

Correcting Sulphur Deficiency for High Yield: Global Perspective

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Washington, DC, USA

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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.



Sulphur: Vital for Life

- Essential for protein in humans, animals and plants
- Valuable raw material for making wide variety of products in everyday life
- Natural element in air, water, and land
- Valuable plant nutrient



Role of Sulphur in Agriculture



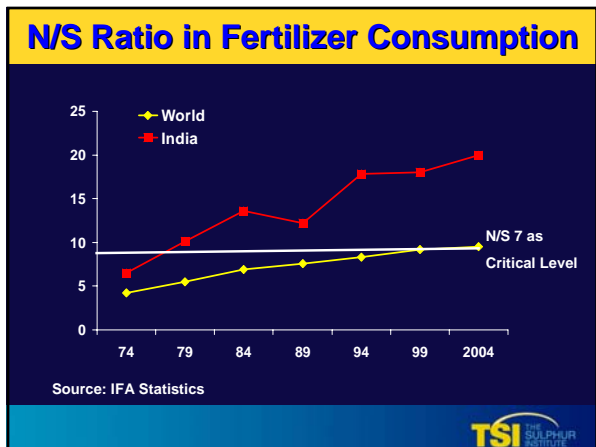
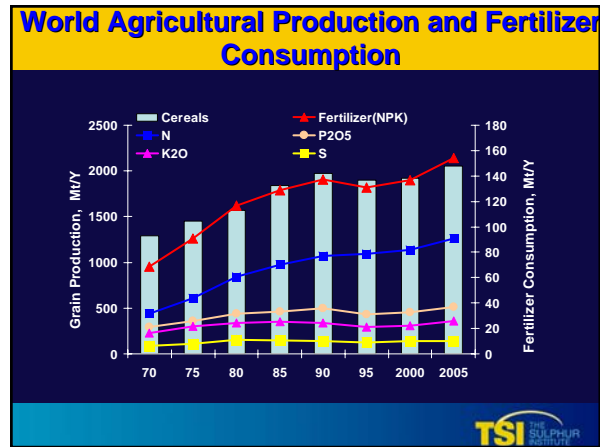
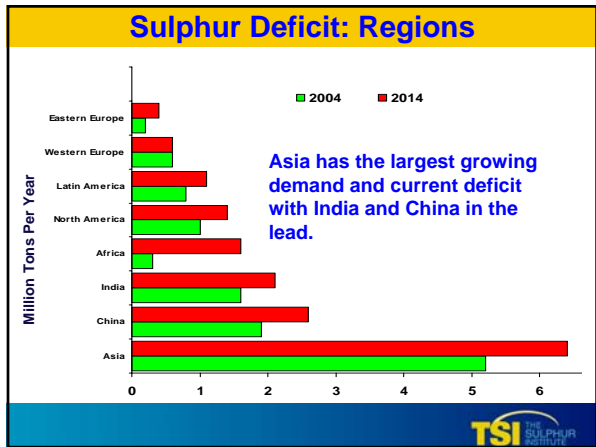
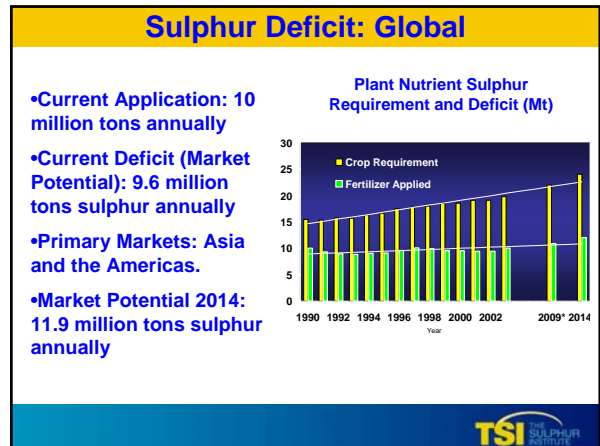
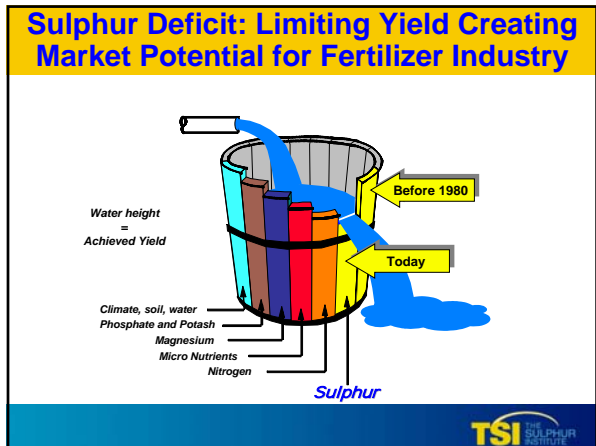
- Increase crop yield
- Increase crop product quality
- Improve fertilizer efficiency and economic returns
- Improve plant health
- Improve soil conditions as soil amendments



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)



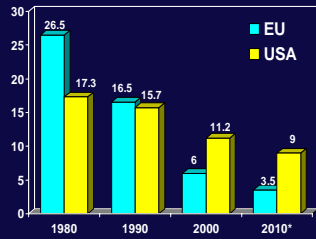


Requirements for Sulphur and Other Nutrients in Crop Production

Crop	Yield (t/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)
Rice	7(grain)	150	25	150	20
Wheat	4(grain)	168	34	110	25
Corn	9(grain)	360	52	230	50
Soybean	3(seed)	200	25	110	15
Peanut	3.5(pod)	250	22	110	28
Tobacco	3(DW)	105	12	180	24
Cabbage	45(FW)	140	16	120	42
Sugarcane	88(cane)	180	30	270	27

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Emission of Sulphur Dioxide in EU and USA from 1980 to 2010 (Million Tons)



This means more S fertilizer demand in agriculture for EU and the US.

* Projected.

Derived from The Swedish NGO Secretariat on Acid Rain Webpage



The European Situation

- Due to emission controls in the last ten years, sulphur deposition in West Europe have 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 U.K. about 50% of the land area have 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.



The European Situation

- 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.
- Field trial results indicate sulphur rates for optimum yield are:
 - Oil crops 0 to 45 kg S/ha
 - Legume Crops 25 to 35 kg S/ha
 - Cereals 20 to 40 kg S/ha



Value:Cost Ratios Provide Economic Incentive

	Value of Extra Yield £/ha	Economic Return VCR
Oil Seed Rape	56-67	15-18
Winter Wheat	25-71	6-18



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
- French production includes the most diverse product line with micronized, sulphur bentonite, liquids, sulphate carriers and compounds with sulphur



The North American Situation



- 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 22 to 44 kg S/ha
 - Southern states 11 to 22 kg S/ha
 - Forages 28 to 56 kg S/ha



North American Situation



- In Canada, cereal grains frequently have 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 Legume Crops 45 to 56 kg/ha
 - Irrigated Legume Crops 22 to 64 kg/ha
 - Cereals 17 to 34 kg/ha



Australia and New Zealand

Ammonium sulphate and SSP have been extensively used as N and P fertilizers, which provided large amount of S to soils in early 1960s.



Intensification of cropping system and increased use of high analysis S-free fertilizers has aggravated S deficiency since 1970s.



New Commercial S Fertilizers

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.



The Chinese Situation

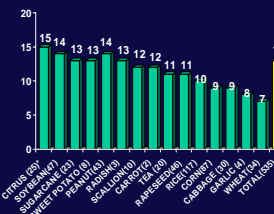
Sulphur deficient area: 30% of arable soil, eq. about 40 million ha



Sulphur deficit in 2004: 1.8 million tons S projected to increase to 2.6 million tons in 2013

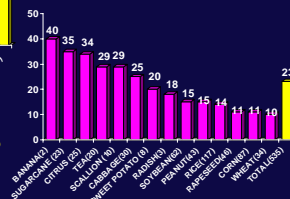


Crop Responses to Sulphur Fertilizer: TSI Projects in China



Average Crop Yield Increase: 13%

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



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



New Sulphur Fertilizers Market Emerge in China

- Single Superphosphate (SSP, 10%-14% S) adds about 3.5 million tons of S annually, representing 78% of total S applied to soils.
- S-based NPK output in 2005: 8.0 Mt, eq. 0.8 Mt S.
- New ES based compound fertilizer productions are coming to the market, to include 50,000 tons Sulphur-Urea (15%S), and 200,000 tons SCU (15 to 20%S).



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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



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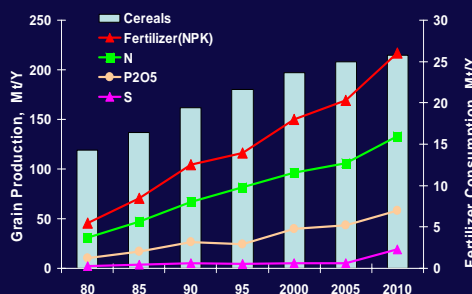
Sulphur Fertilizer Consumption in China and India

	China	India
S Fertilizer, Mt S	3.2	0.6
SSP, Mt S	2.8	0.3
S Fertilizer, kg S/ha	26.1	4.3
N:S	7.5	16.3
P ₂ O ₅ :S	2.9	5.9

From the view of balanced fertilization, sulphur deficiency in Indian agriculture is more severe than China. India needs to increase sulphur fertilizer supply to meet the increasing demand in balanced fertilization.

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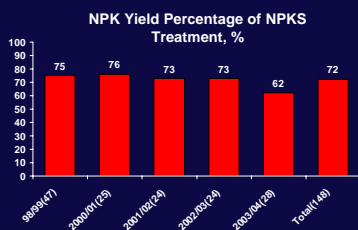
Indian Agricultural Production with Fertilizer Consumption



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

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



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TSI-FAI-IFA project


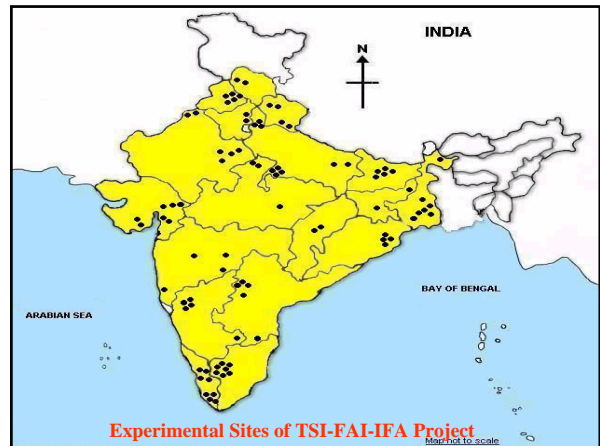
Objectives

- To delineate the areas of sulphur deficiency in India
- To evaluate the response of important crops & cropping systems to sulphur application under on-farm conditions
- To promote use of sulphur in Indian agriculture

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TSI-FAI-IFA Project - Highlights

- Project launched in May 1997 and continued up to 2006 in 3 phases
 - Phase I - 1997-98 to 1998-99
 - Phase II - 2000-01 to 2002-03
 - Phase III - 2003-04 to 2005-06
- Covered 18 states (5- NZ, 5- WZ, 4- SZ, 4-EZ)
- No. Experimental Sites: 75
- No. of collaborative institutes: 26
 - SAUS- 19, ICAR Inst.-3, Fert. Cos.- 3, State -1
- No. of Soil Samples analysed: over 49,000


Achievements and Benefits from the TSI-FAI-IFA Project To Date



- Base of information established: Severe S deficiency with 46% of S deficient and 30% of potential deficient soils,

All India (49,194 samples)

24% 46% 30%

Low Medium High


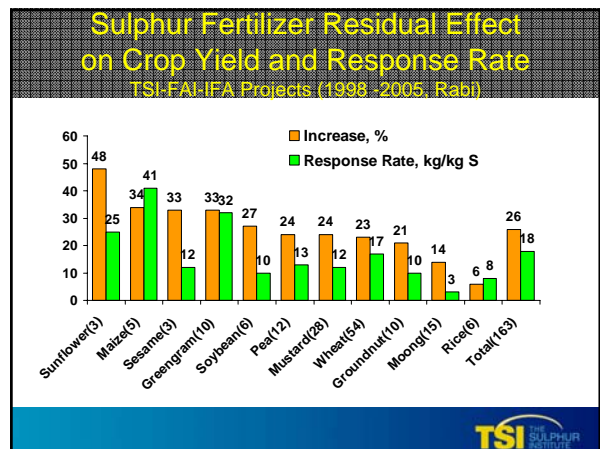
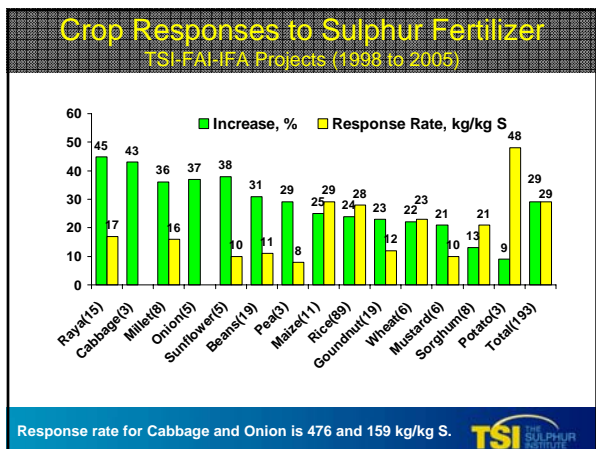

- Scientific community supports sulphur fertilization
- Government recognition of sulphur importance by writing it into FCO
- Industry awareness and activity increasing

Major Nutrient Deficiency in India

Nutrient	Samples	Deficient	Potentially Deficient
		(Low)	(Medium)
N	3650000	63%	26%
P	3650000	42%	38%
K	3650000	13%	37%
S	49194	46%	30%

Source: Motsara, 2002 and Tewatia, 2006.

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



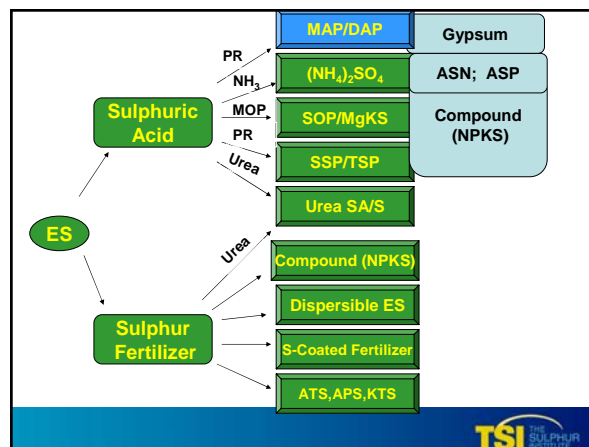
Challenges

- Progress made, but more to do
- Still lack of awareness and knowledge about S at various levels
- Inadequate efforts and funding for promotion, extension and publicity by all sectors
- Outcome: Insufficient S fertilizer supply, inefficient use of existing S resources, and unbalanced fertility situation.

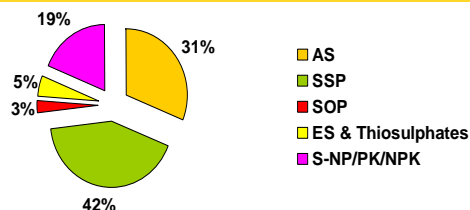


Time for Action

- Sulphur fertilizer products must be produced and available.
- Governments and regional authorities need to ensure that fertilizer policies do not impose obstacles on S product manufacturing and application, and encourage its use
- Education, training and promotion will need to be implemented by all sectors
- Include sulphur in fertilizer statistics
- Put sulphur 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!



Fertilizers Containing Sulphate

Available in India:

- Single Superphosphate (0-16-0-12S)
- Ammonium Sulphate (21-0-0-24S)
- Ammonium Phosphate-Sulphate (20-20-0-15S)
- Potassium Sulphate (0-0-50-18S)
- Potassium Magnesium Sulphate (0-0-27-22S)
- Various Micronutrient Sulphate Salts

Potential new products:

- Ammonium Nitrate-Sulphate (26-0-0-14S)
- Urea-Ammonium Sulphate (40-0-0-9S)



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: 8.5 million tons in 2005, providing 800,000 tons S



Urea-Ammonium Sulphate (38 to 40-0-0-13S)

- Modified N/S ratios by coating $(NH_4)_2SO_4$ fines with urea in a granulator and by air prilling
- Good physical and chemical properties result in considerable flexibility in the correction of N and S deficiencies in most soils; and suitable for various uses



Single Superphosphate (0-12 to 22-0-10 to 14S)

- World output in 2002: 34 Mt, eq. 4.1 Mt S, mostly in China, Brazil, India, Australia and New Zealand. The SSP market is relatively stable with tendency to decline in recent years
- Reduction of future market of SSP will require more S addition from new sources



Potassium Sulphate (0-0-50-17S)

- Fertilizer containing both K and sulphate-S;
- World annual production: 1.6 Mt, eq. 0.3 Mt S; Half is mined directly; and half is produced by reaction of KCl with sulphuric acid. SOP production is increasing in China.
- Good for direct use or formulating bulk blending fertilizer for Cl sensitive, valuable cash crops
- Good for saline and alkaline soils; and salt sensitive crops.



Potassium Magnesium Sulphate (0-0-22-22S-11Mg)

- Fertilizer containing K, Mg and sulphate-S; most produced by selective washing of Cl from langbeinite
- Cl free, low salt index and high solubility
- Good for direct use or formulating bulk blending fertilizer for Cl sensitive, valuable cash crops
- Good for saline, acid and alkaline soils; and salt sensitive crops.



Potential Market for Fertilizers Containing Elemental S

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



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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.

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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.

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New Products Improve Fertilizer Efficiency

- Elemental sulphur (S⁰) 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.



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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

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Urea-Sulphur 40-0-0-10S or 36-0-0-20S

- A homogeneous granular product made from a mixture of urea and liquid S
- S particle size: <100 um
- Good storage and handling properties, and no anti-caking agent
- Good nutrient availability and use efficiency



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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)



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.



TSI-FAI Partnership 20 Years of Successful Cooperation



Symposia, Field Trials, Market Studies, Publications and Promotion 1987-2006

