Badger Turf and Grounds Club

Significance of Exchangeable Cation Ratios During Bentgrass Establishment

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INTRODUCTION

There is a significant difference in how soil testing laboratories interpret exchangeable calcium, magnesium and potassium for turfgrass. Some use the concept that it is essential that the ratios of these cations be maintained within certain limits. Others ignore the ratios and simply assess whether or not there are sufficient quantities of each cation present for unrestricted turfgrass growth.

The idea that soil Ca, Mg, and K have to be in the proper ratios in order to supply turfgrass with adequate amounts of these nutrients dates to the 1940's. New Jersey agronomists (1,7) conducted a series of experiments with alfalfa from which they noted several things. For one, the sum of plant Ca, Mg, and K was fairly constant and increased uptake of one nutrient as a result of liming or fertilization leads to reductions in tissue concentrations of one or both of the other cations. Secondly, the researchers noted that alfalfa yield response to application of one of the three nutrients appeared to be governed in part by the ratio of that nutrient to the other cations on the soil exchange complex. Eventually, the researchers suggested that the "ideal soil" is one in which 65% of the cation exchange sites are occupied by Ca, 10% by Mg, 5% by K and 20% by H. Graham (3) later claimed that crop yields are not affected as long as the cation exchange site saturation of Ca ranges from 65 to 85%, Mg from 6 to 12%, and K from 2 to 5%. These are the values applied most commonly today by soil testing labs that ascribe to the optimum cation ratio concept.

Is this a valid concept, particularly in regard to turfgrass? Many researchers (6, 8, 9) have presented evidence that crop yield responses to applications of Ca, Mg, and K are better predicted by examining the absolute amounts on the soil exchange complex than the ratios or percent saturations of the cations. The cation ratio concept is founded upon the idea that Ca, Mg, and K ions in soil solution need be in the same ratio in which they are required by plants. The inference is that plant uptake of these ions is controlled by their soil solution concentrations. Studies of nutrient uptake processes over the past 10 to 15 years have clearly shown that this is not the case (5). Plant uptake of nutrients is dependent upon much more than the supply in the soil solution. Examples of other factors involved include the growth rate of the plants, soil moisture holding capacity, ion diffusion rates in different soils, plant transpiration rates, root architecture and the numbers and longevity of root hairs, root age, and the mechanism whereby nutrients are transported to root surfaces. Merely the fact that Ca and Mg are transported by one mechanism and K by another is taken as a strong argument that plant uptake of the three nutrients is not controlled by their relative amounts in soil solution and on the exchange complex (4).

Finally, there is the issue of relative plant nutrient requirements. Legumes have high Ca, Mg, and K requirements while grasses have low requirements. This is believed to account for the fact that in those few instances where changes in soil Ca, Mg, and K ratios have altered plant growth, the influences have been observed for legumes but not grasses (2, 6, 8). Application of the cation ratio concept in the interpretation of soil tests for Ca, Mg, and K for turfgrasses has led to some dubious recommendations in Wisconsin. In one instance, the recommendation was that fairways with pH values of 6.7 to 6.9 be treated with 2 tons per acre of gypsum. Another golf course was advised to apply 500 pounds per acre of magnesium sulfate even though long term irrigation with hard water had elevated soil pH to 7.1 to 7.4. Both recommendations were based on the cation balance concept and ignored the fact that the soils contained several-fold more Ca and Mg than the turfgrass could use.

The purpose of the present study was to observe whether or not manipulation of the Ca, Mg, and K saturations of the exchange sites in a putting green rootzone mix significantly affects creeping bentgrass establishment. The study was conducted in a greenhouse environment.

In putting green rootzone mixes prepared with materials that satisfy

USGA specifications, the organic amendment is the predominant source of cation exchange sites and exchangeable cations. Therefore, the approach taken in this study was to create ranges in Ca, Mg, and K saturation by liming acid (pH 2.9) sphagnum peat with liming materials of different compositions, add various amounts of K, and then blend the peat on an 80:20 (v/v) basis with sand. The liming materials used were laboratory grade calcium carbonate, magnesium carbonate, and a 50:50 (w/w) blend of the two. The rate of application was that estimated to be required to adjust the pH of the peat to 6.5.

The pH of the peat stabilized after a 2-month equilibration period during which the limed peat was mixed and its moisture content adjusted on a weekly basis. Each limed peat sample was then air-dried for two days, split into three lots, and each lot moistened with solutions that provided 100, 250, or 500 ppm K. The next day each limed peat-K combination was leached with distilled water to remove excess Ca, Mg, and K. The peat samples were once again allowed to air-dry to a moisture content suitable for blending with sand. Subsamples of the blends were reserved for analysis for pH, cation exchange capacity, and exchangeable Ca, Mg, and K.

The rootzone mixes were packed into one-quart, 6-inch depth ice cream cartons, treated with the equivalent of 2 lb N/M as starter fertilizer (19-26-5) and seeded to 'Penncross' creeping bentgrass at the rate of 3 lb/M. All Ca-Mg-K treatments were replicated three times. The pots were watered daily to the predetermined moisture holding capacity of 12.9% by weight.

When there was sufficient growth, the pots were clipped three times over a two-week period at a height of 1/2 inch. The clippings from each cutting were oven-dried, weighed, and then combined and ground for analysis for Ca, Mg, and K.

RESULTS

The salt pH of the rootzone mixes ranged from 6.35 to 6.45 and the cation exchange capacity from 10.8 to 12.9 milliequivalents/100g (Table 1). Only when the spaghnum peat was limed with calcium carbonate were the Ca saturations in the optimum range of 65 to 85%. All Mg saturations were above the optimum range, indicating that substantial Mg was originally present in the peat and that the ion was very competitive with Ca++ for exchange sites.

Table 1. Analyses of rootzone mixes used.

Liming material	K applied	pH*	CEC+	Exchangeable cations Ca	Mg	K
	ppm		me/100g	percent saturation		
CaCO3	100	6.40	11.3	72	16	0.7
	250			71	17	1.5
	500			71	17	2.0
MgCO3	100	6.35	10.8	46	26	1.1
	250			46	24	1.7
	500			48	22	2.4
50:50 CaCO3 + MgCO3	100	6.45	12.9	60	21	0.7
	250			61	20	1.2
	500			61	19	1.9

*In 0.01 N CaCl2. + At pH 7.0.

Treating the limed peat samples with 500 ppm K was theoretically enough K to provide up to 10% saturation of the exchange complex. The highest saturation achieved was only 2.4%. This demonstrates what has long been known about the relative bonding strengths of cations to organic exchange sites. These sites have a very strong preference for polyvalent cations capable of forming bonds with partial covalent character. Potassium, with its single positive charge, cannot do this. Consequently, K forms weak bonds, leaches readily from rootzone mixes, and it is impractical to try to achieve high soil test K levels in USGA putting green mixes.

During and over the 24-day growth period of the creeping bentgrass, varying the Ca, Mg, and K saturations had no influence on clipping weights (Table 2). Likewise, there were no visual differences among the treatments with regard to bentgrass density or color.

Table 2. Creeping bentgrass growth responses during establishment to various rootzone mix Ca, Mg, and K percent saturations.

Cation saturation Ca	Mg	K	Clipping weight 13 da.	19 da.	24 da.	total
percent			mg/pot			
72	16	0.7	249	211	188	648
71	17	1.5	242	242	171	655
71	17	2.0	200	194	178	572
46	26	1.1	281	236	176	693
46	24	1.7	283	203	171	674
48	22	2.4	251	212	179	642
60	21	0.7	176	228	173	577
61	20	1.2	176	194	169	539
61	19	1.9	153	229	182	564
Duncan's LSD (p=.05)			NS*	NS	NS	NS

*No significant differences.

Clipping concentrations of Ca, Mg, and K varied significantly and, in a general way, seemed to reflect the percent saturations of the cations (Table 3). However, all concentrations of Ca and Mg were within what are believed to be sufficiency ranges for normal turfgrass growth (4). Clipping concentrations of K were consistently high. Thus, over the brief 24-day growth period even K saturations of 0.7%, well below the optimum 2 to 5%, provided the bentgrass with luxury amounts of the nutrient. This is likely another consequence of the weakness of chemical bonds formed between organic exchange sites and K.

Table 3. Effects of different rootzone mix Ca, Mg, and K saturations on creeping bentgrass clipping Ca, Mg, and K concentrations.

Cation saturation Ca	Mg	K	Clipping concentration Ca	Mg	K
percent			percent		
72	16	0.7	0.88	0.40	3.60
71	17	1.5	0.77	0.36	3.93
71	17	2.0	0.77	0.36	4.17
46	26	1.1	0.58	0.65	3.68
46	24	1.7	0.50	0.57	3.72
48	22	2.4	0.51	0.51	4.12
60	21	0.7	0.70	0.50	3.81
61	20	1.2	0.65	0.46	4.45
61	19	1.9	0.60	0.41	4.77
Duncan's LSD (p=.05)			0.06	0.02	0.42

Although the creeping bentgrass showed no growth response to the Ca-Mg-K treatments, the substantial differences in clipping concentrations of the nutrients and their soil test ranges provide data that allowed examination of the relationships between the soil tests and plant uptake of Ca, Mg, and K. This is of considerable interest because a reliable soil test is one that accurately predicts plant uptake of the nutrient in question.

Indications were that Ca and K uptake were equally well and significantly related to their rootzone test values whether expressed in relative terms as percent saturation or in absolute terms as lb/acre (Table 4). In contrast, % Mg saturation did not correlate significantly with Mg uptake while lb Mg/acre did.

There were several instances where uptake of one cation was significantly correlated with soil measures of one or more of the other cations (Table 4). This suggests interacting effects in the sense that uptake of one cation may have been sensitive to the supply of the other cations. This prompted examination of the degree of dependency of Ca, Mg, and K uptake and total clipping weight on rootzone mix levels of the cations. The approach taken was that of multiple regression in which clipping weight of Ca, Mg and K uptakes served as dependent variables and measures of rootzone mix Ca, Mg, and K as independent variables.

Table 4. Correlations between measures of rootzone mix Ca, Mg, and K and bentgrass uptake of the nutrients during establishment.

Measure of rootzone mix Ca, Mg, or K	Nutrient taken up		
	Ca	Mg	K
		Corr. coeffic., r*	
Percent saturation			
Ca	0.785**	-0.326	-0.068
Mg	-0.696**	0.372	-0.038
K	-0.536*	-0.258	0.621*
Absolute amount, lb/A			
Ca	0.774**	0.190	-0.115
Mg	-0.577**	0.577*	-0.058
K	-0.532*	-0.196	0.631**

* and ** indicate significance at $p = 0.05$ and 0.01.

The regression analyses revealed that when the rootzone mix Ca, Mg, and K levels were expressed as percent saturations, they reliably predicted the uptake of Ca ($R2 = 0.855$**) but not of total clipping weight or Mg or K uptake. When expressed in absolute terms (lb/acre), the soil tests reliably predicted uptake of Ca, Mg, K and total clipping weights ($R2 =$ 0.679* to 0.856**).

SUMMARY AND CONCLUSIONS

In the rootzone mixes used in this study, percent saturations of Ca ranged as low as 29% below optimum, Mg ranged 33 to 117% above optimum, and K was as much as 65% below optimum. Yet, creeping bentgrass clipping weights were not significantly affected and tissue concentrations of the three nutrients were entirely within or above their sufficiency ranges. There were no visual effects of the Ca, Mg, and K treatments on bentgrass density or color during establishment. Correlation and regression analyses indicated that bentgrass uptake of Ca, Mg, and K is more reliably predicted when rootzone mix exchangeable Ca, Mg, and K are viewed in absolute terms as lb/acre than as percentages of the soil cation exchange capacity.

Based on the above evidence, a reasonable conclusion is that the percent Ca-Mg-K saturation approach is unreliable for interpreting soil tests for the purpose of establishment of creeping bentgrass in rootzone mixes prepared from USGA specification sand and organic amendments. A better approach is to base lime and fertilizer recommendations on the absolute amounts of exchangeable Ca, Mg and K present. This has the added advantage of not having to estimate or measure the cation exchange capacity of the mix.

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