Balanced crop nutrition: Fertilizing for crop and food quality

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Topics

- How common is “Unbalanced fertilization”?
- Outcome of unbalanced crop nutrition
  - India
  - China
  - Egypt
  - Bulgaria
- Balanced and timely nutrient application
  - Long term observations
  - Organic agriculture?
  - Effect on yields, quality and plant health
  - Economics & extension
- Conclusions

IPI experiment in Haryana, India (PI, 2004)
How common is Unbalanced Fertilization?

IPI experiment in Chhattisgarh, India (VN, 2004)

Why K is always complaining?

Global balance: Annual macronutrient content of crops, crop residues, and input of mineral fertilizers

<table>
<thead>
<tr>
<th>Global outputs and inputs</th>
<th>Nitrogen (N)</th>
<th>Phosphorus (P)</th>
<th>Potassium (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvested crops</td>
<td>50</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Crop residues</td>
<td>25</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>Total crop phytomass</td>
<td>75</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>Fertilizers (inorganic)</td>
<td>80</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Ratio Fertilizer / total crop phytomass</td>
<td>80/75=1</td>
<td>14/14=1</td>
<td>19/60=0.3</td>
</tr>
</tbody>
</table>

K is partially replaced

Adapted from V. Smil, 1999: Crop residues: Agriculture’s largest harvest. Bioscience, Vol. 49 No. 4, pp299-308
Production of major crop groups in developed and developing countries, 1980-2004

![Graph showing production of major crop groups in developed and developing countries, 1980-2004.](image)

Source: FAO, 2005

Nutrient consumption in developed and developing countries, 1980-2004

![Graph showing nutrient consumption in developed and developing countries, 1980-2004.](image)

**Q:** Do these fresh supplies of nutrients suffice their removal in harvested and crop residues?

**A:** Growth rates are similar, yet the weigh is unbalanced

Source: FAO, 2005
Production and growth rates of major crop groups and averaged nutrient consumption in developed and developing countries (1980-2004)

<table>
<thead>
<tr>
<th>Crop / factor</th>
<th>Developed countries</th>
<th>Developing countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1980</td>
<td>2004</td>
</tr>
<tr>
<td><strong>Million ton</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereals</td>
<td>783.7</td>
<td>990.7</td>
</tr>
<tr>
<td>Fruit &amp; Vegetables</td>
<td>271.8</td>
<td>301.2</td>
</tr>
<tr>
<td>Roots and tubers</td>
<td>184.4</td>
<td>182.7</td>
</tr>
<tr>
<td>Soybean</td>
<td>51.1</td>
<td>91.6</td>
</tr>
<tr>
<td>Meat</td>
<td>89.7</td>
<td>81.6</td>
</tr>
<tr>
<td><strong>Nutrient consumption</strong></td>
<td><strong>(growth rate, %)</strong></td>
<td><strong>(growth rate, %)</strong></td>
</tr>
<tr>
<td>N</td>
<td>(0.8)</td>
<td></td>
</tr>
<tr>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</td>
<td>(3.0)</td>
<td></td>
</tr>
<tr>
<td>K&lt;sub&gt;2&lt;/sub&gt;O</td>
<td>(2.8)</td>
<td></td>
</tr>
</tbody>
</table>

Source: FAO, 2005

Apparent K balance during 1988-2000 in a long-term rice-wheat experiment, Punjab, PAU

Long-term effects of inorganic and organic inputs on available K content in soil


The importance of crop residues:
Rice yields with different residue management at two N levels

Source: IPI India, GBPUAT Pantnagar project, 2005

Crop residue management

K=60 kg K2O/ha

Improved N utilization

Texture Clay fraction
silt clay loam 7.78
O.C. (%) 1.18
Available N (kg/ha) 225
Available P (kg/ha) 41.5
Available K (kg/ha) 219
Interim conclusions - India

- “Current K fertilizer recommendations for P and K are inadequate in the long run”

- The decline in SOM is not the reason of negative yield trends

- Adverse changes in climatic parameters..... and decreased soil supply of available K are associated with declining yields

- CR management are critical for K balance and nutrient use efficiency.


Change of K balance in the agroecosystems in China from 1997 to 2001

Large N & P surpluses are accompanied with K deficit

<table>
<thead>
<tr>
<th>Province</th>
<th>N balance</th>
<th>P₂O₅ balance</th>
<th>K₂O balance</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>90-150</td>
<td>26-45</td>
<td>&gt;72</td>
<td>Low K input</td>
</tr>
<tr>
<td>Shanghai</td>
<td>&gt;200</td>
<td>&gt;45</td>
<td>&gt;72</td>
<td>High K; high removal; leaching</td>
</tr>
<tr>
<td>Jiangsu</td>
<td>&gt;200</td>
<td>&gt;45</td>
<td>&gt;72</td>
<td>High K; high removal; leaching</td>
</tr>
<tr>
<td>Zhejiang</td>
<td>&gt;200</td>
<td>26-45</td>
<td>&gt;72</td>
<td>High K; high removal; leaching</td>
</tr>
<tr>
<td>Hubei</td>
<td>151-199</td>
<td>&gt;45</td>
<td>&gt;72</td>
<td>High K; high removal; leaching</td>
</tr>
<tr>
<td>Xinjiang</td>
<td>&lt;37</td>
<td>&lt;9.9</td>
<td>&gt;72</td>
<td>Low K input</td>
</tr>
</tbody>
</table>


K balance of corn and soybean in various locations in China

Interim conclusions - China

- Low K inputs (e.g. Xinjiang and Beijing)
- High yet not sufficient K inputs, along with N & P surpluses
- High correlation between K negative balance and:
  - GOVA - per capita Gross Output Value of Agriculture (
  \( r=0.470^{**} \))
  - NIRH - per capita net income of rural households (\( r=0.511^{**} \)) \(^{(1)}\)


Nutrient removal!!!
(China, 2003)

Mean (2002-2004) area, production, yield and calculated removal rates of potassium in various crops in Egypt

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area ('000 ha)</th>
<th>Production ('000 mt)</th>
<th>Yield (t/ha)</th>
<th>K₂O Removal (mt) (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>626</td>
<td>6,143</td>
<td>9.8</td>
<td>168,000 (Straw removed)</td>
</tr>
<tr>
<td>Wheat</td>
<td>1,045</td>
<td>6,882</td>
<td>6.6</td>
<td>140,000 (Straw left in field)</td>
</tr>
<tr>
<td>Fruit</td>
<td>443</td>
<td>7,447</td>
<td>16.8</td>
<td>66,450</td>
</tr>
<tr>
<td>Vegetables &amp; melons</td>
<td>576</td>
<td>14,854</td>
<td>25.8</td>
<td>115,200</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>489,650</td>
</tr>
</tbody>
</table>

Application = ~50,000 tonnes K₂O/year

\(^{(1)}\) Source: K+S / Nutrient removal; accessed December 2005
Different K status in soils of Bulgaria 1989 to 2002

![Bar chart showing K status in 1989 and 2002](chart.png)

- **Low K status**
- **Medium K status**
- **High K status**

- **1989**
- **2002**

Frequency (%)

- Frequency of K status for the years 1989 and 2002 is shown.

- **Diary – positive**
- **Arable – negative**
- **-200,000 kg K$_2$O/year**

Adapted from Nikolova, 2005


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Balanced and timely nutrient application

- **SSP application (China, 2002)**
- **SEAP experiment in Indonesia (2005)**
Response of annual seed cotton yield to annual K applications on a vertisol

Highest yields & increase through the years with high K application


Nutrient balance after 21 years comparing organic and mineral fertilization treatments

How should organic systems refer to negative K balance?

Nitrogen in harvested crops and leaching: A challenge for organic agriculture


Are can organic systems improve application methods?

Effect on yields, quality and plant health
• Effect of balanced fertilization at field level: Simple and not even innovative
• Obtained with, and demonstrated to large groups of farmers
• Adopting various technologies
• From different locations where we (IPI) are operating

Simple fertilization practices:
Yield response to K application in various provinces with different cropping systems

Source: IPI-ISSAS 2003-2005 report
**China**

New technology: IPI fertigation project in apple (Yantai, Shandong, 2005)

- **Yield**
  - FFP
  - Fertigated

- **Weight of apple**
  - per group

- **Hardiness**
  - Potassium (kg K₂O/ha)


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**Belarus**

Effect of fertilizer treatments on wheat grain yield and protein content on Podzoluvisol loamy sand soil

- **Yield**
  - Control
  - 90-0-90
  - 90-30-90
  - 90-60-180

- **Protein yield**
  - Control
  - 90-0-90
  - 90-30-90
  - 90-60-180

K is used also to reduce radionuclides (e.g. ¹³⁷Cs & ⁹⁰Sr) in agri products

Source: IPI East Europe / Belarus, 2004
Potassium effect on yield increase in Peas, Maize and Sunflower

![Graph showing yield increase (%) vs. K application (kg K2O/ha) for Peas, Maize, and Sunflower. The x-axis represents K application (kg K2O/ha) ranging from 30 to 90, with increments of 30. The y-axis represents yield increase (%) ranging from 0 to 50, with increments of 10. The graph shows that yield increase is highest at 90 kg K2O/ha. The available K content is 100-270 kg/ha for Sandy loam. Source: M. Brar, KVK Bahowal, Directorate of Extension of PAU - IPI project, PAU, 2004. Results are average of five districts.]

Effect of K on infection of soybean from various insects and disease

![Graphs showing the effect of K on infection of soybean from various insects and disease. The x-axis represents K application (kg K2O/ha, as MOP) ranging from 0 to 75, with increments of 25. The y-axis represents % infected and % mortality. The graphs show that with increasing K application, the % infected and % mortality decrease. Source: IPI India 2005: IPI-ICAR project, annual report 2004.]

N=20 kg N/ha
P=60 kg P2O5/ha
Effect of real-time N management on sheath blight intensity and rice yield in the 2001 wet season at IRRI in the Philippines.

<table>
<thead>
<tr>
<th>N management</th>
<th>Disease intensity (%)</th>
<th>Grain yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed time and rate</td>
<td>33 (6)</td>
<td>4.0 (0.8)</td>
</tr>
<tr>
<td>SSNM, real time</td>
<td>21 (11)</td>
<td>4.5 (0.2)</td>
</tr>
</tbody>
</table>

A standard leaf color chart (LCC)


Benefits from balanced fertilization practices

<table>
<thead>
<tr>
<th>Site</th>
<th>Crop</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Best treatment  FFP Difference</td>
</tr>
<tr>
<td>Southern India(1)</td>
<td>Rice, SSNM ($)</td>
<td>520 352 168 (+47%)</td>
</tr>
<tr>
<td>Central Luzon, Philippines(1)</td>
<td>Rice, SSNM ($)</td>
<td>1,218 1,078 140 (+13%)</td>
</tr>
<tr>
<td>Indore, India(2)</td>
<td>Soybean, split K ($)</td>
<td>641 470 171 (+36%)</td>
</tr>
<tr>
<td>Pune, India(3)</td>
<td>Sugarcane, drip + K (WUE)</td>
<td>1.5 0.6 X2 WUE</td>
</tr>
</tbody>
</table>

Sources:
(1) IRRI 2005
(2) IPI India NRCS project
(3) IPI India VSI project
Balanced fertilization - Whom to address? Lessons from SSNM in India

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fertilizer K (kg/ha)</th>
<th>Old Delta</th>
<th>New Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current recommendation</td>
<td>42</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Use by surveyed farmers</td>
<td>21</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>SSNM recommendation</td>
<td>42</td>
<td>65</td>
<td></td>
</tr>
</tbody>
</table>

Need to convince:
1. Local extension / university
2. Farmers


Conclusions

1. Negative K balances are mainly caused by high CR removal and insufficient K fertilization
2. Common reasons for inadequate K use are scientific conviction and its penetration through to farmers
3. Long term inadequate K supply leads K depletion and thus to stagnation and reduction of yields: The rebound is not always immediate
4. Significant increased returns in terms of yields and quality may be achieved by:
   - Adoption of simple, clear fertilizer recommendations
   - And in employing advanced tech (fertigation)
5. The effect of K on disease intensity is of high importance and need to be understood better
6. Balanced fertilization generates higher profits for the farmers, not necessarily through reduced inputs
7. The role of education and extension in delivering the up-to-date knowledge on nutrient management is crucial, challenging and continuous.
Acknowledgments / Our team

Hillel Magen, Director of the International Potash Institute (IPI).

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Dr. Patricia Imas, IPI coordinator for India, is a senior agronomist at ICL Fertilizers (Israel).

Dr. Alexey Naumov is Professor at the Faculty of Geography at the Lomonosov Moscow State University, and is IPI coordinator for Latin America.

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