Corrections of Sulphur, Magnesium, Zinc and Boron Deficiencies in China

中国土壤硫、镁、锌和硼的缺乏与平衡施肥效果

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The Law of Minimum

“...It is by the minimum that crops are governed, be it lime, potash, nitrogen, phosphate, magnesium, or any other mineral constituent: it regulates and determines the amount or survival of the crops.”

Justus Von Liebig, 1863

植物必需营养元素:

Macronutrients: N, P, K, Mg, Ca, S
Micro: B, Fe, Cu, Mn, Cu, Ni, Zn, Mo

Macronutrients 大量营养元素
C, H, O from air and water
N, P, K, Ca, Mg, S from soil

Micronutrients 微量营养元素
Fe, B, Mn, Cu, Zn, Mo, Cl, Ni from soil
Intensification of agricultural production and large amount of using macronutrient fertilizer, like NPK, cause secondary and micronutrient deficiencies in China, which limits crop yields and potential efficiency of NPK application on crop production.

Zinc is the 2nd most deficient nutrient, only after P. (2nd National Soil Survey Results in 1980s)
Role of Sulphur in Agriculture

Increase crop yield
Increase crop product quality
Improve fertilizer efficiency and economic returns
Improve plant health
Improve soil conditions as soil amendments

43% of Soil, eq. 60 million Ha Are Sulphur Deficient

S deficient soils in Shaanxi, Inner Mongolia, Jilin and Yunnan Provinces are >50%
Anhui, Henan, Jiangxi, Fujian, Liaoning, Guangxi, Guangdong Provinces have 30-50% S deficient soils.

10% Increase of Crop Yield
By Sulphur Fertilizer: 24-30 Million Tons
Sulphur Fertilizer Demand: 1.6 Million Tons
Reduce N Loss (10%) 1.2 Million Tons N
Sulphur Deficient Soil and Area

- Light textured sandy soils
- Low organic matter and acid soils
- High rainfall, irrigated land
- Low SO\textsubscript{2} pollution
- High yield crops or crop rotations containing high S-demanding crops, like oil and sugar crops
- Limited history of using sulphur fertilizer like ammonium sulphate or SSP
- Low temperature

Crop Responses to Sulphur Fertilizer: TSI Projects in China

- Average Crop Yield Increase: 13%
- Average Economic Returns on Fertilizer Investment: 23 to 1 (Value : Cost Ratio)
**Sulphur Increased Crop Yield and Efficiency of N and P Fertilizers**

**Corn in Jiangsu, China**

- Yield Increase %
- VCR
- Kg grain/Kg N

<table>
<thead>
<tr>
<th></th>
<th>Yield Increase %</th>
<th>VCR</th>
<th>Kg grain/Kg N</th>
</tr>
</thead>
<tbody>
<tr>
<td>N200</td>
<td>7.9</td>
<td>3.8</td>
<td>6</td>
</tr>
<tr>
<td>N200S30</td>
<td>17.6</td>
<td>6.5</td>
<td>11.6</td>
</tr>
</tbody>
</table>

**Soybean in Anhui, China**

- Yield, t/ha
- Yield increase, %
- kg Grain/kg P
- kg P Uptake/ha

<table>
<thead>
<tr>
<th></th>
<th>Yield, t/ha</th>
<th>Yield increase, %</th>
<th>kg Grain/kg P</th>
<th>kg P Uptake/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0S0</td>
<td>2.327</td>
<td>11.7</td>
<td>7.1</td>
<td>3.096</td>
</tr>
<tr>
<td>P36S0</td>
<td>2.492</td>
<td>11.7</td>
<td>7.1</td>
<td>3.096</td>
</tr>
<tr>
<td>P36S36</td>
<td>3.096</td>
<td>33</td>
<td>13.6</td>
<td>5.5</td>
</tr>
</tbody>
</table>

**Soil Mg Deficiencies in China**

- Soil available Mg in selected Chinese soils (CAAS-IPNI Soil Testing Lab, 2011)
- Total of 56,880 soil samples
- Soil extractable Mg content ranging from 1.0 mg/L to 7034 mg/L, average 331 mg/L, among them:
  - 7% of soil samples very low, representing 8.54 million ha
  - 12% of soil samples low, representing 14.64 million ha
  - 32% of soil samples in medium level, 39.04 million ha
  - 36% of soil samples are high level
  - 13% of soil samples are very high.

19% of total arable soils in China are Mg deficient, and another 32% are potential Mg deficient, representing 24 million ha and 38 million ha, respectively.
Soil Mg Deficiencies in China

- Soils from most north-China provinces are high in available Mg.
- Soils from tropical or South China are very low or low in available Mg, like Hainan, Guangdong, Guangxi, Fujian and Jiangxi.
- Soils from sub-tropical or South-central China are low or medium level in available Mg, like Hunan, Hubei, Sichuan.
- 89% of Sandy soils are low to medium in available Mg.
- Low soil pH, high precipitation, high soil available K⁺ and NH₄⁺ increase plant Mg deficiency.

Crop Response to Mg Fertilizer in Selected Provinces in China

Summarized from Field Trial Results of IPNI Cooperative Network

<table>
<thead>
<tr>
<th>Crop</th>
<th>Province</th>
<th># of field trials*</th>
<th>Average Yield increase, % **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>Gaungxi</td>
<td>16/23</td>
<td>4.82</td>
</tr>
<tr>
<td>Corn</td>
<td>GX,SC,YN</td>
<td>5/9</td>
<td>8.34</td>
</tr>
<tr>
<td>Wheat</td>
<td>GX,SC,YN</td>
<td>3/5</td>
<td>3.54</td>
</tr>
<tr>
<td>Soybean</td>
<td>Guangxi,Fujian</td>
<td>3/3</td>
<td>3.54</td>
</tr>
<tr>
<td>Peanut</td>
<td>Guangxi</td>
<td>5/7</td>
<td>9.33</td>
</tr>
<tr>
<td>Potato</td>
<td>Sichuan</td>
<td>2/2</td>
<td>7.42</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>GX,GD,SC,YN</td>
<td>23/26</td>
<td>8.23</td>
</tr>
</tbody>
</table>

* # of field trials with yield increase / total field trials
** Average yield increase of field trials with positive yield response only.
**Crop Response to Mg Fertilizer in Selected Provinces in China**  
**Plantation Crops**  
Summarized from Field Trial Results of IPNI Cooperative Network

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<tr>
<th>Crop</th>
<th>Province</th>
<th># of field trials*</th>
<th>Average Yield increase, % **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus</td>
<td>Gaungxi, Guangdong</td>
<td>12/16</td>
<td>23.6</td>
</tr>
<tr>
<td>Banana</td>
<td>GD, GX, Hainan</td>
<td>11/20</td>
<td>5.35</td>
</tr>
<tr>
<td>Pineapple</td>
<td>Guangxi, Hainan</td>
<td>5/10</td>
<td>9.33</td>
</tr>
<tr>
<td>Lichi</td>
<td>Guangdong</td>
<td>6/10</td>
<td>21.5</td>
</tr>
<tr>
<td>Mango</td>
<td>Guangxi, Guangdong</td>
<td>6/7</td>
<td>6.84</td>
</tr>
<tr>
<td>Tea</td>
<td>Yunnan</td>
<td>11/12</td>
<td>16.5</td>
</tr>
<tr>
<td>Mulberry</td>
<td>Guangxi</td>
<td>5/9</td>
<td>18.8</td>
</tr>
</tbody>
</table>

* # of field trials with yield increase / total field trials  
** Average yield increase of field trials with positive yield response only.

**Effects of Zinc Deficiency in Plants**

- **Visible symptoms of physiological stress** (stunting, chlorosis, spike sterility etc.)
- **Poor quality of crop products** (e.g., Zn and protein contents; size & appearance of fruit)
- **Reduced dry matter production & yields of grain, fruits and roots.**
- **Increased susceptibility to infection by certain fungal diseases.**
- **Increased susceptibility to injury by high light intensity & temperature.**
Zinc Bioavailability to Plants

- high lime content
- high pH
- clay soils
- low organic matter
- low soil moisture
- low temperature
- high available P and Si
- high Fe and Al oxides

Limited Zn uptake

Enhanced Zn adsorption and precipitation; low Zn bioavailability

Zinc deficiency became more critical and widespread in Chinese Soils

Results from 28258 soil samples tested in CAAS during 1995-2004 and the results of 2nd Soil Survey, 1980-1985

- 80-85
- 95-04

% of Zn Deficient Soil

Source: Dr. Jin, 2006

Estimated Zinc Deficient Soil Area: 60 Million Ha
Zn Application Rate: 5 - 10 kg Zn/ha
Total Zinc Fertilizer Requirement: 300-600,000 tpy
Effect of Zn Fertilizer by Province and Crop in Field Trials

Zinc...essential for life

Yield Increase, %

Value Increased/Zn Cost

Effect of Zn Fertilizer by Crops

IZA-MOA Project 2011-2012
Application of ZnSO₄·H₂O 15kg/ha increase Zn content in corn grain, 2-6 ppm, or 15-40%; Application of ZnSO₄·H₂O 15kg/ha increase Zn content in corn grain, 4-7 ppm, or 28-50%;
Based on 2nd National Soil Survey Results in 1980s, China B deficient Arable soil area: 500 Million Mu (25% of the total), most distributed in Southeast, Northwest, North China and North Hui River.

Results from 28258 soil samples tested in CAAS during 1995-2004, Dr.Jin JY. 2006
### Effect of Boron Fertilizer on Crop Yield and Economic Returns in China

硼肥对作物的增产效果和经济效益

<table>
<thead>
<tr>
<th>Crops</th>
<th>Av. Yield (MT/ha)</th>
<th>Increase in Yield % (Average)</th>
<th>Av. Selling Price (RMB/MT)</th>
<th>Increase in Value (RMB/ha)</th>
<th>Doses Applied (MT/ha)</th>
<th>Cost of B added (RMB/ha)</th>
<th>Cost/ Benefit Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>6.3</td>
<td>5</td>
<td>2000</td>
<td>630</td>
<td>0.75</td>
<td>55</td>
<td>1:12</td>
</tr>
<tr>
<td>Wheat</td>
<td>6.75</td>
<td>5</td>
<td>2000</td>
<td>675</td>
<td>0.75</td>
<td>55</td>
<td>1:12</td>
</tr>
<tr>
<td>Maize</td>
<td>7.5</td>
<td>5</td>
<td>2000</td>
<td>750</td>
<td>0.75</td>
<td>55</td>
<td>1:14</td>
</tr>
<tr>
<td>Soybean</td>
<td>3</td>
<td>10</td>
<td>3500</td>
<td>1050</td>
<td>0.75</td>
<td>55</td>
<td>1:19</td>
</tr>
<tr>
<td>Cotton</td>
<td>3</td>
<td>10.3(526)*</td>
<td>10000</td>
<td>3090</td>
<td>0.75</td>
<td>55</td>
<td>1:56</td>
</tr>
<tr>
<td>Peanut</td>
<td>4.5</td>
<td>8.3(174)*</td>
<td>4000</td>
<td>1490</td>
<td>0.75</td>
<td>55</td>
<td>1:27</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>3</td>
<td>38(342)*</td>
<td>4000</td>
<td>4560</td>
<td>0.75</td>
<td>55</td>
<td>1:83</td>
</tr>
<tr>
<td>Apple</td>
<td>15</td>
<td>5</td>
<td>3000</td>
<td>2250</td>
<td>1.05</td>
<td>77</td>
<td>1:29</td>
</tr>
<tr>
<td>Citrus</td>
<td>11.25</td>
<td>20(290)*</td>
<td>2000</td>
<td>4500</td>
<td>0.75</td>
<td>55</td>
<td>1:82</td>
</tr>
<tr>
<td>Potato</td>
<td>30</td>
<td>7</td>
<td>1500</td>
<td>3150</td>
<td>0.75</td>
<td>55</td>
<td>1:58</td>
</tr>
<tr>
<td>Cabbage</td>
<td>45</td>
<td>5</td>
<td>1000</td>
<td>2250</td>
<td>0.75</td>
<td>55</td>
<td>1:41</td>
</tr>
</tbody>
</table>

Increases in Yield and Benefits of Boron Enriched (Fertilizer 15-15-15+0.2%B)

* ) Quantity of the field trails. Data source: Soil and Fertilizer Institute, Chinese Academy of Agricultural Sciences.

In trial work, B is applied to B deficient areas. “Normal” values represent an increase that is nearer to a yield increase that is sustainable each year in the mature markets.

*The price of Fertibor was calculated at 5500RMB/MT. If 0.2%B was added to Fertilizer 15-15-15 per MT, the cost will increase 73RMB per ton.