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 (Kc) methods, which measure soil exchangeable K (Kex) and non-exchangeable K (Knex), respectively. QTK is based on a routine soil test and Kc is an assigned estimate appropriate to the soil group. No consideration is given to the variations of the Knex 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 Kc values of the YGE soils in the North and South Islands. A glasshouse experiment showed that the supply of Knex 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 Knex 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 Knex 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, Kex, and the amount of specifically held K were determined, in order to explain the variations in Knex supply. The threshold K levels were not related to the Knex 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 Kc. The highest simple correlation was obtained from an improved acid-extractable K procedure (r = 0.96; P < 0.01). The differences in the Knex uptake by ryegrass from various soils were better explained by a simple method of determining soil Knex i.e., step K, than by the existing Kc 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 $K_{\text{max}}$ 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 $K_{\text{max}}$ release and supply to the soil mineralogy. Although the gross mineralogy of the 19 soils was similar, differences in the $K_{\text{max}}$ 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 ($K_{ext}$ supply) within the YGE soil group were dealt with. The measured $K_{ext}$ supply in the North Island YGE soils ranged from 20-40 kg ha$^{-1}$ yr$^{-1}$, whereas the expected $K_{ext}$ supply based on an assigned $K_c$ value is 30 kg ha$^{-1}$ yr$^{-1}$. The difference between the expected and the measured $K_{ext}$ 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.
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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_{net}/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 : 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_{net}/reserve form to K_{ex} and K 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, and K_{ex} forms e.g., NH4OAc-K_{ex}, QTK (also NH4OAc-extractable), CaCl2-K_{ex}, resin K etc.

K_{net} releasing power (K_{net} release) : K extracted by chemical methods believed to measure soil K_{net} of different solubility e.g., nitric
acid K (HNO₃-K), resin K etc.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{ex} + K_{nex}$ releasing power</td>
<td>K extracted by chemical methods that measure soil $K_{ex}$ and $K_{nex}$ e.g. HNO₃-K (acid-extractable K), NaTPB K etc.</td>
</tr>
<tr>
<td>$K$ fixation</td>
<td>Reverse of $K$ release. It is the phenomenon by which the &quot;available $K$&quot; becomes unavailable due to fixation by clay minerals and can not be easily extracted by methods used to assess &quot;$K_{ex}$ release.&quot;</td>
</tr>
<tr>
<td>$K$ supplying power (K supply)</td>
<td>Supply of K to plants. Any biological method e.g., a ryegrass pot trial, that determines &quot;available $K$&quot; is a measure of K supplying power.</td>
</tr>
<tr>
<td>$K_{ex}$ supplying power (K$_{ex}$ supply)</td>
<td>Total K uptake minus $K_{nex}$ uptake.</td>
</tr>
<tr>
<td>$K_{nex}$ supplying power (K$_{nex}$ supply)</td>
<td>$K_{nex}$ uptake calculated from total K uptake minus fall in NH₄OAc extractable $K_{ex}$.</td>
</tr>
<tr>
<td>$K$ losses</td>
<td>The predicted amount of K lost from a farming system by leaching, product removal etc.</td>
</tr>
<tr>
<td>Soil K supply (Soil K gain)</td>
<td>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.</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_{e}$</td>
<td>K extracted by boiling HNO₃. It is a measure of difficultly soluble soil $K_{nex}$. It is analogous to constant rate K.</td>
</tr>
<tr>
<td>$K_{ex}$</td>
<td>K extracted by ammonium acetate (NH₄OAc). It either measures soil $K_{ex}$ plus $K_{e}$ or $K_{ex}$ alone.</td>
</tr>
</tbody>
</table>
Threshold K level: Critical K concentration in the equilibrated soil solution below which K release from K\textsubscript{nex} sources is initiated.

Solution K: K measured in equilibrated 0.01 M CaCl\textsubscript{2} solution.

\(K_T\): K desorbed in CaCl\textsubscript{2} solution plus K extracted with NH\textsubscript{4}OAc.

\(AR^K\): K-Ca activity ratio in equilibrated soil solution.

\(K_G\): Gapon constant. This gives a measure of relative tightness of binding of K\textsuperscript{+} in relation to other cations.

\(QTK\): Quick test K. This measures approximately 80% of the soil K\textsubscript{ex} plus K\textsubscript{r}.

NaTPB K: K extracted by sodium tetraphenyl boron (NaTPB) reagent. This reagent measures soil K\textsubscript{ex} and K\textsubscript{nex}.

Resin K: K extracted by a mixed cation and anion resin membrane. In Chapter 6 it was used to measure soil K\textsubscript{ex} plus K\textsubscript{r}.

Acid-extractable K: K extracted by boiling with 1 M HNO\textsubscript{3}. It is a measure of soil K\textsubscript{ex} and easily soluble fraction of soil K\textsubscript{nex}.

Step K: A measure of soil K\textsubscript{nex} obtained by the difference between acid-extractable K and K\textsubscript{ex}. It is therefore a computed value.

\(QSK\): Quick step K. This is a measure of soil K\textsubscript{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
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