Evaluation of soil fertility and partial nutrient balances for improved fertilizer recommendations under intensive agriculture in India

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Changing scene of Indian agriculture

<table>
<thead>
<tr>
<th>Parameters</th>
<th>1950-51</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Area Under food Grains (million ha)</td>
<td>97.3</td>
<td>124.4</td>
</tr>
<tr>
<td>Gross Irrigated Area Under food Grains (million ha)</td>
<td>18.3</td>
<td>56.6</td>
</tr>
<tr>
<td>Per Capita Gross Sown Area (ha person⁻¹)</td>
<td>0.34</td>
<td>0.16</td>
</tr>
<tr>
<td>Cropping Intensity (%)</td>
<td>112</td>
<td>135</td>
</tr>
<tr>
<td>Fertilizer consumption (million tones)</td>
<td>0.07</td>
<td>23.02</td>
</tr>
<tr>
<td>Food Grain production (million tones)</td>
<td>50.8</td>
<td>230.7</td>
</tr>
</tbody>
</table>
This presentation was made at the IPI-OUAT-IPNI International Symposium, 5-7 November 2009, OUAT, Bhubaneswar, Orissa, India. The Role and Benefits of Potassium in Improving Nutrient Management for Food Production, Quality and Reduced Environmental Damage.

Structure of Presentation

- Trends in fertilizer use and crop response
- Soil fertility evaluation approaches
- Fertilizer recommendation philosophies
- Partial nutrient balances
- Balanced fertilization and FUE

Trends in fertilizer N, P and K consumption and food grain production in India (1950-51 to 2007-08)
Partial factor productivity of fertilizer NPK for food grains production in India and Punjab

Nutrient response ratios in cereals

Drawn from long-term fertilizer experiments data averaged over 1972-2003 and several locations of rice, wheat, maize and finger millet.
Inefficient use of fertilizers is

- Uneconomical
- Unecological

Which may lead to:

- Environmental pollution
- Groundwater contamination
- Soil health problems

Soil fertility evaluation

1. Soil testing
2. Plant analysis

1) Soil testing
   - To estimate the nutrient-supplying power of a soil by biological or chemical methods
   - Soils classified into low, medium and high
2) **Plant Analysis**

- Valuable supplement to soil testing.
- Useful in confirming nutrient deficiencies, toxicities or imbalances

**Limitations:**

- Does not consider nutrient balances and interactions
- Requires different critical values for different tissue ages

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**Soil Test Interpretation and Fertilizer Recommendations Approaches**

- Generalized Fertilizer recommendation (GRD)
- Soil Test based fertilizer recommendation (STRD)
- Critical Value or sufficiency approach
- Fertilizer recommendation for targeted yields
- Build-up and maintenance concept
- Response surfaces and mechanistic modeling
Generalized or state level blanket fertilizer recommendation

- It is most commonly advocated and followed method
- Ideally suited to soils of medium fertility

Limitations:
- Due to variation in soil fertility it does not ensure economy and efficiency of applied fertilizer
- Wastage in high fertility and sub-optimal use in low fertility soils

Soil Test Based fertilizer recommendations

Fertilizer recommendation is based on soil which is considered as medium.

**Fertilizer dose**
- increase by 25% for low soils
- decreased by 25% for high soils

Limitations
- Same dose for extremely low and moderately low soil
- Same dose for extremely high and moderately high soils
- Only single nutrient is considered
- Interaction with other nutrients and soil properties are ignored
Solution

- Fertilizer recommendation should be based on actual soil test value instead of soil fertility class.

- Interaction effect should be considered, e.g., response to P depends both on P status and organic carbon status of soil.

Fertilizer P requirement for 5 t/ha wheat yield in relation to SOC and Olsen P

Values at the top of the curves indicate Olsen P (mg kg⁻¹).
Critical Value Approach

- Applied to differentiate responsive from non-responsive soils
- Maximum data points should fall in 1st and 3rd quadrant

Critical limits of available K in soils for different crops and soils

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soils Type</th>
<th>Critical Limit (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Medium Black</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Alluvial</td>
<td>190</td>
</tr>
<tr>
<td></td>
<td>Laterite</td>
<td>80</td>
</tr>
<tr>
<td>Wheat</td>
<td>Alluvial</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>Calcarious</td>
<td>60</td>
</tr>
<tr>
<td>Sorghum</td>
<td>Vertisol</td>
<td>335</td>
</tr>
</tbody>
</table>

Based on data from different regions of India
Fertilizer recommendations for K

- Extraction with NH$_4$OAc is adopted in Soil Testing labs. and a value of 55 mg K kg$^{-1}$ is used to differentiate responsive from non-responsive soils.
- The glaring discrepancy in K availability by adopting uniform critical values for all soils could be seen by comparing the illite rich mineral soils with smectite dominant soils.

<table>
<thead>
<tr>
<th>Soil</th>
<th>NH$_4$OAc-K (mg K kg$^{-1}$)</th>
<th>Response to K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illite rich mineral soil</td>
<td>60</td>
<td>Non-responsive</td>
</tr>
<tr>
<td>Smectite dominant soils</td>
<td>300</td>
<td>Responsive</td>
</tr>
</tbody>
</table>

Relationship between exchangeable and water soluble K for illitic and smectitic soils

(Sekhon et al. 1992)
## Relationship between exchangeable and water soluble K

<table>
<thead>
<tr>
<th>Soil</th>
<th>Relationship</th>
<th>Solution K (mg Kg⁻¹)</th>
<th>Exch. K (mg Kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illitic</td>
<td>Y=2.59 + 0.286X</td>
<td>12.0</td>
<td>33</td>
</tr>
<tr>
<td>Smectitic</td>
<td>Y=5.14 + 0.023X</td>
<td>12.0</td>
<td>300</td>
</tr>
</tbody>
</table>

Y = Solution K ; X = Exchangeable K

## Site-specific nutrient management

- Feeding crops with nutrients as and when needed
- The application and management of nutrients are dynamically adjusted to crop needs of the location and season

**Example:**
- Use of leaf colour chart (LCC) or Chlorophyll meter
- Target yield concept
**Target yield concept**

- It not only prescribes the optimum dose of nutrient but also predicts the level of yield that a farmer can expect.

  Fertilizer dose is obtained by computing three basic parameters:
  - NR - nutrient requirement per unit of economic yield
  - CS - contribution from soil available pool
  - CF - fractional recovery of applied fertilizer nutrient

**Limitations:**

- Problems in estimating contribution of nutrient from soil available pool (CS)
- CS is influenced by soil type, texture, rooting depth and nutrient release characteristics of the soil
- Heavily biased towards high fertility of native and applied nutrients
- Difficult to estimate the contribution of non-exchangeable K towards plant uptake
Soil test based fertilizer K recommendations for target yield of rice (7 t/ha) in alluvial soils of Punjab

Imbalanced fertilization and nutrient balances

1. The present NPK use ratio of 6.8:2.8:1 in India is typically unfavourable to K compared to the generally proclaimed ideal ratio of 4:2:1

2. Punjab having highest productivity of wheat (4.52 t ha\(^{-1}\)) & paddy (5.8 t ha\(^{-1}\)), has highest imbalanced use of NPK (33.7:9.2:1.0) and substantial mining of K from soils
3. Ratio of 4:2:1 could be satisfactory for cereals but for other crops like legumes the ratio could vary from 1:1:1 to 2:1:2

4. Imbalanced use of NPK is main cause for declining crop response ratios

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<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Addition thro' fertilizer (X10^3 tonnes)</td>
<td>Nil</td>
<td>7</td>
<td>29</td>
<td>14</td>
<td>43</td>
</tr>
<tr>
<td>Total K removal (X10^3 tonnes)</td>
<td>159</td>
<td>305</td>
<td>495</td>
<td>820</td>
<td>825</td>
</tr>
<tr>
<td>Net loss (X10^3 tonnes)</td>
<td>159</td>
<td>299</td>
<td>466</td>
<td>806</td>
<td>782</td>
</tr>
<tr>
<td>Loss (kg/ha/crop)</td>
<td>44</td>
<td>67</td>
<td>82</td>
<td>122</td>
<td>118</td>
</tr>
</tbody>
</table>
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K removed (kg ha\(^{-1}\)) by maize-wheat sequence (1970-71 to 1983-84)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Removed</th>
<th>Applied</th>
<th>(\Delta E-K)</th>
<th>(\Delta NE-K)</th>
<th>Total E-K + NE-K</th>
<th>Release from NE-K</th>
<th>Unaccounted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>803</td>
<td>0</td>
<td>-51</td>
<td>-597</td>
<td>-648</td>
<td>752</td>
<td>155</td>
</tr>
<tr>
<td>N100</td>
<td>1392</td>
<td>0</td>
<td>-72</td>
<td>-1110</td>
<td>-1182</td>
<td>1320</td>
<td>210</td>
</tr>
<tr>
<td>N100 P22</td>
<td>1766</td>
<td>0</td>
<td>-78</td>
<td>-1483</td>
<td>-1561</td>
<td>1689</td>
<td>205</td>
</tr>
<tr>
<td>N100 P22</td>
<td>2323</td>
<td>1097</td>
<td>+6</td>
<td>-1101</td>
<td>-1095</td>
<td>1250</td>
<td>149</td>
</tr>
</tbody>
</table>

Adapted from Singh and Brar (1986)

Annual K balance in long term rice-wheat cropping system at Ludhiana (India) during 1988-2000

<table>
<thead>
<tr>
<th>Year</th>
<th>Without incorporation</th>
<th>With incorporation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>157</td>
<td>219</td>
</tr>
<tr>
<td>2</td>
<td>304</td>
<td>309</td>
</tr>
<tr>
<td>3</td>
<td>-147</td>
<td>-90</td>
</tr>
</tbody>
</table>

Yadvinder-Singh et al. (2004)
Balanced Fertilization and fertilizer Use Efficiency

<table>
<thead>
<tr>
<th>Crop</th>
<th>Soil type/Location</th>
<th>N use efficiency (%)</th>
<th>P use efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>NP</td>
</tr>
<tr>
<td>Maize</td>
<td>Inceptisol/Ludhiana</td>
<td>16.7</td>
<td>23.5</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>32.0</td>
<td>50.6</td>
</tr>
<tr>
<td>Maize</td>
<td>Alfisol/Palampur</td>
<td>6.4</td>
<td>34.7</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td>1.9</td>
<td>35.6</td>
</tr>
</tbody>
</table>

Fertilizer N use efficiency could be improved if the fertilizer N rate is adjusted for the actual SOC concentration instead of fertility classes

Source: Benbi and Chand (2007)
Conclusions

- The fertilizer consumption in India increased dramatically but the response has declined.

- While there is a wide-scale adoption of blanket fertilizer recommendation there is a need for site-specific nutrient management for balanced fertilization.

- Need to monitor soil fertility and emerging nutrient deficiencies.

- Soil test methods should be augmented with other chemical and biological fractions for better interpretations.

- Fertilizer adjustment for K, needs to consider non-exchangeable K along with exchangeable or water soluble K.

- Different critical levels for available K should be used for soils with different mineralogical composition.
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