

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**POTASSIUM RELEASING AND SUPPLYING POWER
OF SELECTED YELLOW GREY EARTH SOILS OF
NEW ZEALAND**

**A thesis presented in partial fulfilment of the requirements for the degree of
Doctor of Philosophy in Soil Science at Massey University**

ARAVIND SURAPANENI

1994

ABSTRACT

The supply of soil potassium (K) to New Zealand pastures is currently being assessed by the quick test K (QTK) and reserve K (K_c) methods, which measure soil exchangeable K (K_{ex}) and non-exchangeable K (K_{nex}), respectively. QTK is based on a routine soil test and K_c is an assigned estimate appropriate to the soil group. No consideration is given to the variations of the K_{nex} supply within a soil group. The objective of this research was to examine the K releasing and K supplying power of selected soils from the yellow-grey earth (YGE) group.

A wide variation was observed in the measured K_c values of the YGE soils in the North and South Islands. A glasshouse experiment showed that the supply of K_{nex} to ryegrass grown on the 13 North Island YGE soils ranged from 0-41 mg 100 g⁻¹ and that of the 6 South Island YGE soils ranged from 3-35 mg 100 g⁻¹. The experiment also showed that there were lower levels of K_{nex} supply in the pasture sites, compared to the virgin sites with respect to the South Island YGE soils. These results have implications to the use of the soil group concept which is used to estimate K_{nex} supply in the Computerised Fertilizer Advisory Service (CFAS) K model, currently used by AgResearch.

In a laboratory study, the threshold K levels in terms of K concentration and the activity ratio in the equilibrated soil solution, K_{ex} , and the amount of specifically held K were determined, in order to explain the variations in K_{nex} supply. The threshold K levels were not related to the K_{nex} release and supply.

The uptake of K by ryegrass was at best poorly to moderately correlated with the K extracted by current methods of determining K releasing power viz, QTK and K_c . The highest simple correlation was obtained from an improved acid-extractable K procedure ($r = 0.96$; $P < 0.01$). The differences in the K_{nex} uptake by ryegrass from various soils were better explained by a simple method of determining soil K_{nex} i.e., step K, than by the existing K_c method. A multiple regression equation with QTK

and step K as independent variables explained 96 % of the variation in total K uptake among soils.

On the basis of K_{nex} taken up by ryegrass in the glasshouse experiment, the 19 soils in this study were broadly grouped into two categories (i) soils with step K values of less than 35 mg 100 g⁻¹ and a K_c range of 8-10 mg 100 g⁻¹ and (ii) soils with step K values greater than 35 mg 100 g⁻¹ and a K_c range of 12-19 mg 100 g⁻¹.

Selected soils were fractioned into sand, silt, and clay separates and acid-extractable K levels of the fractions were measured. There was a wide range in the acid-extractable K levels among the soils for the same size fraction e.g., clay, and for different size fractions within the same soil. When weighted according to the particle size distribution of the soil, the sand was found to contribute 4-45 %, silt 10-40 %, and clay 15-85 % of the K released by the sum of the 3 separates, using the improved acid extraction method. In all the soils, the clay separate released the most K per unit weight.

An agar pot trial technique was developed to measure the K supplying power of the soil separates. Although on a unit weight basis the clay separates showed a much greater activity than the other separates on a weighted basis, the contributions of sand and silt separates to the total K uptake of Marton (38 %), Matapiro (41 %), and Wharekaka (25 %) soils was of considerable importance. The results demonstrated that the role of sand and silt separates deserve more consideration in estimating potential K releasing and supplying power than has hitherto been the case.

The study also attempted to relate K_{nex} release and supply to the soil mineralogy. Although the gross mineralogy of the 19 soils was similar, differences in the K_{nex} release and supply could be related to subtle differences and gradual changes in the clay mineralogy. The XRD patterns of the clays with a K_c range of 8-10 mg 100 g⁻¹ of soil differed from those with a K_c range of 12-19 mg 100 g⁻¹ of soil. The latter group of clays contain more K bearing minerals than the former group.

The practical implications of the measured differences in K_c values (K_{dex} supply) within the YGE soil group were dealt with. The measured K_{dex} supply in the North Island YGE soils ranged from 20-40 kg ha⁻¹ yr⁻¹, whereas the expected K_{dex} supply based on an assigned K_c value is 30 kg ha⁻¹ yr⁻¹. The difference between the expected and the measured K_{dex} may be sufficiently economically significant as to invalidate applying a single K_c value to a soil group. Possible improvements to the soil K supply component of the CFAS K model were suggested, particularly that step K values should replace K_c in the K supply model.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks, gratitude and appreciation to the following people for their contribution towards the completion of this thesis.

My supervisors, Drs. J.H. Kirkman, P.E.H. Gregg, A.H.C. Roberts and R.W. Tillman for their valuable guidance. Thank you for your time, patience and encouragement.

All the past and present staff in the Department of Soil Science. I would like to take this opportunity to thank, in particular, Drs. N.S. Bolan, M.J. Hedley, and A. Basker all of whom were ready to discuss and forward sound criticism of the research presented here.

Dr. A.S. Palmer for helping in soil classification, Dr. R.C. Wallace for identifying primary minerals, and Dr. S. Saggar for resin K analysis.

The department's technical staff, headed by Lance Currie, is acknowledged. I would like to thank Mike Bretherton and Anne West for preparing some diagrams in this thesis, and Malcolm Boag for his proof reading.

Denise and Nicola for their friendship.

All my fellow postgraduates for their friendship.

The Fertilizer and Lime Research Centre and the University Grants Committee for funding my study.

Lee, Katy and Mike. Let us never forget the days of the alternative tea club.

Rosie, Henry and John at the Dynasty Restaurant. Their friendship during my time at the Dynasty was invaluable.

My mother and brothers in India, and my brothers in U.S. Thank you for your strength, blessings and support.

Finally I would like to thank my family - my wife, Chaithanya, and my son, Theja - for looking after me steadfastly during my last few years of study; especially you, Chaithanya, for you have been through so much since your arrival in New Zealand. I cannot thank you enough.

This thesis is dedicated to my late father and beloved mother.

GLOSSARY OF K TERMS USED IN THIS THESIS

GENERAL TERMS

- Structural K* : Strongly bonded K in the crystal structure of minerals. It is variously called *mineral K*, *native K*, *inert K*, *matrix K*, or *unweathered K*.
- Fixed K* : K present in the wedge (w-), step (s-), crack (c-), and interlayer (i-) positions of weathered micaceous minerals and amorphous clays.
- K_{nex}/Reserve K* : Non-exchangeable K (structural K plus fixed K).
Also known as K_c in New Zealand.
- K_{ex}* : K present on planar (p-) and edge (e-) positions of clays and K sorbed at exchange sites on organic matter.
- K_s* : K in soil solution.
- Available K* : The K taken up by plants or K extracted by chemical methods that aim to mimic uptake by plants.
- K availability* : Reflects a complex of interdependent soil and plant processes that release the K that is taken up by plants. It is difficult to quantify.
- K releasing power (K release)* : Release of K from *K_{nex}/reserve* form to *K_{ex}* and *K_s* forms.
Any chemical method that determines total "available K" is a measure of K releasing power.
- K_{ex} releasing power (K_{ex} release)* : K extracted by chemical methods that measure soil *K_s* and *K_{ex}* forms e.g., $\text{NH}_4\text{OAc-K}_{\text{ex}}$, QTK (also NH_4OAc -extractable), $\text{CaCl}_2\text{-K}_{\text{ex}}$, resin K etc.
- K_{nex} releasing power (K_{nex} release)* : K extracted by chemical methods believed to measure soil *K_{nex}* of different solubility e.g, nitric

- acid K ($\text{HNO}_3\text{-K}$), resin K etc.
- K_{ex} plus K_{nex} releasing power* : K extracted by chemical methods that measure soil K_{ex} and K_{nex} e.g, $\text{HNO}_3\text{-K}$ (acid-extractable K), NaTPB K etc.
- K fixation* : Reverse of K release.
- It is the phenomenon by which the "available K" becomes unavailable due to fixation by clay minerals and can not be easily extracted by methods used to assess "*K_{ex} release*."
- K supplying power (K supply)* : Supply of K to plants. Any biological method e.g., a ryegrass pot trial, that determines "available K" is a measure of K supplying power.
- K_{ex} supplying power (K_{ex} supply)* : Total K uptake minus K_{nex} uptake.
- K_{nex} supplying power (K_{nex} supply)* : K_{nex} uptake calculated from total K uptake minus fall in NH_4OAc extractable K_{ex} .
- K losses* : The predicted amount of K lost from a farming system by leaching, product removal etc.
- Soil K supply (Soil K gain)* : The predicted amount of total K supplied to a farming system. It constitutes soil K_{ex} supply and soil K_{nex} supply, but may or may not include fertilizer K depending on the context in which the term is used.

TERMS USED WHILE REFERRING TO THE METHODS THAT DETERMINE K RELEASING POWER

- K_c : K extracted by boiling HNO_3 . It is a measure of difficultly soluble soil K_{nex} . It is analogous to *constant rate K*.
- K_{ex} : K extracted by ammonium acetate (NH_4OAc). It either measures soil K_{ex} plus K_s or K_{ex} alone.

<i>Threshold K level</i>	:	Critical K concentration in the equilibrated soil solution below which K release from K_{nex} sources is initiated.
<i>Solution K</i>	:	K measured in equilibrated 0.01 M CaCl_2 solution.
K_T	:	K desorbed in CaCl_2 solution plus K extracted with NH_4OAc .
AR^k	:	K-Ca activity ratio in equilibrated soil solution.
K_G	:	Gapon constant. This gives a measure of relative tightness of binding of K^+ in relation to other cations.
<i>QTK</i>	:	Quick test K. This measures approximately 80 % of the soil K_{ex} plus K_{v} .
<i>NaTPB K</i>	:	K extracted by sodium tetraphenyl boron (NaTPB) reagent. This reagent measures soil K_{ex} and K_{nex} .
<i>Resin K</i>	:	K extracted by a mixed cation and anion resin membrane. In Chapter 6 it was used to measure soil K_{ex} plus K_{v} .
<i>Acid-extractable K</i>	:	K extracted by boiling with 1 M HNO_3 . It is a measure of soil K_{ex} and easily soluble fraction of soil K_{nex} .
<i>Step K</i>	:	A measure of soil K_{nex} obtained by the difference between acid-extractable K and K_{ex} . It is therefore a computed value.
<i>QSK</i>	:	Quick step K. This is a measure of soil K_{nex} obtained by the difference between acid-extractable K and QTK. It is also a computed value.
OTHERS		
**	:	Significant at $P < 0.05$
*	:	Significant at $P < 0.01$
LSD	:	Least-squares difference
NS	:	Non significant
C.V	:	Coefficient of variation

TABLE OF CONTENTS

ABSTRACT	ii
ACKNOWLEDGEMENTS	v
GLOSSARY OF K TERMS USED IN THIS THESIS	vii
CONTENTS	x
LIST OF FIGURES	xix
LIST OF TABLES	xxii
LIST OF APPENDICES	xxvi

CHAPTER 1 INTRODUCTION

1.1 THE PURPOSE OF THE STUDY	1
1.2 THE STRUCTURE OF THE STUDY	3

CHAPTER 2 REVIEW OF LITERATURE

2.1 INTRODUCTION	5
2.2 FORMS OF SOIL K	5
2.2.1 Structural K	7
2.2.2 Fixed K	10
2.2.3 Exchangeable K (K_{ex})	12
2.2.4 Soil solution K (K_s)	12
2.3 POTASSIUM EQUILIBRIA IN SOILS	12

2.4	RELEASE OF K FROM PRIMARY (STRUCTURAL K) AND SECONDARY (FIXED AND EXCHANGEABLE K FORMS) MINERALS IN SOILS	13
2.5	POTASSIUM FIXATION	15
2.6	PLANT AVAILABILITY OF K IN RELATION TO RELEASE/FIXATION PROCESSES	17
2.7	METHODS OF ASSESSING PLANT AVAILABLE K	19
2.7.1	Methods for assessing K supplying power	20
2.7.2	Methods for assessing K releasing power	22
2.7.2.1	<i>Methods for assessing K_{ex} releasing power</i>	22
2.7.2.2	<i>Methods for assessing K_{ex} plus K_{nex} releasing power</i>	23
2.7.2.3	<i>Methods for assessing K_{nex} releasing power</i>	24
2.7.2.4	<i>Additional methods for assessing both K_{ex} and K_{nex} releasing power</i>	26
2.7.3	Relationship between K releasing power and K supplying power	27
2.8	CONCEPTS FOR MAKING K FERTILIZER RECOMMENDATIONS	30
2.8.1	Method that does not directly quantify either soil K gains (release/supply) or soil K losses	31
2.8.2	Method that directly quantifies only the soil K gains (release/supply)	31
2.8.3	Method that directly quantifies only the K losses	33
2.8.4	Method that directly quantifies both soil K supply (gains) and soil K losses	35
2.9	THE CFAS MODEL FOR CALCULATING K FERTILIZER REQUIREMENTS	36

**CHAPTER 3
GENERAL MATERIALS AND METHODS**

3.1	INTRODUCTION	42
3.2	SOILS	42
3.3	SOIL PROPERTIES	49

**CHAPTER 4
CHARACTERIZATION OF YGE SOILS BASED ON NON-EXCHANGEABLE
K RELEASING AND SUPPLYING POWER**

4.1	BACKGROUND	52
4.2	MATERIALS AND METHODS	55
	4.2.1 Soils and chemical measurements	55
	4.2.2 Artificial leaching technique	56
	4.2.3 Glasshouse experiment	56
	4.2.4 Statistical analysis	58
4.3	RESULTS AND DISCUSSION	58
	4.3.1 Exchangeable K release before cropping in the unleached and in the leached soils	58
	4.3.2 Dry matter yield	58
	4.3.2.1 <i>Total dry matter yields from unleached soils</i>	59
	4.3.2.2 <i>Total dry matter yields from leached soils</i>	62
	4.3.3 Potassium content of herbage	62
	4.3.4 Potassium uptake	65
	4.3.4.1 <i>Potassium uptake from control pots</i>	65
	4.3.4.2 <i>Potassium uptake from unleached soils</i>	65
	4.3.4.3 <i>Potassium uptake from leached soils</i>	69

4.3.5	Exchangeable K release after cropping the unleached and the leached soils	70
4.3.6	Comparative contribution of K_{ex} and K_{nxx} to total K uptake from unleached and leached soils	71
4.3.6.1	<i>Unleached soils</i>	71
4.3.6.2	<i>Leached soils</i>	72
4.3.6.3	<i>K_{nxx} supply versus K_{nxx} release</i>	72
4.4	GENERAL DISCUSSION ON ARTIFICIAL LEACHING TECHNIQUE	74
4.5	CONCLUSIONS	75

CHAPTER 5

POTASSIUM THRESHOLD LEVELS OF YGE SOILS IN RELATION TO K RELEASING POWER, SUPPLYING POWER, AND SPECIFICITY

5.1	BACKGROUND	77
5.2	MATERIALS AND METHODS	82
5.2.1	Soils	82
5.2.2	Determination of the threshold K level	82
5.3	RESULTS AND DISCUSSION	87
5.3.1	Threshold K levels expressed in terms of K concentration in the equilibrating soil solution	87
5.3.2	Relationship between Gapon constant (K_G) and K_{ex}	93
5.3.3	Variation of threshold K levels	93
5.4	CONCLUSIONS	99

CHAPTER 6
ASSESSMENT OF THE K RELEASING POWER OF YGE SOILS IN
RELATION TO PLANT AVAILABLE K USING SELECTIVE SOIL TESTING
PROCEDURES

6.1	BACKGROUND	100
6.2	MATERIALS AND METHODS	102
6.2.1	Soils	102
6.2.2	Plant growth studies	102
6.2.3	Chemical extraction methods for assessing K releasing power	102
6.2.3.1	<i>Conventional methods</i>	102
6.2.3.2	<i>Standardisation of an acid</i> <i>extraction procedure</i>	103
6.2.3.3	<i>Acid extraction procedure</i>	103
6.2.3.4	<i>Step K</i>	104
6.2.4	Sand and silt separation	104
6.2.5	Relative contribution of the soil separates to whole soil acid-extractable K	104
6.3	RESULTS AND DISCUSSION	106
6.3.1	Relationship between soil tests and dry matter yield of ryegrass grown on the unleached and the leached soils	106
6.3.2	Relationship between soil tests and K uptake from the unleached and the leached soils	110
6.3.3	Relationship between soil tests and K_{net} uptake	115
6.3.4	Characterization of YGE soils based on acid-extractable K and step K methods of assessing K releasing power	120

6.3.5	Contribution of acid-extractable K from soil separates	124
6.3.5.1	<i>Potassium extracted from the peroxidised soil and soil separates by the acid extraction procedure</i>	125
6.3.5.2	<i>Relative contribution of the soil separates to whole soil acid-extractable potassium</i>	128
6.4	CONCLUSIONS	130

CHAPTER 7
**POTASSIUM RELEASING POWER AND SUPPLYING POWER OF SOIL
TEXTURAL SEPARATES**

7.1	BACKGROUND	131
7.2	MATERIALS AND METHODS	133
7.2.1	Soils	133
7.2.2	Separation of textural fractions (soil separates)	134
7.2.3	Chemical extractions	134
7.2.4	Removal of K_{ex} from the soil separates	134
7.2.5	Percent contribution of K content (total K, K_{ex} , acid-extractable K, and step K) of the soil separates on a whole soil basis	134
7.2.6	Growth chamber experiment	135
7.2.6.1	<i>Agar pot cylinder</i>	135
7.2.6.2	<i>Agar potting technique</i>	137
7.2.7	Relative contribution of the soil separates to whole soil plant K uptake	138
7.3	RESULTS AND DISCUSSION	139
7.3.1	Potassium releasing power of soil separates	139

7.3.1.1	<i>Total K in the soil separates</i>	139
7.3.1.2	<i>Exchangeable K of the soil separates</i>	141
7.3.1.3	<i>Potassium releasing power of soil separates as assessed by the acid-extraction procedure</i>	143
7.3.1.4	<i>Potassium releasing power of soil separates as assessed by step K</i>	143
7.3.2	Potassium supplying power of soil separates	145
7.3.2.1	<i>Dry matter yields</i>	145
7.3.2.2	<i>Potassium content of herbage</i>	146
7.3.2.3	<i>Potassium uptake</i>	149
7.3.2.3.1	<u>Uptake of K from the control pots</u>	149
7.3.2.3.2	<u>Uptake of K from the soil separates</u>	151
7.3.2.3.3	<u>Exchangeable K after cropping</u>	151
7.3.2.3.4	<u>Comparative contribution of K_{ex} and K_{acc} uptakes to total K uptake from the soil separates</u>	152
7.3.2.3.5	<u>Predicted contribution of soil separates to K uptake of ryegrass grown in whole soil</u>	152
7.3.3	Validity of the computational method used to arrive at the relative contribution of soil separates to whole soil K releasing and supplying power	155
7.3.4	Relationship between acid-extractable K and plant K uptake	158
7.4	CONCLUSIONS	161

CHAPTER 8
MINERALOGY OF YGE AND RELATED SOILS IN RELATION TO NON-EXCHANGEABLE K RELEASING AND SUPPLYING POWER

8.1	BACKGROUND	163
8.2	MATERIALS AND METHODS	165
	8.2.1 Clay mineralogy	165
	8.2.2.1 <i>Procedure for identification of clay minerals by X-ray diffraction analysis</i>	165
	8.2.2.2 <i>Interpretation of XRD patterns for clay mineral identification</i>	166
	8.2.2.3 <i>Transmission electron microscopy</i>	167
	8.2.2 Sand and silt mineralogy	168
8.3	RESULTS AND DISCUSSION	168
	8.3.1 Clay mineral identification	168
	8.3.2 XRD patterns of the clays with K_c ranges of 8-10 and 12-19 mg 100 g soil⁻¹	169
	8.3.3 Relationship between mineralogy and K_{nex} releasing and supplying power of soils	177
	8.3.4 Sand and silt mineralogy	180
8.4	CONCLUSIONS	182

CHAPTER 9
ASSESSMENT OF THE K SUPPLYING POWER OF YGE SOILS

9.1	BACKGROUND	183
9.2	THEORY	184
9.3	RESULTS AND DISCUSSION	188
	9.3.1 Soil K supply from exchangeable sources	188

9.3.2	Predicted soil K supply from non-exchangeable sources based on the assigned and measured K_c values	188
9.3.3	Relationship between observed K uptake by plants and predicted soil K supply	191
9.3.4	Development of a model for predicting soil K supply from the pot trial	194
9.4	GENERAL DISCUSSION	196
9.4.1	Variations due to reserve K supply	196
9.4.2	Variations due to soil K_{ex} supply	198
9.4.3	Possible improvements to the CFAS soil supply model	200
9.5	CONCLUSIONS	203

CHAPTER 10

SUMMARY	205
BIBLIOGRAPHY	211
APPENDICES	225

LIST OF FIGURES

CHAPTER 2

Fig. 2.1	The dynamic equilibria between the forms of soil potassium	6
Fig. 2.2	The dynamics of weathering of primary minerals	8
Fig. 2.3	Model of a 2:1 layer-silicate clay showing 1.0 and 1.4 nm layers and planar (p), edge (e), interlayer (i), wedge (w), crack (c), and step (s) exchange sites (Goulding, 1987)	11
Fig. 2.4	Dry matter response to K fertilizer (Smith <i>et al.</i> , 1978)	32
Fig. 2.5	Schematics of computation of fertilizer K to reach near-maximum yields on individual farms (McLean and Watson, 1985)	34
Fig. 2.6	Theoretical relationship between fertilizer K required for 90 % maximum yields and both QTK and K_c values	40

CHAPTER 4

Fig. 4.1	K_{ex} of unleached soils before and after cropping	60
Fig. 4.2	K_{ex} of leached soils before and after cropping	61
Fig. 4.3	Total dry matter of ryegrass grown on unleached and leached soils	63
Fig. 4.4	Total K uptake of ryegrass grown on unleached and leached soil	66
Fig. 4.5	Actual K_{ex} and K_{nex} contribution from the unleached soils	67
Fig. 4.6	Actual K_{ex} and K_{nex} contribution from	

the leached soils 68

CHAPTER 5

Fig. 5.1 **Theoretical relationship between K concentration in the equilibrium soil solution and K_T 80**

Fig. 5.2 **Relationship between total K extracted (K_T) and exchangeable K of soils 88**

Fig. 5.3 **Relationship between total K extracted (K_T) with K concentration in an equilibrated solution of 0.01 M CaCl_2 (K_e) 89**

Fig. 5.4 **Relationship between total K extracted (K_T) and K-Ca activity ratio (AR^K) of soils 90**

Fig. 5.5 **Relationship between Gapon constant (K_G) and exchangeable K (K_{ex}) of soils 94**

CHAPTER 6

Fig. 6.1 **Relationship between soil tests (mg K 100 g⁻¹) and dry matter yield (g pot⁻¹) of ryegrass grown on the unleached soils 107**

Fig. 6.2 **Relationship between soil tests (mg K 100 g⁻¹) and dry matter yield (g pot⁻¹) of ryegrass grown on the leached soils 111**

Fig. 6.3 **Relationship between soil tests (mg K 100 g⁻¹) and K uptake by ryegrass (mg 100 g⁻¹) from the unleached soils 112**

Fig. 6.4 **Correlation of soil tests (mg K 100 g⁻¹) with K uptake (mg 100 g⁻¹) from the leached soils 116**

Fig. 6.5 **Correlation of K_c , NaTPB K, acid-extractable K, and step K with K_{net} uptake from the unleached soils (mg 100 g⁻¹) 117**

	with K_{ex} uptake from the leached soils (mg K 100 g ⁻¹)	118
Fig. 6.7	Changes in step K (mg 100 g⁻¹) of soils due to leaching and cropping	122
Fig. 6.8	Percent contribution of the acid-extractable K from the soil separates	129
 CHAPTER 7		
Fig. 7.1	Agar pot cylinder	136
Fig. 7.2	Relationship between K releasing power for the whole soil (Actual) and for the soil separates on a whole soil basis (Predicted)	156
Fig. 7.3	Relationship between K supplying power for the whole soil (Actual) and for the soil separates on a whole soil basis (Predicted)	157
Fig. 7.4	Relationship between acid-extractable K (mg 100 g⁻¹) and K uptake by ryegrass (mg 100 g⁻¹) from the soil separates and soils	159
 CHAPTER 8		
Fig. 8.1	X-ray diffractograms of soil clays (< 2 μm), K_c range 8-10 mg 100 g soil⁻¹	171
Fig. 8.2	X-ray diffractograms of soil clays (< 2 μm), K_c range 12-19 mg 100 g soil⁻¹	173

LIST OF TABLES

CHAPTER 3

Table 3.1	USDA, New Zealand Genetic (NZ genetic), and new New Zealand (New NZ) classification of soils used for the study	43
Table 3.2	Particle size analyses of the soils	50
Table 3.3	Some selected soil properties	51

CHAPTER 4

Table 4.1	Ranges of values used for K_{ex} and K_c to classify the K status of New Zealand soils for field (Metson, 1980) and fertilizer recommendation (Campkin, 1985) purposes	53
Table 4.2	K_c values for the soils, and field classification (Metson, 1980) and classification for fertilizer recommendations (Campkin, 1985) based on the ranges given in Table 4.1	54

CHAPTER 5

Table 5.1	Some features used for selecting soils to determine threshold K levels	83
Table 5.2	Ratios of soil:solution used for determining threshold K levels	84
Table 5.3	Threshold K levels (mean of duplicates) in terms of K concentration in equilibrium soil solution, K_{ex} , and AR^K , and the amount of specifically held K	92
Table 5.4	Increase in K_T beyond threshold K level in relation to K_{nex} uptake	96
Table 5.5	Changes in Solution and Exchangeable K (mean of duplicates) with increasing shaking time (h) at 1:400 Soil:CaCl ₂ solution ratio	98

CHAPTER 6

Table 6.1	Regression analyses between dry matter (g pot ⁻¹) and K releasing power (mg 100 g ⁻¹)	109
Table 6.2	Regression analyses between K uptake and K releasing power (mg 100 g ⁻¹)	114
Table 6.3	Regression analyses between K _{nex} uptake and K _{nex} releasing power for unleached soils (mg 100 g ⁻¹)	120
Table 6.4	K releasing and supplying power (mg 100 g ⁻¹) of Marton soil used in this study compared to the pot trial of Campkin (1972)	123
Table 6.5	Acid-extractable K of peroxidised soil and its separates (mg 100 g ⁻¹)	126

CHAPTER 7

Table 7.1	Some details of the soils selected for the study based on Chapter 6 data	133
Table 7.2	Potassium contents of soil separates before artificial removal of K _{ex}	140
Table 7.3	Potassium contents (mg 100g ⁻¹) of soil separates after extraction of K _{ex} (before cropping)	142
Table 7.4	Relative contribution of soil separates to whole soil acid-extractable potassium	144
Table 7.5	Total dry matter (g pot ⁻¹) of ryegrass shoots grown on soil separates and on whole soils	147
Table 7.6	Dry matter, herbage K, and K uptake of ryegrass roots in the clay separate	147
Table 7.7	Percent herbage K in ryegrass shoots for three harvests	148
Table 7.8	Total K uptake (less control) by ryegrass shoots from soil separates and from whole unperoxidised soil (mg 100 g ⁻¹)	150

Table 7.9	Actual contribution of K_{ex} and K_{nec} to total K uptake of ryegrass tops from the soil separates ($mg\ 100\ g^{-1}$)	153
Table 7.10	Percent contribution of K_{ex} and K_{nec} to total K uptake of ryegrass tops from the soil separates	153
Table 7.11	Percent contribution of total plant K uptake (shoots) from the soil separates on whole soil basis (calculated as described in section 7.2.7)	154

CHAPTER 8

Table 8.1	K_c , Step K, and K_{nec} supply ($mg\ 100\ g^{-1}$) of the unleached YGE soils of different regions (data from Chapters 4 and 6)	164
Table 8.2	Differences in the clay mineralogy and the amounts (subjective assessment), and in K releasing/supplying power of the YGE and related soils in the two K_c ranges	170
Table 8.3	Summary of clay minerals of 3 soils identified using XRD patterns in conjunction with TEM	178
Table 8.4	Non-exchangeable K releasing power and supplying power ($mg\ 100\ g^{-1}$) of clay fraction (Chapter 7 data)	179
Table 8.5	Primary minerals in sand and coarse silt fractions expressed as percentage of total sample (soil after removal of organic matter, amorphous materials, and water)	181
Table 8.6	Probable sources of K from the clay and sand plus silt fractions	182

CHAPTER 9

Table 9.1	Simplified equations to estimate soil K supplies ($kg\ ha^{-1}\ yr^{-1}$) for low, medium, and high K_c soils (Campkin, 1985)	186
-----------	---	-----

Table 9.2	K_c rating and measured K_c and QTK values of 19 soils	187
Table 9.3	Predicted soil K supply from K_{ex} and K_{noz} sources	189
Table 9.4	List of New Zealand soils that have K_c values of more than 0.70 meq % as reported in the literature	192
Table 9.5	Regression analyses between K uptake (kg ha^{-1}) from the pot trial (Y-variable) and the soil K supply ($\text{kg ha}^{-1} \text{ yr}^{-1}$) predicted using existing models (X-variable)	193
Table 9.6	Relationship between observed and predicted uptake in other pot experiments in New Zealand using Campkin equation (9.1)	195
Table 9.7	Regression analyses between K_{noz} uptake (kg ha^{-1}) observed in the pot trial (X-variable) and that predicted ($\text{kg ha}^{-1} \text{ yr}^{-1}$) by models (Y-variable)	195
Table 9.8	Relationship between the observed and the predicted K uptake by ryegrass using equation 9.9 in the other pot experiments in New Zealand	197
Table 9.9	Quick test K values (parts per 250,000 of extract) of reference paddocks on No. 4 dairy farm on Massey University (M.J. Hedley, pers. comm.)	199
Table 9.10	Changes in step K (kg ha^{-1}) due to leaching and cropping	202

LIST OF APPENDICES

CHAPTER 4

- Appendix 4.1 Dry matter (g pot^{-1}) of ryegrass grown on unleached (UL) and leached (L) soils 225
- Appendix 4.2 Percent K content of ryegrass tops grown on unleached (UL) and leached (L) soils during four cuts 226
- Appendix 4.3 Uptake of K (mg pot^{-1}) by ryegrass tops grown on unleached (UL) and leached (L) soils 227

CHAPTER 7

- Appendix 7.1 Dry matter (mg pot^{-1}) of ryegrass shoots for the three harvests 228
- Appendix 7.2 Potassium uptake (less control) by ryegrass tops from the soil separates for the 3 harvests ($\mu\text{g pot}^{-1}$) 229