Non-exchangeable potassium in southern African soils: a neglected reserve from a crop nutritional perspective

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The cost squeeze in agriculture
The cost squeeze in agriculture

- Improved efficiency in the use of inputs
- Improved income through yield enhancement
Estimated current annual expenditure on NPK fertilisers in the South African sugar industry

<table>
<thead>
<tr>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>448</td>
<td>212</td>
<td>489</td>
<td>1 149</td>
</tr>
</tbody>
</table>
Soil testing for potassium

- Most soils have relatively large amounts of **total** K, but small amounts of **plant-available** K.
- Soils may contain minerals (typically micas & illites) that release K slowly and/or ‘fix’ it.
- **Routine soil testing** involves extraction of *exchangeable / soluble* K with salt solutions.
- Slowly-available (‘reserve’) K may be estimated using **boiling HNO₃** or **sodium tetraphenylboron** extraction.
Potassium pools in soils

- K in clay structures
- Slowly available ‘Nitric K’
- ‘Fixed’ K in micas & illites
- Exchangeable K
- ‘Soil-test’ K
- K in soil solution

Weathering → Release / Fixation

Exchange
The issue ........

• In soils containing micaceous clays, slow release of K is a major reservoir of K for crop growth.

• Although long known, this phenomenon not accommodated in routine soil testing.

• Potential for appreciable savings in K?
This presentation

- Data from maize and sugarcane field trials
- Boiling nitric-acid extractable K (‘nitric K’) in 429 topsoil samples from five Southern African countries
- Prediction of nitric K using routinely-measured soil properties and MIR
Field trial results...
Long-term maize trial at Bergville

- Avalon soil, 36% clay
- Nitric K = \(2.08\ \text{cmol}_c/\text{kg}\)
- No yield response over 25 years (all stover and grain removed at harvests).
Bergville Maize Trial

![Graph showing the relationship between K removal (kg K/ha) and K soil test (mg K/L) over years. The graph includes data points for K soil test and K removal, with a trend line indicating a positive correlation. The years range from 0 to 30, and the K removal and K soil test scales range from 0 to 700. The K soil test values are represented by green diamonds, and the K removal values are represented by red circles. There is an orange box highlighting a specific area of the graph.]
Sugarcane response to potassium on a Glenrosa soil in Mpumalanga

- Initial soil $K = 150$ ppm
- Nitric $K = 2.6$ cmol$_c$/kg
Potassium response of sugarcane on a Glenrosa soil in Mpumalanga

No response to K over three ratoons (estimated annual removal = 250 kg K/ha)
Long-term sugarcane trial at Mt Edgecombe (BT1 Trial)

- Arcadia (vertic) soil
- Nitric K = 1.52 cmol$_c$/kg
- No response to NPK for 18 years
Sugarcane trial on the Umfolozi flood-plain

- Dundee (alluvial) soil (42% clay)
- Soil test K: 110 mg/L
- Nitric K = 3.84 cmol$_c$/kg
- No response to K for 2 seasons

Top-yielding farmer: no K for 5 years
So..... no responses to applied K in field trials with nitric K’s of 1.5 to 3.8

Overseas field trial findings...?
Criteria suggested for modification of K recommendations in Australia

- Haysom (1971) field trial data interpretation:

<table>
<thead>
<tr>
<th>Nitric K (cmol_c/kg)</th>
<th>Category</th>
<th>Recommended K (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.8</td>
<td>Low</td>
<td>100</td>
</tr>
<tr>
<td>0.8 – 1.5</td>
<td>Medium</td>
<td>82</td>
</tr>
<tr>
<td>1.5 – 2.5</td>
<td>High</td>
<td>45</td>
</tr>
<tr>
<td>&gt;2.5</td>
<td>Very high</td>
<td>0</td>
</tr>
</tbody>
</table>

- Schroeder et al. (2006): Reduce K recoms by ±20% if nitric K >0.70
Nitric K levels in Southern African sugarcane topsoils
Median nitric K levels in Southern African soils

- KZN Midlands: 100
- KZN Coastal: 92
- Umfolozi: 30
- Pong/Mpum: 40
- Zambia: 27
- Malawi: 38
- Tanzania: 72
- Zimbabwe: 30

**Australia: zero K fert**

**SA field trials**
Nitric K: which soils have higher reserves?

- Many soils in drier irrigated areas
- Alluvial soils (e.g. Umfolozi flood-plain)
- Structured soils in rainfed areas
The problem of soil heterogeneity

• Frequent high soil heterogeneity implies marked variations in K reserves over small distances.

• Not possible to extrapolate results over large areas.
Frequency distribution of nitric K in sugarcane fields on the North Coast of SA
Nitric K in profiles surrounding SASRI
Nitric K in profiles surrounding SASRI

156 kg/ha K applied per ratoon (R1900/ha)
Imperative: the routine prediction of nitric K in order to modify K recoms

How … nitric K determination not suited to use in routine soil-testing lab

- Multiple regression based on routinely-measured soil properties ($R^2 = 40.4$)
- Offer nitric K as an optional supplementary analysis at additional cost?
- Use MIR to routinely estimate nitric K on all samples?
Mid-infrared reflectance prediction of nitric K reserves in soil of the Southern African sugar industries
Mid-infrared reflectance prediction of nitric K reserves in soil of the Southern African sugar industries
Bad news for the fertiliser industry???

OPPORTUNITIES

☑ Improved efficiencies → enhanced sustainability.

☑ More effectively address other crop nutrient problems...N, S, micros.
Conclusions

• Field trial results point to the unnecessary use of K on many soils in Southern Africa

• Exploiting slowly-available K reserves → significant cost savings, without compromising production.

• MIR → possible solution to the problem of routine measurement of K reserves