LEACHING AND SURFACE RUNOFF LOSSES OF SULPHUR AND

POTASSIUM FROM A TOKOMARU SOIL

A thesis presented in partial fulfilment
of the requirements for the Degree of
Master of Philosophy in Soil Science at
Massey University

Christine M. Smith

1979.

ABSTRACT

Sulphur and potassium surface and subsurface drainage water losses from grazed pastures on a yellow-grey earth soil, the Tokomaru silt loam, were investigated in field experiments. Runoff losses from undrained and drained pastures fertilised in spring or autumn were measured over a six week winter interval in 1976. Losses from undrained pastures were measured throughout the runoff season in 1977. In 1977, S and K leaching losses from pastures fertilised in spring or autumn, were determined by measuring tile drainage water losses and monitoring changes in soil S and K levels. An attempt was also made to relate soil S and K levels to tile drainage water losses.

This field study illustrates that SO_4-S is readily leached in the Tokomaru silt loam. Losses in tile drainage waters occurred from all depths above the mole drains (i.e. 45 cm depth) during individual flow events. On average 7.5 kg dissolved SO_4-S ha^{-1} was lost from the two non-irrigated pastures fertilised in spring. An additional 6.7 kg SO_4-S ha^{-1} was discharged in tile drainage waters from two irrigated pastures fertilised in spring (i.e. total 14.2 kg SO_4-S ha^{-1}). Evidence indicated that SO_4-S may have bypassed the drains in water seeping beyond the fragipan.

An autumn application of fertiliser S (45 kg S ha^{-1}) significantly enhanced the extent of leaching. The equivalent of 10% of the applied S (4.47 ± 1.5 kg SO_4-S ha^{-1}) was leached over a period of 17 weeks from July 1 to September 21. Losses occurred throughout this period. On average, 15.2 kg SO_4-S ha^{-1} was discharged from the two non-irrigated pastures fertilised in autumn. An additional 3.4 kg SO_4S ha^{-1} was lost from the two irrigated pastures.

An appreciable quantity (13.8 kg SO_4-S ha^{-1}) of the fertiliser S applied in autumn but not leached in tile drainage waters, was recovered as water soluble SO_4-S, leached below the 20 cm depth (i.e. below the zone from which pasture species are likely to obtain most

of their S.

Over a period of six weeks in 1976, 0.9 kg SO_4-S ha^{-1} was lost in surface runoff from an undrained pasture fertilised (19 kg S ha^{-1} in superphosphate) in spring. Less SO_4-S was lost from the associated drained plot (0.2 kg SO_4-S ha^{-1}). Undrained and drained plots fertilised in autumn (57 kg S ha^{-1} in superphosphate) lost 8% and 1.8% of the S applied (i.e. 5.5 and 0.9 kg SO_4-S ha^{-1}) respectively. In 1977, on average only 0.8 kg SO_4-S ha^{-1} was transported in surface runoff off two undrained plots fertilised (36 kg S ha^{-1} in superphosphate) in spring. An average of 8.0 kg SO_4-S ha^{-1} was lost from two plots fertilised (55 kg solution S ha^{-1}) in autumn. Hence surface runoff is an important S loss mechanism if undrained plots are fertilised in autum.

Sulphur received in the rainfall over a five month interval in 1977 amounted to 3.1 kg ha^{-1}.

From these results it was concluded that total drainage water losses from non-irrigated, drained pastures were likely to be largely offset by S received in the rain in 1977. A significant net S loss (in relation to annual pasture S requirements) will have occurred from pastures irrigated the preceding summer and/or fertilised in autumn.

Sulphur fertilisation in autumn and winter is not recommended. Under the conditions likely to prevail at this time an appreciable fraction of the applied S may be lost in drainage waters.

Results of this study indicate that leaching is not an important K loss process in the Tokomaru silt loam. Dissolved K leaching losses from pastures fertilised in spring or autumn averaged 4.66 and 4.05 kg K ha^{-1} respectively.

Potassium surface runoff losses are generally of no consequence. In 1976 only 1.1 kg K ha^{-1} was lost from an undrained pasture fertilised (50 kg K ha^{-1}) in spring, whilst 0.3 kg K ha^{-1} was discharged from the associated drained plot. A minimal fraction (3%) of the K applied in autumn (50 kg K ha^{-1}) to an undrained plot was lost in surface runoff. Less than 1% of that applied was discharged from the associated drained plot. Throughout 1977, on average, 1.35 kg K ha^{-1} was discharged from undrained plots fertilised (57 kg K ha^{-1}) in spring. An additional 3.75 kg K ha^{-1} was lost from pastures fertilised (55 kg K ha^{-1}) in autumn.

Rainfall K additions measured over a five month interval in 1977 were low (total 1.4 kg K ha^{-1}). However, because of the trend for K concentrations to vary on a seasonal basis it was concluded that K received in rainfall throughout 1977 was likely to largely offset total drainage water losses from undrained and drained pastures.

The results indicate that K deficiencies in pasture on K retentive yellow-grey earth soils are not attributable to drainage water losses.

Regression analyses showed that SO_4-S concentrations in leachate, but not SO_4-S loadings, were significantly related to water soluble soil SO_4-S levels (0-40 cm), determined at frequent intervals during the drainage season, if the quantity of water percolating through the soil is measured. No relationship was found between measured water soluble or ammonium acetate extractable soil K levels and leachate K concentrations or loadings.

ACKNOWLEDGEMENTS

I wish to express my thanks to Dr P.E.H. Gregg, Department of Soil Science, Massey University, who suggested this study and gave helpful advice, criticism and encouragement during all stages of the project.

Thanks are also extended to Mr R. Tillman of the Soil Science Department, Massey University, for help and advice, and to J. Macintosh for his assistance with the field work.

My sister, Julie's assistance with the figures, and my mother's support throughout, are much appreciated.

Finally, my sincere thanks to Mrs E. Hartstone who so ably typed the manuscript.

TABLE OF CONTENTS

CHAPTER III (continued) Page

LIST OF PLATES

LIST OF FIGURES

LIST OF TABLES

CHAPTER I INTRODUCTION

In grazed pastures, nutrient ions move continuously from the soil to the plant and back into the soil, either directly in plant residues or indirectly via the grazing animal. Nutrient ions exist in a variety of soil, plant and animal pools within this cycle. Additions to and losses from the cycle occur by a variety of processes.

Within this cycle, the size of a particular plant available soil nutrient pool at any one time (assuming the other nutrient levels are adequate), controls and may limit plant growth and hence animal production.

Factors which influence the size of the plant available pool, aside from the rate of plant nutrient uptake, include:

(i) the rate at which the nutrient ion is recycled into the plant available soil pool, and

(ii) the balance between non-cyclic additions to and losses from the plant available soil nutrient pool.

If the relative importance of those factors affecting the pool size can be defined, the principal factors responsible for inducing pasture nutrient deficiencies can be determined and reasoned improvements made in management practices.

The most widespread nutrient deficiency in New Zealand pastures is phosphate-phosphorus. The P-cycle in grazed pastures, and the importance of various loss mechanisms in inducing P deficiencies have, however, been studied in some detail.

Pasture production is also frequently limited by sulphur and potassium deficiencies.

Sulphur deficiencies generally follow a cessation in S fertiliser applications, but deficiencies do also occur in areas receiving regular S applications at rates sufficient to meet pasture requirements. In some instances, the S cycle turnover rate may limit productivity. Net S immobilisation may also account for the occurrence of S deficiencies. Frequently, however, pasture S deficiencies in New Zealand have been attributed to significant plant available soil SO_4-S losses in surface and, in particular subsurface drainage waters. At the time this study was commenced, S drainage water losses in New Zealand had not been measured in the field.

In New Zealand pasture potassium deficiencies are endemic on certain soils. In other areas, K deficiencies have arisen following the correction of other nutrient deficiencies and subsequent increases in the general level of productivity. The K cycle turnover rate is unlikely to limit productivity as K, existing only in ionic combination, may move rapidly through the cycle. Potassium losses from the cycling pool must exceed additions to the cycle. Potassium losses associated with grazing animals may be important. Controversy exists, regarding the importance of K drainage water losses in promoting K deficiencies. Drainage water K losses have not been investigated in the field in New Zealand.

The principal aim of this study was to measure plant available sulphate-sulphur and potassium surface and subsurface drainage water losses, from a New Zealand soil in the field.