# THE IMPACT OF SOIL ACIDITY AMELIORATION ON GROUNDNUT PRODUCTION ON SANDY SOILS OF ZIMBABWE

by

**MONICA RUJEKO MURATA**

**SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE**
**PHD PLANT PRODUCTION: AGRONOMY**

**DEPARTMENT OF PLANT PRODUCTION AND SOIL SCIENCE**

**FACULTY OF NATURAL AND AGRICULTURAL SCIENCES**

**UNIVERSITY OF PRETORIA**
**PRETORIA**

**JANUARY 2003**

**SUPERVISOR: Prof P.S. Hammes**
**CO-SUPERVISOR: Dr G.E. Zharare**

# THE IMPACT OF SOIL ACIDITY AMELIORATION ON GROUNDNUT PRODUCTIVITY ON SANDY SOILS OF ZIMBABWE

By

**Monica Rujeko Murata**

**SUPERVISOR: Prof P.S. Hammes**

**CO-SUPERVISOR: Dr G.E. Zharare**

**DEPARTMENT: Plant Production and Soil Science**

**DEGREE: PhD**

## ABSTRACT

The bulk of Zimbabwe's groundnut (*Arachis hypogaea* L.) crop is grown on sandy soils in the smallholder sector where sustainable production is hindered by acid soil infertility. The study goal was thus to examine the effects of soil acidity amelioration by four Ca-containing materials on nutrient composition, vegetative and reproductive growth, and quality of groundnut to formulate ameliorative strategies to improve productivity on acid soils. The effectiveness of calcitic lime (CL), dolomitic lime (DL), gypsum (G) and single superphosphate (SSP) in ameliorating soil acidity was determined in field experiments conducted for three seasons at two Research Stations in Zimbabwe, and in greenhouse experiments conducted for two seasons at Harare Research Station. In both experiments the lime application rates were from 0 to 4000 kg $ha^{-1}$, while G application rates were from 0 to 3450 kg $ha^{-1}$, and those of SSP were from 0 to 250 kg $ha^{-1}$. Calcitic or dolomitic lime applied at 2000 or 4000 kg $ha^{-1}$ increased soil pH and Ca and Mg contents in the pod and root zones, and in the plant material. Gypsum and SSP applications at 200 and 250 kg $ha^{-1}$ respectively, had no significant effects on pH, Ca and Mg levels, but when applied in equivalent amounts of Ca as lime, gypsum improved soil Ca status. Effects of the four ameliorants on the N, P and K levels in the soils and in plant material were generally neither significant nor consistent. The direct and residual benefits of application of CL or DL were manifested in improved plant stands, better growth, nodulation, productivity and quality of

groundnut. Gypsum applied at equal Ca rates as CL or DL was the superior Ca-source in improving pod and kernel quality. By the end of the third season, the increases in cumulative kernel yields due to application of 4000 kg $ha^{-1}$ lime over non-application were up to 319%. The major growth-limiting factors on the studied acid soils were identified as deficiencies of Ca and Mg, and low pH *per se.*

In a field experiment conducted to evaluate the tolerance of 15 groundnut genotypes to soil acidity, significant differences in yield and nutrient utilization efficiency of the genotypes were observed, implying that productivity on acid soils can be increased by growing genotypes efficient in uptake and utilization of nutrients.

Results from greenhouse and growth chamber studies conducted to examine the effects of pH (3.0 - 7.0) and its interactions with Ca (0 - 2000 μ*M* Ca) on early seedling growth and reproductive growth of groundnut indicated that low pH *per se* has a major detrimental impact on seedling survival, growth, pod formation, yield and quality of groundnut, but not on germination. The adverse effects of low pH were more pronounced in the absence of Ca, and became progressively less as the solution Ca concentrations increased. Further experiments showed that it is feasible to mitigate the adverse effects of soil acidity on groundnut germination and seedling survival by pelleting seeds with small amounts of $CaCO_3$, or priming with $CaSO_4$.

**Key words:** *Arachis hypogaea*, calcium, germination, nutrient efficiency ratio (NER), nutrient use efficiency (NUE), pH, seed pelleting, reproductive growth, seed priming, soil acidity amelioration, vegetative growth.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF TABLES CONT

## LIST OF FIGURES

## LIST OF APPENDICES

## ACKNOWLEDGEMENTS

I owe a debt of gratitude to my study supervisor, Prof P.S. Hammes, and to my co-supervisor Dr G.E. Zharare, not only for being outstanding mentors, but also for instilling in me the passion to pursue academic research. I greatly appreciate their guidance, patience and support at every phase of the program. I would also like to thank the reviewers of the thesis for their valuable comments.

I am grateful to the Government of Zimbabwe, and the Department of Agricultural Research and Extension for granting me special leave to undertake my study. I have been privileged in receiving financial support for my study from the Rockefeller Foundation, and I express my gratitude to Prof. Malcolm Blackie, Dr Akin Adesina, Lynda Mullen and Mr Joseph Bookmyer for their assistance. I am grateful for the unwavering support rendered by the Head of Agronomy Institute (Mrs Danisile Hikwa), and the assistance in trial monitoring and data collection by the technical staff in the Groundnut Agronomy Program.

Appreciation is expressed to the Soil Productivity Research Laboratory in the Chemistry and Soils Research Institute, Zimbabwe for chemical analyses of the plant and soil samples, and to the Central Agricultural Laboratories in Pelindaba, Pretoria, for chemical analyses of seed samples. Thank you to the staff in the Laboratory for Microscopy and Micro-analysis, University of Pretoria, for introducing me to the exciting world of scanning electron microscopy, and for helping me with the microscopy work.

My thanks go to colleagues and staff at the University of Pretoria, Department of Plant Production and Soil Science for motivating and encouraging me during my study. I am grateful to Mr Eugene Beyers and staff at the Hatfield Experimental farm who made my research and data collection under controlled environments possible. The invaluable assistance of Micah Masuku with the correlation analyses is greatly appreciated. I would like to extend a special thank you to Joey Herman for her expertise in policies and procedures, and for her friendship.

Finally, a special thank you to my entire family, particularly my parents (Joseph and Lusypa), my brothers and sisters (Stuart, Nancy, Fortune, Josephine, Miriam and Joseph) and their spouses, my son Elton, Ivy, Rudo, Paul, Noreen and Doreen for being loving, supportive, and being around when I really need you. You walked the journey with me in your special way. We did it!!