum at the 4 480 and 8 960 kg ha^{-1} rates decreased soil Na levels within 3 MAT while the lowest application rate did not (Table 3). Twelve months after the 1986 treatment, however, a significant linear decrease in Na levels was observed. For 1988, the inability of the lowest gypsum rate to reduce Na levels and the 4 480 and 8 960 kg ha^{-1} treatments to be effective 3 MAT was again observed. However, unlike the first year, the 1988 6 and 12 MAT sampling times found all the gypsum treatments to be equally effective in reducing Na levels. Therefore, it appears that gypsum applied at 2 240 kg ha^{-1} could be as effective as the higher rates tested following the second annual applications.

Increased salinity of a soil through the addition of an amendment could have detrimental effects on plant growth. Gypsum applications resulted in a significant, but temporary, increase in EC in 1987 and 1988. This increase was observed only at the 3-month sampling times after which EC returned to the level of the untreated plots.

Gypsum should not influence soil pH as drastically as elemental S. This was found to be the case; however, there was a slight and statistically significant decrease in pH at 3 and 12 months after the 1986 application and 3 months after the 1987 application. Change in pH was not linearly related to the amount of gypsum applied, but some of the applied sulfate-S was apparently being reduced to sulfuric acid.

Although infiltration of water into this soil in relation to gypsum application was measured, there was no increase in infiltration. This study site was located on the edge of a fairway next to primary rough where golf cart traffic was unrestricted. The slow infiltration rates measured were therefore attributed to the mechanical compaction of the soil and not due to sodic soil conditions. Gypsum, although ineffective in increasing water movement into this soil, probably would help in preventing infiltration problems resulting from a combination of Na accumulation and golf cart traffic.

CONCLUSIONS

Gypsum applications were effective in reducing soil Na levels in this effluent-irrigated fairway soil. However, a 2 240 kg ha^{-1} rate required at least 6 months to reduce significantly Na while the 4 480 and 8 960 kg ha^{-1} rates reduced Na within 3 months. The 2 240 kg ha^{-1} application rate of gypsum was as effective as the higher rates tested in this study but only after the second annual application and not immediately after this application. Therefore, the recommendation of repeated annual applications of 2 240 kg gypsum ha^{-1} to control Na in effluent-irrigated turf seems appropriate and effective, providing that an immediate reduction in soil Na levels is not required.

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Table 1. Soil chemical properties prior to the application of calcium sulfate.

Ca	WSCa	Mg	Na	K	S	ESP	EC	pH	Sand	Silt	Clay	IR
----------mg kg^{-1} ----------							ds m^{-1}		---------- % ----------			(mm hr^{-1})
4450	157	348	817	948	335	12.5	5.4	7.8	50	39	12	4

Table 2. Mean chemical properties of effluent irrigation water from April 1987 to July 1988 (modified from Hayes, 1988).

Ca + Mg	Na	K	SAR	EC	pH
----------mM L^{-1} ----------				(ds m^{-1})	
1.3	4.1	0.1	3.7	0.7	7.7

Table 3. Soil chemical properties after the application of gypsum in November 1987 and November 1988.

						1987				
Months after treat- ment	Gypsum treat- ment	Ca	WSCa	Mg	Na	K	S	EC	pH	IR
	kg ha^{-1}	mg kg^{-1}						ds m^{-1}		mm hr^{-1}
3	0	5530	97	353	587	707	51	3.2	8.0	4
	2 240	5300	177	320	507	780	85	4.0	7.7	6
	4 480	5467	313	313	427	773	153	4.6	7.8	6
	8 960	4733	447	297	453	793	201	4.2	7.7	7
	Linear reg.	ns	***	*	ns	ns	***	ns	ns	ns
	Orthog. cont.	ns	nt	nt	b	ns	nt	a	a	ns
6	0	5467	101	320	613	787	130	5.0	nd	3
	2 240	4733	113	273	673	767	157	4.9	nd	4
	4 480	5600	187	287	640	800	213	5.4	nd	2
	8 960	4800	313	260	627	753	293	6.6	nd	4
	Linear reg.	ns	**	ns	ns	ns	**	ns	nt	ns
	Orthog. cont.	ns	nt	a	ns	ns	nt	ns	nt	ns
12	0	3933	148	337	540	770	123	3.3	8.0	4
	2 240	3567	108	307	413	703	133	2.9	7.9	4
	4 480	4033	162	300	390	727	268	3.2	7.9	8
	8 960	3600	137	260	287	687	237	2.6	7.8	6
	Linear reg.	ns	ns	ns	**	ns	ns	ns	ns	ns
	Orthog. cont.	ns	ns	b	nt	ns	b	ns	a	ns

Table 3. (continued)

Months after treatment	Gypsum treat-ment	Ca	WSCa	Mg	Na	K	S	EC	pH	IR
					1988					
	kg ha^{-1}	------------------------------mg kg^{-1}------------------------------						ds m^{-1}		mm hr^{-1}
3	0	3133	129	297	555	775	83	4.9	7.9	3
	2 240	3233	147	263	558	725	111	5.4	7.6	3
	4 480	3817	296	243	498	860	156	6.4	7.7	6
	8 960	3650	470	223	457	683	260	6.4	7.6	6
	Linear reg.	ns	**	***	ns	ns	**	**	ns	ns
	Orthog. cont.	ns	nt	nt	b	ns	nt	nt	a	ns
6	0	3450	115	300	553	728	77	3.1	7.8	2
	2 240	3350	128	277	340	662	98	3.0	7.6	4
	4 480	3533	148	248	305	690	121	2.1	7.9	4
	8 960	3283	166	228	278	610	135	2.9	7.6	5
	Linear reg.	ns	**	***	ns	ns	**	ns	ns	ns
	Orthog. cont.	ns	nt	nt	a	c	nt	ns	ns	ns
12	0	3133	101	302	495	750	80	1.9	7.9	4
	2 240	3217	103	287	305	723	70	2.2	7.9	5
	4 480	3270	108	253	290	685	142	2.0'	8.0	3
	8 960	3018	110	235	273	647	134	2.1	7.9	4
	Linear reg.	ns	ns	*	ns	*	ns	ns	ns	ns
	Orthog. cont.	ns	ns	nt	a	nt	b	ns	ns	ns

nd = no data; ns = non-significant at P = <.05. *, **, and *** = significant at P = > .05, .01 and .001, respectively. Orthogonal contrasts (P = 0.05); a = 0 vs. 2 240, 4 480 and 8 960; b = 0 and 2 240 vs. 4 480 and 8 960; c = 0, 2 240 and 4 480 vs. 8 960; nt = not tested.