

NONACID CATION BIOAVAILABILITY IN SAND ROOTZONES

A dissertation

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

Micah Sharpe Woods

January 2006

© 2006 Micah Sharpe Woods

## NONACID CATION BIOAVAILABILITY IN SAND ROOTZONES

Micah Sharpe Woods, Ph.D.

Cornell University 2006

Soil nutrient analyses are used as indices of nutrient availability to plant roots. The 1 M NH<sub>4</sub>OAc, Mehlich 3, Morgan, 1:5 H<sub>2</sub>O, and 0.01 M SrCl<sub>2</sub> extracting solutions were evaluated for measurement of extractable nonacid cations in a calcareous sand rootzone. The 1:5 H<sub>2</sub>O and 0.01 M SrCl<sub>2</sub> tests adjusted to sample pH during the extraction process, but the 1 M NH<sub>4</sub>OAc, Mehlich 3, and Morgan tests did not adjust to sample pH. When comparing the extraction methods for their ability to detect K-induced changes in extractable Ca or Mg from a calcareous sand, the methods that adjusted to sample pH were sensitive to the changes, but the non-adjusting methods were not. The 0.01 M SrCl<sub>2</sub> method also predicted cation exchange capacity (CEC). In a selection of 37 sands and 17 soils, CEC was estimated by summation of the nonacid cations extracted by soil nutrient analyses. These CEC estimates were compared to CEC measured by compulsive exchange of Mg<sup>2+</sup> for Ba<sup>2+</sup>. In sand samples, the 0.01 M SrCl<sub>2</sub> estimates of CEC were very similar to measured CEC, but the 1 M NH<sub>4</sub>OAc, Mehlich 3, and Morgan estimates of CEC were larger than the measured CEC. The nonacid cations extracted by 0.01 M SrCl<sub>2</sub> can be used to estimate CEC in calcareous and non-calcareous sands and soils. All extracting solutions were able to detect increased K availability to creeping bentgrass [*Agrostis stolonifera* var. *palustris* (Huds.) Farw.] in field and greenhouse experiments. Cation exchange membranes detected increased K supply rates in field plots to which K fertilizer had been applied. However, leaf K content varied between sampling dates, so although leaf K was related to soil K at individual dates, it was difficult to predict creeping bentgrass K content from soil nutrient analyses of sand rootzones. By

expressing leaf K as the concentration of K in tissue water ( $K_w$ ), variability associated with changes in leaf water content between sampling dates was reduced. Performance of L-93 creeping bentgrass in a calcareous sand classified as low in K was not affected by K fertilizer application or by changes in soil K, Ca, and Mg. These results suggest that current interpretations of nonacid cation soil test sufficiency levels should be re-evaluated for sand rootzones. Under greenhouse conditions, A-1 creeping bentgrass grown in sands with pH ranging from 5.0 to 8.5 had leaf Ca, Mg, and K content within sufficiency levels, even in sands classified as low in Mehlich 3 extractable Ca, Mg, and K. Testing methods that adjust to sample pH were suitable for assessing nonacid cation availability in calcareous and non-calcareous sands. Future research should more clearly identify the relationship between extractable nonacid cations and turfgrass growth.

## BIOGRAPHICAL SKETCH

Micah Woods was born in 1976 at Forest Grove, Oregon. He grew up in Oregon's Willamette Valley and in the Allegheny Mountains of southwestern Pennsylvania. After graduating from Woodrow Wilson High School in Portland in 1993, Micah worked for a year on the maintenance crew at Waverley Country Club, and then he enrolled at Oregon State University to study horticulture. Over the next four years, Micah completed the requirements for his undergraduate degree and worked at golf courses in Arizona, Mississippi, and Georgia. In 1997, he worked on the maintenance crew for the Masters Tournament and on the Greenkeeping Support Team for the Open Championship at Royal Troon. Micah graduated from Oregon State in 1998, and he moved to Shanghai to work at Shanghai Links Golf and Country Club as the assistant superintendent. He worked as the golf course superintendent from November 1998, and remained in that position through August 2000. Micah then moved to Chiba prefecture in Japan, where he worked as an agronomist and golf course superintendent for Environmental Turfgrass Systems until August 2001. At that time, Micah began graduate studies at Cornell University in Ithaca, New York.

## ACKNOWLEDGMENTS

I thank my wife, Maria Derval Diaz, for her assistance in collecting data and samples from my experiments. Thanks are also due to the golf course superintendents who sent soil samples to me, and also to those who allowed me to collect samples from their properties. I appreciate the advice, generosity, and able guidance of Frank Rossi, chair of my graduate committee. The other members of my committee, Quirine Ketterings, A. Martin Petrovic, and Maxim Schlossberg, also provided valuable ideas and direction, and I thank them for their help.

## TABLE OF CONTENTS

Biographical sketch	iii
Acknowledgments	iv
List of Figures	vi
List of Tables	viii
1. Introduction .....	1
2. Effectiveness of standard soil tests for assessing potassium availability in a calcareous sand .....	5
3. Measuring the effects of potassium application on calcium and magnesium availability in a calcareous sand .....	29
4. Potassium availability indices and turfgrass performance in a calcareous sand putting green .....	50
5. Potassium supply rate as measured by exchange membranes in a calcareous sand .....	78
6. A simple method for predicting cation exchange capacity, with special respect to sand rootzones .....	91
7. Assessing the availability of nonacid cations to creeping bentgrass in sand rootzones .....	114
8. Summary and research needs .....	132

## LIST OF FIGURES

Figure 2.1. Correlation of K extracted by different methods .....	13
Figure 2.2. Extractable K after 4 fertilizer applications .....	15
Figure 2.3. Net change in extractable K under low and high irrigation ...	20
Figure 2.4. Relationships between extractable K and creeping bentgrass leaf K .....	22
Figure 3.1. Mean leaf Ca and Mg content at different K rates .....	37
Figure 3.2. Extractable Ca and Mg prior to initiation of K treatments ....	43
Figure 3.3. Extractable Ca and Mg by 0.01 M SrCl <sub>2</sub> and 1:5 H <sub>2</sub> O extraction methods from 2002 to 2004 .....	44
Figure 4.1. Mean K extracted from plots receiving 6 rates of K fertilizer .....	55
Figure 4.2. Precipitation and irrigation at test site from June 2002 through May 2004 .....	57
Figure 4.3. Creeping bentgrass K content as affected by K application rate .....	63
Figure 4.4. Effect of leaf N on creeping bentgrass K content .....	65
Figure 4.5. Soil K and associated leaf K content with leaf K expressed as a percentage of the nonacid cations .....	68
Figure 4.6. Ratings of gray snow mold in 2003 and 2004 .....	71
Figure 5.1. Cation exchange membrane and method of insertion .....	82
Figure 5.2. Potassium supply rate in 2002 and 2003 .....	84
Figure 5.3. Relationships between K supply rate and creeping bentgrass leaf K content .....	86

Figure 6.1. Relationships between $CEC_{sum}$ and $CEC_{CE}$ for 37 sand samples .....	101
Figure 6.2. Relationships between $CEC_{sum}$ and $CEC_{CE}$ for 17 soil samples .....	104
Figure 6.3. Relationships between 0.01 M $SrCl_2$ $CEC_{sum}$ and $CEC_{CE}$ for a selection of 54 sands and soils .....	107
Figure 7.1. Greenhouse air temperature .....	119
Figure 7.2. Scatterplot of extractable Ca and leaf Ca content .....	122
Figure 7.3. Scatterplot of extractable Mg and leaf Mg content .....	124
Figure 7.4. Scatterplot of extractable K and leaf K content .....	125
Figure 7.5. Scatterplot of extractable K and leaf K expressed as $mmol\ K\ L^{-1}$ tissue water ( $K_w$ ) .....	126
Figure 7.6. Dry matter production of creeping bentgrass as affected by leaf K content and $K_w$ .....	127

## LIST OF TABLES

Table 2.1. Physical and chemical properties of RMS sand .....	10
Table 2.2. Mean pH of extracting solutions before and after shaking with RMS sand .....	12
Table 2.3. Intercepts, slopes, and coefficients of determination for K extracted from a calcareous sand green .....	17
Table 2.4. Maximum predicted leaf K content based on extractable K in sample collected in July and September 2002 .....	24
Table 3.1. Schedule of soil and leaf sample collection dates .....	34
Table 3.2. Effect of K application on extractable Ca .....	38
Table 3.3. Effect of K application on extractable Mg .....	40
Table 4.1. Coefficient of determination for simple linear regression between soil and leaf K .....	66
Table 6.1. List of sands analyzed for CEC .....	95
Table 6.2. List of soils analyzed for CEC .....	97
Table 7.1. Extractable nonacid cations and pH of sands used for greenhouse experiment .....	118