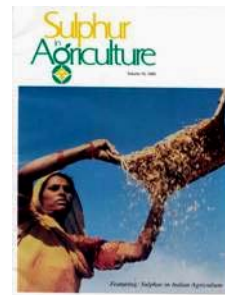


Correcting Sulphur Deficiency for High Yield: Global Perspective

Ming X. Fan and D.L. Messick
The Sulphur Institute
Washington, DC, USA

Presented at the IFA Crossroads Symposium
December 17 -19, 2007 Bali, Indonesia



TSI Members:



Abu Dhabi National Oil Company	Kuwait Petroleum Corporation
AgipKCO	Martin Operating Partnership, L.P.
BCT Chemtrade Corporation	Mitsubishi Corporation
BHP Billiton Marketing, Inc.	Mitsui & Co. (U.S.A.), Inc.
BP Canada Energy Company	Mosaic Fertilizer LLC
BP Products North America, Inc.	OCP Group
California Sulphur Company	Polish Steamship Company
Canadian National	PRISM Sulphur Corporation
Canadian Pacific Railway	Qatar Petroleum
ConocoPhillips Company	Savage Services Corporation
Enersul Inc.	Shell Canada Energy
ExxonMobil Oil Corporation	Shell Oil Products Europe
H.J. Baker & Bro., Inc.	Shell Oil Products US
ICEC	Sultran Ltd.
Interacid Trading S.A.	Tessenderlo Kerley, Inc.
JSC Oteko	Valero Marketing and Supply Company
Jupiter Sulphur L.L.C.	Verschure Shipping B.V.
Koch Sulfur Products Company LLC	Zwaans van der Heuvel Tankvaart BV



Our Mission:

TSI is committed to being the global advocate for sulphur, representing all stakeholders actively engaged in producing, buying, selling, handling, transporting, or adding value to sulphur.



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



Sulphur in Agriculture: Raw Material to Valuable Nutrient

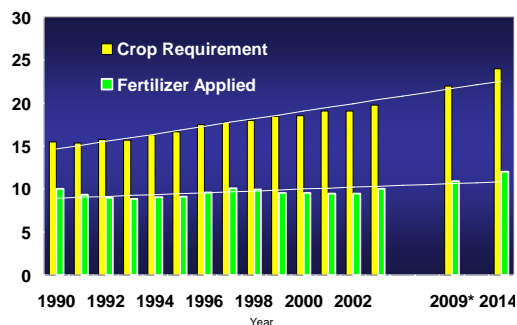
- Once sulphur was only thought of as a raw material to produce phosphate and ammonium fertilizers...this has changed:
 - Reduction in traditional S-containing materials AS and SSP
 - Cleaner air programs reduced S levels in the atmosphere
 - Intensified agriculture increased crop demand and depleted natural reserves
 - Increasing sulphur deficiencies limiting reducing crop production and quality
- S is gaining prominence as a major nutrient with Nitrogen(N), Phosphorus(P) and Potassium(K)



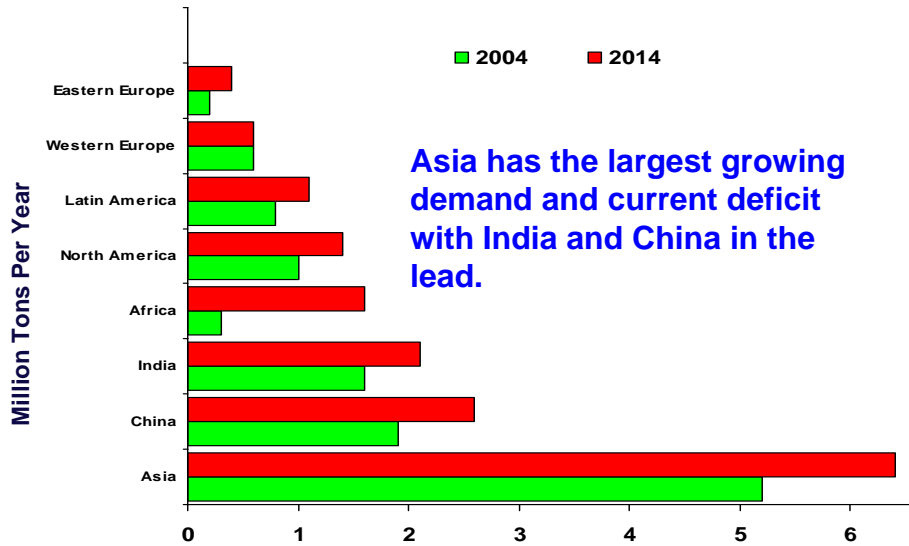
Sulphur Deficit: Global

- Current Application: 10 million tons annually
- Current Deficit (Market Potential):9.6 million tons sulphur annually
- Primary Markets: Asia and the Americas.
- Market Potential 2014: 11.9 million tons sulphur annually

Plant Nutrient Sulphur Requirement and Deficit (Mt)



Sulphur Deficit: Regions

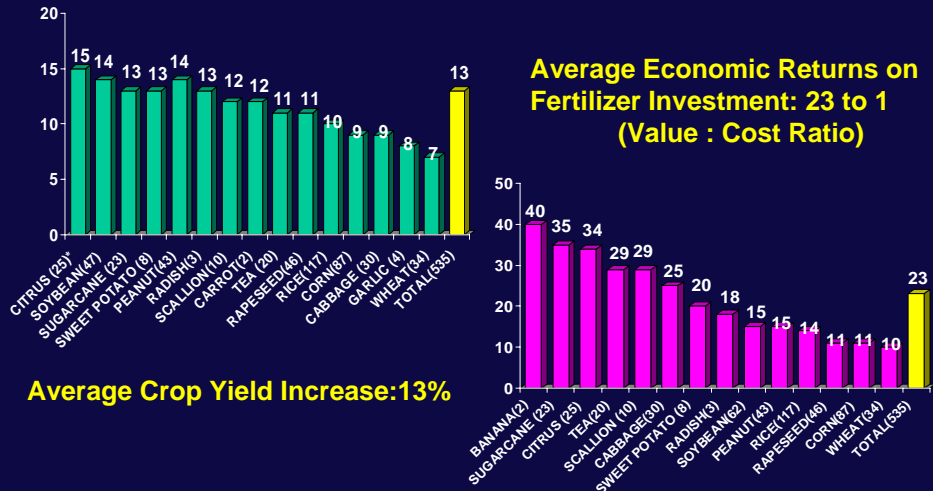


The Chinese Situation

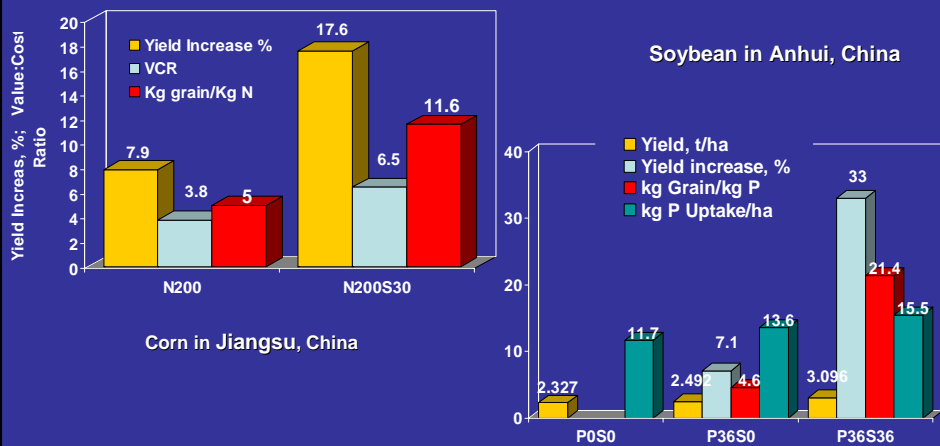
- Sulphur deficient area: 30% of arable soil, eq. about 40 million ha
- Sulphur deficit in 2004: 1.8 million tons S projected to increase to 2.6 million tons in 2013



Crop Responses to Sulphur Fertilizer: TSI Projects in China



Comparison of S Effect with N and P on Crop Yields



S fertilizer increased rapeseed and sugarcane production by 15 to 20% in Yunnan Province



Chinese Crop Recommendation Rates Range from 20 to 80 kg S/ha

Crops	kg S/ha	Crops	kg S/ha
Cereals	20-40	Tea	20-50
Soybean	30-60	Vegetables	30-60
Oil Crops	30-60	Fodders	30-60
Tubers	30-60	Sugarcane	40-80

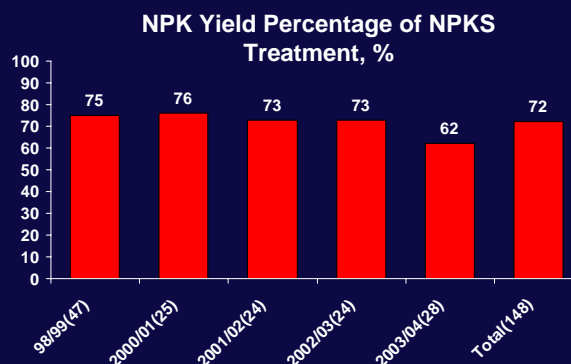
India: Much to be Done

- Limited sulphur fertilizer production in India
 - S-containing fertilizer production in 2005: 600,000 tons S
 - The total crop requirement for S was 2.2 million tons, which resulted in about 1.6 million tons sulphur deficit



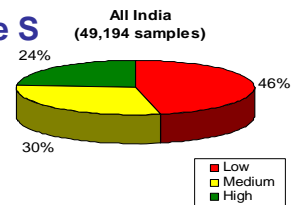
Challenges for Balanced Fertilization: S Fertilizer is Essential for High Yield

- Without S:
 - Low Yield
 - Low Fertilizer Efficiency
 - Low Crop Quality
 - Low Economic Return

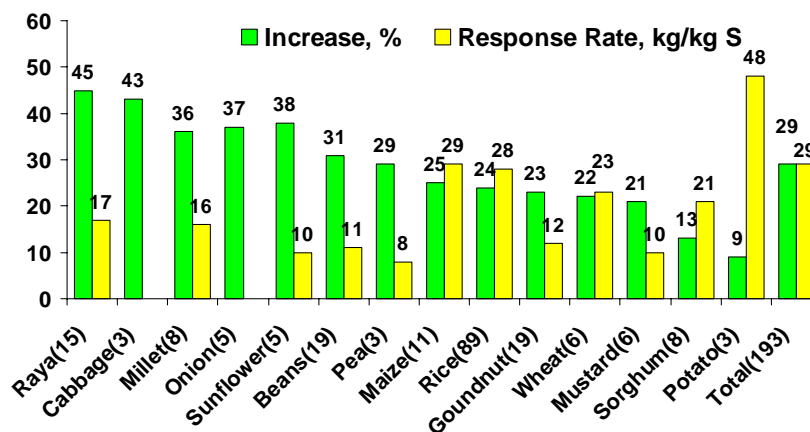


Achievements and Benefits: TSI-FAI-IFA Project

- Base of information established: Severe S deficiency with 46% of S deficient and 30% of potential deficient soils,
- Scientific community supports sulphur fertilization
- Government recognition of sulphur importance by writing it into FCO
- Industry awareness and activity increasing



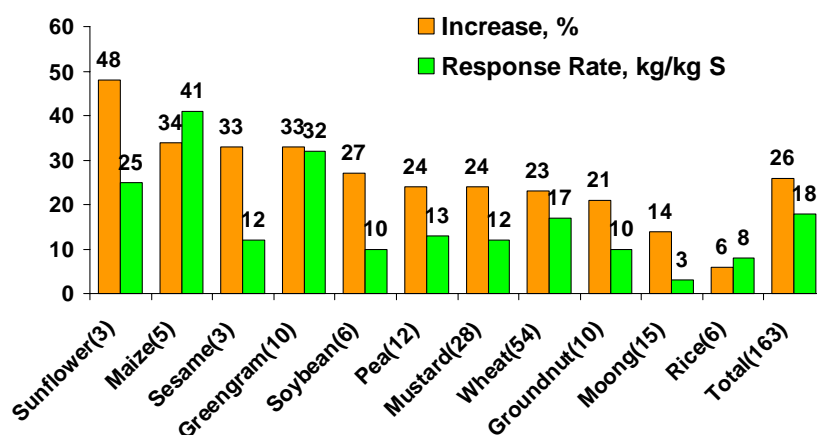
Crop Responses to Sulphur Fertilizer TSI-FAI-IFA Projects (1998 to 2005)



Response rate for Cabbage and Onion is 476 and 159 kg/kg S.

Sulphur Fertilizer Residual Effect on Crop Yield and Response Rate

TSI-FAI-IFA Projects (1998 -2005, Rabl)



TSI THE SULPHUR INSTITUTE

Economic Return to Sulphur Fertilizer (VCR)

TSI-FAI-IFA Projects

(2003/2004 to 2005/2006)

Cropping System	Trials	VCR	VCR*
		1 st crop	Cropping system
Raya – Moong	15	13	17
Millet - Wheat	3	14	40
Groundnut - Wheat	3	45	76
Bean - Wheat	3	30	57
Bean – Mustard	9	7	24
Millet - Mustard	3	17	68
Garlic - Maize	3	28	39
Onion - Maize	3	38	59

VCR: Value : Cost Ratio, calculated based on fertilizer and product market price by Indian collaborators.

TSI THE SULPHUR INSTITUTE

**Economic Return to Sulphur Fertilizer (VCR)
TSI-FAI-IFA Projects
(2003/2004 to 2005/2006)**

Cropping System	Trials	VCR 1 st crop	VCR Cropping system
Rice – Rice	6	35	58
Rice - Bean	9	31	42
Rice - Sesame	6	21	25
Wheat - Soybean	3	34	46
Wheat – Rice	6	30	34
Total	72	26	45

**Yield Increase Potential in Indian
Crop Production by Sulphur Fertilizer**

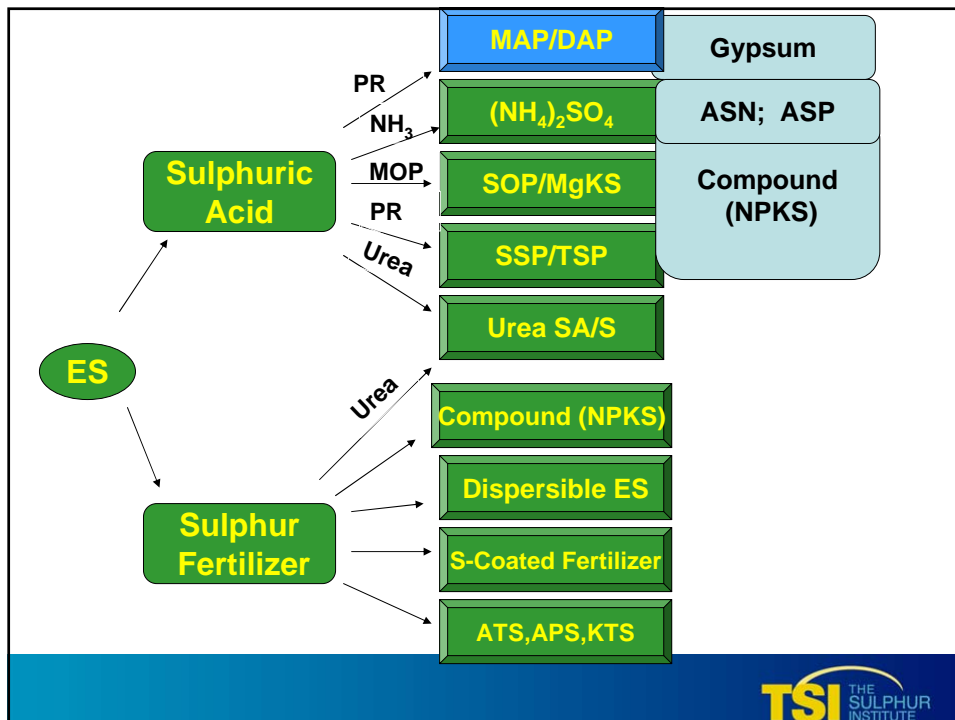
Estimated S Deficient Soil Area: 60 Million Ha

**10% Increase of Crop Yield
By Sulphur Fertilizer: 24-30 Million
Tons**

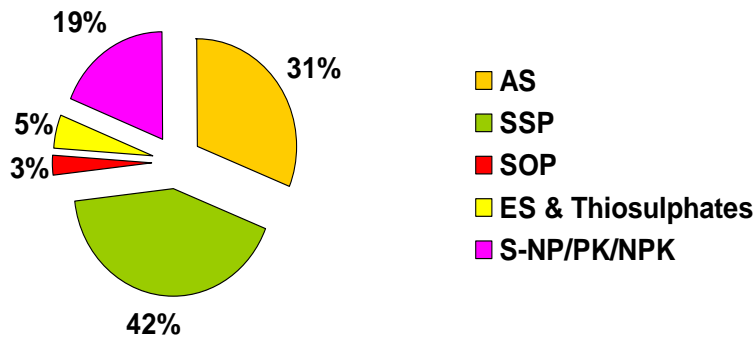
**Sulphur Fertilizer Demand: 1.6 Million
Tons**

Time for Action

- S deficiencies are limiting crop yield and fertilizer efficiencies
- S fertilizer products must be produced and applied as an essential fertilizer nutrient
- Governments and regional authorities need to develop favorable policies for promotion of S fertilizer manufacturing and application
- Education, training and promotion will need to be implemented by all sectors
- Include sulphur in fertilizer recommendation and balanced fertilization programs
- Put S in its rightful place along N, P, and K



Traditional Sulphur Fertilizers Take Major Market Share (2005)



But, new products are emerging and growing in volumes!

Ammonium Phosphate-Sulphate (20/16-20-0-15/8S)

- Compound Fertilizers containing N, P, and S with flexible ratios of N:P:S
- Made by reacting a mixture of H_3PO_4 and H_2SO_4 with NH_3 , or introducing $(NH_4)_2SO_4$ solutions and H_2SO_4 into H_3PO_4 plant reaction circuit
- Good physical and chemical properties for both direct application and formulating bulk blends for various soils and crops

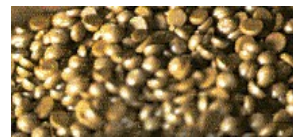
NPKs with Sulphur in China

- Chinese government listed S-based NPK compound fertilizer as development priority in 2000, and the production grows at an annual rate of 20%
- Uses phosphate rock, sulphuric acid, ammonia, urea and potassium chloride combining technologies
- Major product is: 14.5-16-14.5-11S
- Production capacity: 9.0 million tons in 2006, providing 900,000 tons S



New Products Improve Fertilizer Efficiency

- Elemental sulphur (S^0) is a slow release fertilizer because it is water insoluble.
- Ideal where sulphate leaching is problematic
- Concentrated sulphur fertilizer with lower transportation, handling, and storage costs
- Increase N, P and micronutrient availabilities in high pH soils



Granular Dispersable Elemental Sulphur (90 to 99% S)

- **Increases in production and marketing in Americas, Europe, Oceania, Asia, and Africa.**
- **Elemental Sulphur fertilizer consumption: 300,000 tons, and 500,000 tons by 2010.**

Elemental Sulphur Enriched Nitrogen/Phosphate Fertilizers

- **New sulphur enriched fertilizers: Sulphate and sulphur enriched MAP; sulphur enhanced DAP; sulphur-enriched SSP.**
- **Increases in production and marketing in N. America, Europe, Oceania and Asia with annual S consumption of 50,000 tons S.**

Elemental Sulphur Coated Nitrogen/Phosphate Fertilizers

- Sulphur-Coated Urea (SCU): Slow or controlled release N and S fertilizer (36-0-0-15S);
- Sulphur Coated TSP; DAP/MAP;
- Good for direct use to meet crop N, P and S needs in a long growing season, not available to correct deficiencies during the early season
- New products made by coating urea with micronized S using binders for use on rice, sugarcane, grass, fruits

Ammonium Thiosulphate (12-0-0-26S)

- A clear liquid fertilizer containing $\text{NH}_4\text{-N}$ and both $\text{SO}_4\text{-S}$ and $\text{S}^0\text{-S}$, produced by reacting of SO_2 with aqueous ammonia to form $(\text{NH}_4)_2\text{SO}_3$, and then further reacts with S^0 to form ATS, under low oxygen condition.
- Widely used in the fluid fertilizer industry to make a wide range of N-P-K-S fertilizers; However, it is not compatible with acidic solutions, and not with anhydrous ammonia.
- Used directly by drip, sprinkler or flood irrigation
- It decomposes in the soil to form equal amount of sulphate and ES, suitable to the S uptake patterns for most crops.

Sulphur Fertilizers: New Ground for Fertilizer Industry

- Traditional S fertilizer production will not meet the increasing demand for sulphur in agriculture.
- Sulphur fertilizers and their use in agriculture provides potential market of 9.6 million tons of sulphur consumption annually, benefiting the fertilizer AND sulphur industry.
- 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.

