Sulphur in Agriculture: Raw Material and Valuable Nutrient

• Sulphur is not only a raw material to produce phosphate and ammonium fertilizers, it is an essential nutrient:

  Deficiencies are increasing with:
  – Reduction in traditional S-containing materials
  – Cleaner air programs
  – Intensified agriculture increasing crop demand

• Sulphur is gaining prominence as a major nutrient with N-P-K.
A Question:

• Nitrogen, phosphorus and potassium are established large-volume materials in agriculture. What nutrient remains holding the largest potential volume in consumption for the fertilizer industry?
Our Mission:

- TSI is the global advocate for sulphur, representing stakeholders producing, buying, selling, handling, transporting, or adding value to sulphur.
Members of The Sulphur Institute

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Sulphur Deficit: Limiting Crop Yield in Agriculture; Creating Market Potential for Fertilizer Industry

Water height = Achieved Yield

Climate, soil, water
Phosphate and Potash
Magnesium
Micro Nutrients
Nitrogen
Sulphur

Before 1980

Today
Sulphur is the fourth major nutrient, required in similar amounts as P, about 20.6 million tons S in 2010.

10 million tons S applied worldwide

An additional market potential for 10.6 million tons S exists today, mainly in Asia and the Americas.
Asia has the largest regional deficit around the world with India and China in the lead.
Due to emission controls in the last ten years, sulphur deposition in West Europe has dropped below the requirements of many crops.

Coupled with the earlier change to low sulphur fertilizers, heavy leaching loss and intensive crop production resulted in decreasing soil sulphur fertility status.

For example, in the UK about 50% of the land area has high or medium risk of sulphur deficiency for winter wheat and rape.

Crop responses to sulphur fertilizer are now common in most countries in West Europe.
Sulphur fertilizer increased cereal grains yield ranging from 10% to 30% and from 20% to 40% on oilseed crops. Crop quality and economic returns of fertilizer are also improved.

New Sulphur Fertilizer Recommendation for optimal yield:

- Oil crops: 20 to 40 lbs S/acre
- Legume Crops: 20 to 30 lbs/acre
- Cereals: 20 to 35 lbs/acre
Ammonium Sulphate consumption: about 750,000 tons S/year

UK recommendation change increased S fertilizer rate: 100,000 tons S/year

Sugar beet campaign: 115,000 tons S/year
The European governments and fertilizer industry recognize the need…

- 16 countries
- 25 products
- 500,000 tons S consumed annually
- France, Germany and Spain represent the largest diversity of companies and products involved, including micronized, sulphur bentonite, liquids, sulphate carriers and compounds with S
- Increase of oilseed rape production for biofuel increases S fertilizer demand
Sulphur Fertilizer Effect on Crop Quality

- Sulphur fertilization increased oil content of rapeseed oil content in the UK by 3.02%

IACR, Rothamsted Research Group, UK
Effects of S on rapeseed oil content

![Graph showing oil content vs. S applied (lbs/acre)](image)
The U.S. Clean Air Act is impacting crop sulphur requirements. Today, significant areas of the southern and northwestern United States have sulphur recommendations:

- Mid-Atlantic: 20 to 40 lbs/acre
- Southern states: 10 to 20 lbs/acre
- Forages: 25 to 50 lbs/acre
• In Canada, canola frequently has yield increases ranging from 10% to 40% and from 10% to 30% on other crops, with some variance depending on province.

• Common sulphur recommendations include:
  – Non-Irrigated Oil and Legume Crops  40 to 50 lbs/acre
  – Irrigated Legume Oil and Crops    20 to 60 lbs/acre
  – Cereals                             15 to 30 lbs/acre

North American Situation
• Current consumption about 1.6 million tons S annually.
• New sulphate and elemental S fertilizers are coming on the market.
• Agricultural production recovery driven by strong demand for food and biofuel: soybean, corn and sugarcane

• S fertilizer requirements increase to 2.6 million tons S, second biggest market only to Asia

• S fertilizer consumption increases to 1.8 million tons

• Still large deficit

• More sulphate and ES fertilizers come to market also ammonium thiosulphate
Widespread S deficiencies resulted in the development of a wide range of crop and pasture S-containing fertilizers.

Fertilizer manufacturers have introduced new products to meet the increasing demand of S containing NP or NPK compound fertilizers or ES enriched N, P, and NPK fertilizers based on specific crop and soil needs.
41% and 36% of Soil Samples (26810) in 11 States in India are Sulphur Deficient or Potentially Deficient

<table>
<thead>
<tr>
<th>States Name</th>
<th>Samples</th>
<th>Sulphur Deficient &lt;10 ppm</th>
<th>Potentially Deficient 10 to 20 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andhra Pradesh</td>
<td>1650</td>
<td>54%</td>
<td>36%</td>
</tr>
<tr>
<td>Uttar Pradesh</td>
<td>6090</td>
<td>50%</td>
<td>38%</td>
</tr>
<tr>
<td>Maharashtra</td>
<td>845</td>
<td>46%</td>
<td>26%</td>
</tr>
<tr>
<td>Bihar</td>
<td>1409</td>
<td>43%</td>
<td>30%</td>
</tr>
<tr>
<td>West Bengal</td>
<td>4500</td>
<td>42%</td>
<td>34%</td>
</tr>
<tr>
<td>Karnataka</td>
<td>1879</td>
<td>39%</td>
<td>32%</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>2005</td>
<td>35%</td>
<td>51%</td>
</tr>
</tbody>
</table>
Indicators

- At least 168 million acres, or 40% of India’s arable land suffers from varying degrees of S deficiency
- Crop responses to S fertilizers were documented in the major agricultural states
• Network of 22 institutes in 11 states:
  – Andhra Pradesh (A.P.)
  – Bihar
  – Chhattisgarh
  – Gujarat
  – Karnataka
  – Madhya Pradesh (M.P)
  – Maharashtra
  – Orissa
  – Tamil Nadu
  – Uttar Pradesh (U.P.)
  – West Bengal

- A total of 114 field trials were completed in 46 sites on direct sulphur fertilizer effect in Kharif season.
- Yield increases up to 38% with greatest responses in oil crops followed by field crops.
- Return on fertilizer investment (VCR) ranged from 9 for potato to 42 for cabbage (VCR of 2 to 2.5 usually results in a fertilizer recommendation).

- 86 field trials were completed on residual sulphur effect in Rabi season
- Yield increases up to 84% with greatest responses in oil crops again followed by field crops
Sulphur Fertilization Increased NPK Fertilizer Nutrient Recovery in Rice-Groundnut Cropping System

(Kasarda, Orissa, 2001)
Formal Recognition of Sulphur – A Big Step for India

• TSI’s foundation work and recent TSI-FAI-IFA cooperative project successes have brought sulphur recognition, convincing the GOI Central Fertiliser Committee that inclusion of sulphur is warranted in the FCO. As of June 2003, the industry is now permitted to market the sulphur in listed fertilizers and print sulphur content on fertilizer bag.
Achievements and Benefits from the Project

• Base of information established
• Scientific community supports sulphur fertilization
• Government recognition of sulphur importance by writing it into FCO
• Industry awareness and activity increasing
India: Great Potential, Great Progress, and Great Task

• Limited sulphur fertilizer production in India – 650,000 tons per year...doesn’t touch potential

• Current deficit: 1.6 million tons sulphur deficit growing to 2.2 million tons by 2015
Achievements and Benefits from the TSI-FAI-IFA Project

- Base of information established: Severe S deficiency with 46% of S deficient and 30% of potential deficient soils,
- S fertilizer increased crop yield by average 29%, ranged from 10% to 60% in over 200 field trials
- Government recognition of sulphur importance by including it into FCO and fertilizer subsidy system
- Industry awareness and activity increasing
The Chinese Situation

- Sulphur deficient area: 30% of arable soil, eq. about 95 million acres
- Sulphur deficit in 2010: 2.0 million tons S projected to increase to 2.6 million tons in 2015
Crop Responses to Sulphur Fertilizer: TSI Projects in China

Average Economic Returns on Fertilizer Investment: 23 to 1 (Value : Cost Ratio)

Average Crop Yield Increase: 13%
New Sulphur Fertilizers Market Emerge in China

- Single Superphosphate (SSP) adds about 3 million tons of S annually, representing most S applied to soils.

- S-based NPK output has grown exceeding 10 Mt of product.

- New ES based compound fertilizer productions are coming to the market, including tons Sulphur-Urea (15%S), and tons SCU (15 to 20%S).

- ...and here comes the ammonium sulphate.
World Plant Nutrient Sulphur Deficit and New Market Potential for Sulphur Fertilizer

Current Application:
10 Million Tons S

Estimated World Annual Plant Nutrient Sulphur Deficit In 2015:
12.5 Million Tons S
Traditional Sulphur Fertilizers Take Major Market Share (2010)

But, new products are emerging and growing in volumes!
Fertilizers Containing Sulphate

- **Traditional:**
  - Single Superphosphate (0-16-0 12S)
  - Ammonium Sulphate (21-0-0 24S)
  - Potassium Sulphate (0-0-50 18S)

- **Emerging:**
  - Ammonium Phosphate-Sulphate (20-20-0 15S)
  - Potassium Magnesium Sulphate (0-0-27 22S)
  - Various Micronutrient Sulphate Salts
  - Ammonium Nitrate-Sulphate (26-0-0 14S)
  - Sulphate-NPK compound fertilizers (15-16-15 11S)
  - Urea-Ammonium Sulphate (40-0-0 9S)
Ammonium Sulphate
(21-0-0 24S)

• World Output in 2010: about 18 Mt, eq. to more than 4 Mt S, most is by-products from caprolactam production in synthetic fiber industry and coke oven gas from steel industry

• Most (3.3 Mt S) directly used in Asia, America, and West Europe, but increasing use in blending or manufacture of NP/NPK fertilizers

• Market opportunities in Central Europe, FSU, America, and Asia
Single Superphosphate
(0 - 12 to 22-0 10 to 14S)

• World output exceeds 5 Mt S, mostly in China, Brazil, India, Australia and New Zealand. The SSP market is relatively stable with tendency to decline in recent years, except Brazil.

• Reduction of future market of SSP will require more S addition from new sources
• World output now exceeds 4 Mt, eq. 0.8 Mt S, mostly in Western Europe, China, and USA.

• Both demand and production will grow, mostly in China.
Ammonium Nitrate-Sulphate
(26-0-0 14S)

- Made by granulating AS with AN or neutralizing H₂SO₄ with NH₃ in AN solution.
- Less hygroscopic, with a satisfactory N/S ratio, and a combination of ammonium and nitrate forms of N; and sulphate form of S.
- Market is growing in Europe and North America.
Sulphate Containing Compound Fertilizers can be produced by the mixed acid route (nitric/phosphoric, and sulphuric/phosphoric acid) with flexible ratios of N:P:S.

Major production: Europe and N. America at about 0.2 million t/a S.

S-based NPK compound fertilizer production in China has grown significantly in recent years.
Elemental S: Emerging Fertilizer Product and Market

- Elemental Sulphur
- Micronized Granular Elemental Sulphur
- Elemental Sulphur Enhanced/Enriched Nitrogen/Phosphate Fertilizers
- Sulphur Coated Fertilizers
Improving Fertilizer Efficiency

- Elemental sulphur (S\textsuperscript{0}) is a slow release fertilizer because it is water insoluble.
- Must be oxidized by microbes to SO\textsubscript{4}\textsuperscript{2-} to be available for plant uptake.
- Ideal where SO\textsubscript{4}\textsuperscript{2-} leaching is serious.
- Most concentrated S-fertilizer with lower transportation, handling, and storage costs.
- Beneficial reactions in soil improve major nutrients efficiency to plants.
Granular Dispersable Elemental Sulphur (90 to 99% S)

- Dispersible in soil and water, releasing finely micronized S particles (40 to 150 μm), effectively converted into sulphate by soil microorganisms in the early growing season.
- Season long S supply with minimized risk of leaching loss.
- Increases in production and marketing in America (N+L), Europe, Oceania, Asia, and Africa.
Elemental Sulphur Enriched Nitrogen/Phosphate Fertilizers

- Liquid S is added into NP or NPK fertilizer product with various technologies to provide 5-20% S.
- New ES enriched fertilizers: Sulphate and ES enriched MAP; ES enhanced DAP; ES-enriched SSP.
- Increases in production and marketing in N. America, Europe, Oceania and Asia.
Elemental Sulphur Enriched Nitrogen/Phosphate Fertilizers

- Sulphur-Coated Urea (SCU) and compound fertilizers: Slow or controlled release S and other nutrients
- Sulphur Coated TSP; DAP/MAP
- New products made by coating urea with micronized S using binders
- Huge market potential: >1 million tons S
Fertilizer Containing Other Forms of Sulphur (in Solution)

- Ammonium Thiosulphate (12-0-0 26S)
- Ammonium Polysulphide (20-0-0 40S)
- Potassium Polysulphide (0-0-22 22S)
- Potassium Thiosulphate (0-0-25 17S)

Thiosulphate fertilizers have gained prominence in North America and is growing in use in Europe and Latin America.
Current production **will not** meet increasing demand.

Sulphur fertilizers provide **potential market of 10 million tons of sulphur consumption annually.**

Fertilizer producers need to address this new market potential:
- **Product choice/Promotion of new sulphur fertilizer production and use, including elemental sulphur based new fertilizers.**
TSI’s Sulphur World Symposium 2015

April 20 – 22, 2015
Barcelona, Spain

For more information on TSI programs please visit:

www.SulphurInstitute.org/symposium15