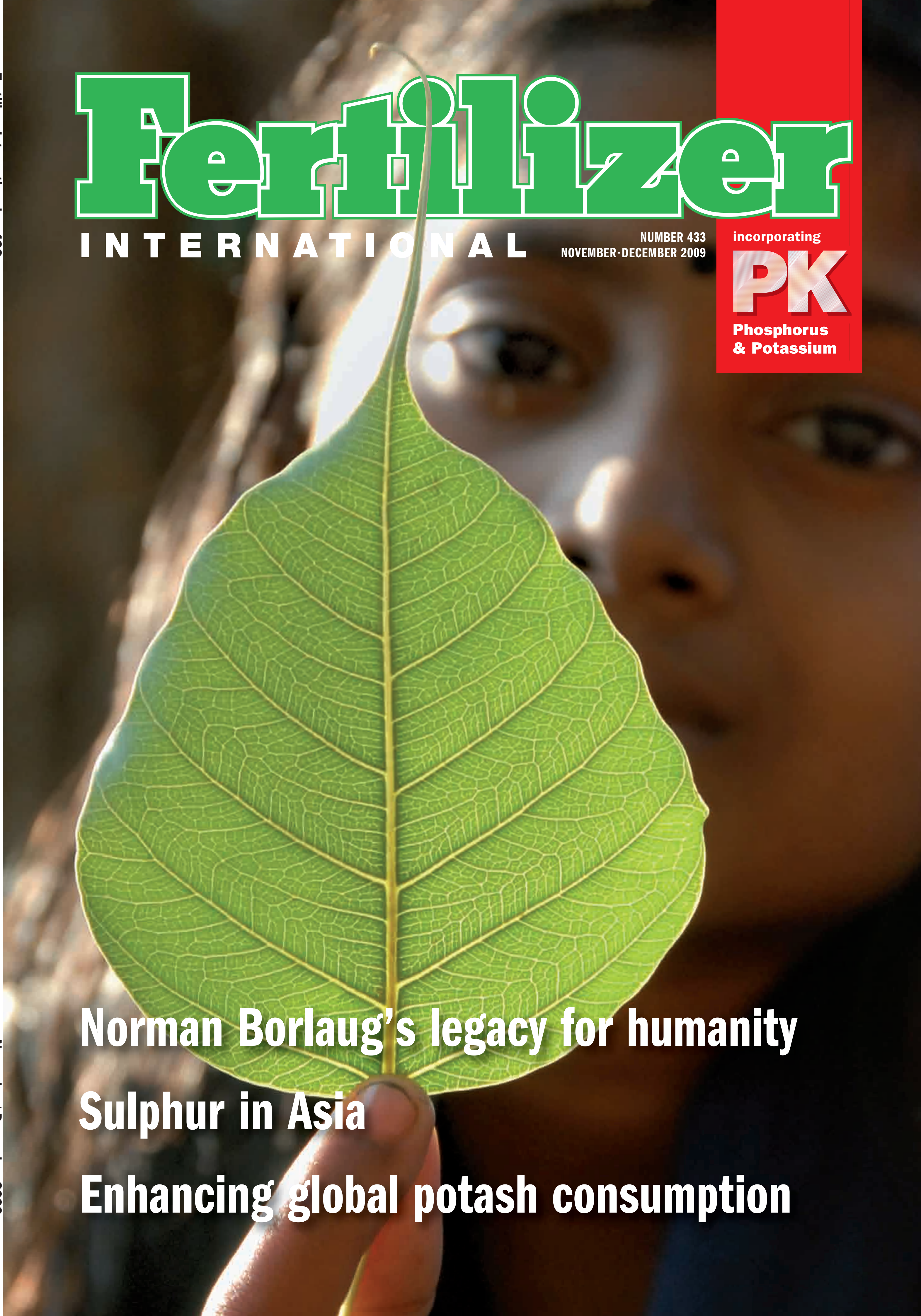

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incorporating PK Phosphorus & Potassium

Norman Borlaug's legacy for humanity

Sulphur in Asia

Enhancing global potash consumption

New recognition – new opportunities

Sulphur deficiency in the soil is a global phenomenon that threatens to limit the continued increase in food production. The problem is most pronounced in Asia. How can the speciality fertilizer producers best meet the region's sulphur nutrient needs?

Sulphur was for long neglected as a fertilizer nutrient in agricultural production in Asia, but in China and India at least, sulphur is now acknowledged as a major plant nutrient in its own right, along with N, P and K. This recognition is timely as S deficiency in China, India and Asia's other leading agricultural nations has become more critical, to the extent that it is limiting crop yield, produce quality, nutrient use efficiency and returns. In China, for example, an estimated 30% of cropped soils were reported to be deficient in sulphur, equivalent to about 40 million ha. Sulphur fertilisation was observed to increase crop yields by between 7-15%. (*Fertilizer Use and the Promotion of Sulphur in Chinese Agriculture*, Gao Xiangzhao. Paper presented at The Sulphur Institute's Sulphur World Symposium, Madrid [March 2009].)

The Sulphur Institute (TSI) is spurring the greater recognition of the so-called Fourth Major Plant Nutrient. In China, TSI has partnered the Ministry of Agriculture and China National Agricultural Technology Service Centre (CNTAESC) in a programme to increase the awareness of the importance of sulphur fertilizer in the country's agriculture. The specific goals of the programme are:

- To recognise S as a major plant nutrient
- Delineate soil sulphur deficiencies and calibrate soil testing results with crop responses in major cropping systems to S fertilisation
- To develop a nationwide S fertilizer recommendation programme.

The co-operative project is scheduled to run between 2008 and 2011 and is being funded jointly by the Chinese government and TSI. The major work being undertaken comprises:

- **Research Programme for China:** Soil S deficiencies are being delineated and fertilizer recommendations are being developed for high crop yields and quality. The China National Program of Soil Testing and Fertilizer Recommendation is collecting soil samples to determine the areas and extent of S deficiencies. By early 2009, over 24,000 samples had been collected in 17 counties within six provinces, namely Anhui, Guangxi, Henan, Liaoning, Shaanxi and Yunnan. The tests showed a wide variation in soil available S, ranging between 22 mg/kg and 41 mg/kg. Taking 20 mg/kg or less as the criterion for sulphur deficiency, it was estimated that 70% of soils in Shaanxi, 47% in Yunnan, 45% in Anhui, 39% in Liaoning, 30% in Guangxi and 15% in Henan were S-deficient.
- **Field trials:** A total of 39 field trials were conducted in farmers' fields in the above-mentioned provinces to determine crop responses to S fertilizer, focusing on rice, wheat, maize and oilseed rape. Higher yields of up to 14% were observed. These trials continue.
- **Promotion and education:** This programme was launched with the production of a promotional/educational brochure on *Sulphur Fertilisation in Crop*

Sunflower also responds well to added S, with yields in India rising by an average 38%.

Production, of which 10,000 copies were distributed to agricultural extension workers, farmers and dealers. Over one million fertilizer recommendation cards have been issued to farmers, which included data on sulphur demand by the major crops, based on the soil testing results.

- **Meetings and workshops:** In December 2008, NATESC and TSI held a national workshop in soil sulphur fertilizer and fertilisation that attracted delegates representing government organisations, agricultural research institutes and extension organisations, fertilizer industrial organisations, producers, dealers and the media.

The goal for 2009 is to encourage 1 million farmers in China to use S fertilizers based on the soil testing and fertilizer recommendations in the 17 participating counties of the six provinces involved in the NATESC study. It is hoped that crop yields will consequently rise by an average 5%, equivalent to 150,000 tonnes of grain. Such an increase would require the consumption of an additional 15,000 t/a of sulphur-containing fertilizers, equivalent to 30 kg S/ha.

Recognition in India

In India, TSI teamed with the Fertiliser Association of India (FAI) and the International Fertilizer Industry Association (IFA) to gather data on soil sulphur content. Whereas in the 1990s only 130 districts were identified as suffering from S deficiency, this total had risen to nearly 250 by 2007. Among the soils sampled, 46% were found to be deficient in S and another 30% were potentially deficient. (*Indian Fertilizer Policy Scenario – Impact on Phosphate and Sulphur*, R.C. Gupta, FAI. Paper presented at The Sulphur Institute's World Sulphur Symposium, Madrid [March 2009].)

While the annual S uptake by different crops grown in India was estimated in 2007/08 at nearly 1.8 million t/a, replenishment through S-containing fertilizers is less than half this total, at only an estimated 800,000 t/a. This is resulting in a net negative balance of around 1.0 million t/a S,which requires application of additional S-containing fertilizers to meet the increasing sulphur demand in fertilizers.

The FAI-TSI-IFA programme also involved various field trials with added S. These showed significant yield increases, ranging from an average 17% for rice, 25% for wheat, 30% in rapeseed and 32% in groundnut. However, TSI and FAI have some way to go in spreading the message about sulphur's benefits: only 15% of the country's farmers are believed to be aware about S fertilizers. India also lags behind China: in 2006, while an average 26.1 kg S/ha is used in China, the equivalent average application in India was just 4.3 kg S/ha.

Bangladesh, Indonesia, Thailand and South Korea are other countries in Asia where sulphur deficiencies have become apparent. In several cases, sulphur deficiencies have been exacerbated as DAP took over from SSP as a primary source of phosphorus. This factor prompted TSI to estimate that Bangladesh's sulphur deficit could rise to over 280,000 tonnes by 2011. (*Sulphur Deficiencies in Asia and Pacific Regions: Importance of Sulphur Fertilisation*, Donald L. Messick, TSI. Paper presented at IFA Regional Conference for Asia and the Pacific, Cheju, South Korea [October 2003].)

As in Bangladesh, S deficiencies in Indonesian agriculture developed soon after traditional S sources like SSP and organic manures were replaced with urea, TSP and DAP. More recently, around 550,000 t/a of ammonium sulphate have been applied in S-deficient soils to improve crop yields. The programme helped Indonesia to achieve self-sufficiency in rice production.

With assistance from the Australian Center for International Agricultural Research (ACIAR), Thailand has also developed a long-term programme to rectify sulphur deficiencies, resulting in increased yields on cassava, maize and sesame crops ranging between 13% and 35%. The programme demonstrated that farmers in Thailand could only obtain maximum efficiency of their NPK fertilizer applications by balancing them with added S.

TSI also helped launch sulphur research programmes in South Korea, in conjunction with the Korean Society of Soil Science and Fertilizer. Ammonium sulphate and potassium sulphate were the main sources of S used in various field trials, which in some cases led to a doubling in dry matter yields of brown rice.

According to estimates of TSI based on crop demand, fertilizer efficiency and current inputs, the current S deficit in Asia is about 5.2 million t/a. With increased food production raising S requirements and assuming slower expansion rates for S application, this S deficit is projected to grow to 6.4 million tonnes by 2015, of which India and China would account for some 70%. The potential problem of S deficiency has been exacerbated by the increased importance of cash crop production throughout the continent. These crops include oil palm, sugar, vegetables, tea and fruits, all of which have major quality requirements. Most cash crops have a higher demand for S and use balanced fertilisation technology to achieve higher market values.

The tools

Effective sulphur fertilizer strategies continue to be devised in most Asian countries and farmers can draw on an ever increasing portfolio of fertilizer products to achieve higher yields and enhanced crop quality. Many fertilizer materials contain significant quantities of S. They can generally be divided into two groups:

- Fertilizers containing sulphur
- Fertilizers containing sulphate.

Sulphate-containing fertilizers provide most of the fertilizer S applied to soils. These materials have the advantages of supplying S primarily as a component of multinutrient fertilizers in the form of SO_4^{2-} that is immediately available for plant uptake. Plants take up S from the soil solution as sulphate. Non-sulphate S sources, such as elemental S, must be converted to sulphate before the plant can access it. This oxidation process is carried out mainly by soil bacteria, converting elemental S into sulphuric acid, and the sulphate contained in this is available for plant uptake. (*Sulphur-Enhanced Fertilizers: A New Generation of N, P, S Fertilizers*, Graeme Blair, Shell Sulphur Solutions, Canada. Paper presented at IFA Technical Symposium, Sao Paulo [March 2008].)

Elemental S is an almost ideal fertilizer as it contains 100% nutrients. The elemental S must be oxidised to sulphate before it is available to plants and since micro-organisms carry out this process, it is moisture- and temperature-dependent, as is the crop demand for S. The rate of oxidation is also dependent on the particle size of S, thus increasing the scope to manage the release rate of sulphate to the plant and minimise losses by surface runoff and leaching.

Much of the elemental S supplied for fertilizer use is predominantly sourced as by-product from the refining of sour oil and natural gas. Among the major suppliers are Shell and Omni Sulphur of Canada. In India, Deepak Fertilisers and Coromandel Fertilisers Ltd. also market direct-application elemental sulphur fertilizers.

Elemental S can be readily incorporated into N and P to provide 5-20% S. In 2001, Shell Canada invented a process to incorporate elemental S into DAP and MAP, subsequently developing sulphur-enhanced fertilizer formulations which have been trialled in China and more recently, Brazil. These formulations typically contain 13% ammonium N, 33-35% P and 15% S, the latter comprising 50% elemental S and 50% sulphate S. Elemental S-fortified TSP, MAP and DAP can be bulk blended with other granular fertilizers or applied directly, particularly for top-dressing legumes when both P and S are required.

Sulphur bentonite fertilizers have been developed to improve the performance of granular element S products by incorporating 5-10% by weight of a swelling clay, such as bentonite. Particles of S bentonite are sized for blending with solid N, P and K fertilizers. When applied to the soil, the bentonite component absorbs soil moisture, causing fertilizer granules to disintegrate into finely divided S, which is more rapidly converted into SO_4^{2-}. This material has gained wide acceptance as a source of plant nutrient S for high-analysis, bulk blend formulations as it provides elemental S in an easy-to-use physical form that can be readily converted to SO_4^{2-} in the soil. Typical recommended application rates are between 50-70 kg/ha.

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Tiger-Sul Products Inc. is the world's leading supplier of sulphur bentonite, which it also incorporates in granular micronutrient formulations. It has pioneered drop-form technology to produce high-quality 90% degradable S from 99% industrial grade sulphur. Tiger-Sul is a highly innovative and research-oriented company and it has recently conducted yield studies on bentonite applications in Fujian province, China. Zafaran Industrial Group of Iran also supplies degradable sulphur bentonite, comprising 90% elemental S and 10% bentonite clay.

Another product in Zafaran's portfolio is sulphur-coated urea (SCU). This fertilizer is formulated for increased efficiency in the use of urea and comprises an S shell around each urea granule. SCU typically contains 77-82% urea (36-38% N) and 14-20% S coating. Although the S in the coating may not be sufficiently available to correct deficiencies during the early season of the first year after application, it becomes an important source of plant available S in the latter growing season and succeeding year. Nu-Gro Technologies, a division of Agrium Inc., is one of the leading suppliers of SCU fertilizers.

Production capacity of S-coated urea (SCU) fertilizers in China has increased rapidly in recent years to about 800,000 t/a under a campaign to increase fertilizer efficiency, with Hangfeng Evergreen Inc. and Shandong Kingenta Ecologic Engineering Co. Ltd. as the leading producers in China. (*Sulphur in Asia: Vital to Fertilizer Industry*, Ming Xian Fan, The Sulphur Institute. Paper presented at FMB Asia Fertilizer Conference & Exhibition, Beijing [February 2009].)

Sulphate sources

In India, among the sulphate-containing fertilizers, the most significant and popular sources are ammonium phosphate sulphur (APS), ammonium sulphate (AS), SSP, potassium sulphate, potassium magnesium sulphate and gypsum. More new sulphate-containing fertilizers continue to enter the market, all playing an important role in correcting S deficiency through balanced fertilisation.

Ammonium nitrate sulphate is produced by neutralising nitric and sulphuric acids with NH_3^- or by granulating ammonium sulphate in the presence of an ammonium nitrate solution. In European markets, 26-0-0-14S is a popular grade. Among the advantages of ammonium nitrate sulphate are that it is less hygroscopic compared with each individual constituent, having a satisfactory N:S ratio for direct application purposes, and combining the ammonium and nitrate forms of N. Ammonium nitrate sulphate is highly suitable for direct application to forage, grass seed crops and small grains. European producers predominate in the supply of ammonium nitrate sulphate, including AMI Agrolinz, *fertiva*, Zuid Chemie, as well as Omni Fertilizers, South Africa.

Granular urea-ammonium sulphate is manufactured by coating AS fines with urea in a granulator or by air prilling. Grades range from 40-0-0-14S to 31-0-0-13S. Urea-ammonium sulphate granules tend to be more resistant to physical breakdown and less hygroscopic than urea prills. The N:S ratio can range between 3:1 and 7:1, resulting in great flexibility in the correction of N and S deficiencies in most soils. The acid-forming reaction of $(NH_4)_2SO_4$ in the soil, when used a a nitrogen source, can reduce urease activity and NH_3 volatisation by reducing the pH rising from urea hydrolysis. Jinan Haohua Industrial Co. is a no-

Table 1: **India – production of S-carrying fertilizers** 1990/91-2007/08, 000 tonnes

Year	Ammonium sulphate	Ammonium phosphate sulphate	SSP	Sulphur bentonite	Total S
1990/91	557.5	600.7	3,650.3	-	607.8
1994/95	584.8	1,110.6	3,024.6	-	611.6
2000/01	593.4	1,582.3	2,742.2	-	643.8
2004/05	615.9	1,384.9	2,461.1	-	592.4
2005/06	619.3	1,814.5	2,795.2	10.0	694.8
2006/07	634.8	2,246.0	2,972.0	14.0	800.7
2007/08	483.1	1,442.8	2,246.3	15.0	560.8

Source: FAI

table supplier to the Chinese market.

Ammonium phosphate sulphate (APS) is a complex of ammonium sulphate and ammonium phosphate. It has gained a niche in India, where the most common grades of APS are 20-20-0-13/15S and 16-20-0-13/15S. Other APS products include 13-39-0-20S, 19-9-0-20S and 23-20-0-7S. APS fertilizers are made by several processes, including reacting a mixture of phosphoric acid and sulphuric acid with ammonia, and introducing AS solutions and sulphuric acid into a phosphoric acid reaction circuit. Leading APS producers include Agrium Inc. and the Indian producers, Coromandel Fertilisers Ltd. (CFL), Gujarat State Chemicals Ltd. and FACT.

> **Nevertheless the transformation of agricultural systems throughout the continent will be a long haul, but a highly worthwhile one.**

During the 1990s, China developed a new technology for producing S-based NPK compound fertilizers, using phosphate rock, sulphuric acid, ammonia, urea and potassium chloride as raw materials. This technology combines all three technical processes for producing ammonium phosphate, potassium and NPKs together, with the resulting simplification of the production process and lower production costs. The major product contains 14.5% N, 16% P_2O_5, 14.5% K_2O and 11%S ($[NH_4]_2SO_4$ and K_2SO_4). Recently, production of S-based NPK compound fertilizers in China increased to 9.5 million tonnes, providing over 1 million tonnes S.

Potassium sulphate is used in place of potassium chloride, especially with tobacco, fruits and vegetables and other crops which are Cl-sensitive. Most of Asia's K_2SO_4 requirements are met by imports from other regions, but there is some indigenous production in China. Potassium magnesium sulphate is a double salt and contains 18% K, 11% Mg and 22% S, offering the advantage of supplying both S and Mg. Leading suppliers of potassium magnesium sulphate are Mosaic Co. and Intrepid Potash of the United States.

Magnesium sulphate (kieserite) containing 13% S and 9.8% Mg are used as sources of both nutrients, being often incorporated in clear liquid fertilizers and foliar sprays. K+S of Germany is a leading supplier.

An interesting new development that extends the range of sulphur-containing fertilizers is Mosaic Co.'s recently launched *MicroEssentials*® range of multinutrient fertilizers. Using MAP as the basis, *MicroEssentials* augments N and P with sulphur. The sulphur in turn takes two forms: elemental and ammonium sulphate. The three nutrients are combined in the correct ratio and in uniformly sized granules. The *MicroEssentials* range includes formulations of 12-40-0 with 10% S and 13-33-0 with 15%S. Mosaic Co. uses a patented technology to manufacture the product range, whereby the sulphur forms a partial layer around the developing granule.

Longer-term goals

While sulphur deficiencies have become a major limiting factor in crop production throughout Asia, the problem is being addressed by organisations such as the TSI and FAI, as well as by government agricultural agencies, agricultural extension services and other fertilizer and farming stakeholders. Within the past 5-10 years, the issue of balanced fertilisation incorporating sulphur has gained increased recognition, spurring the development of new fertilizer products. There nevertheless remains a very pressing need for continued investment in education, training, as well as the supply and effective distribution of products wherever they are required.

In India, while the total use of sulphur as a raw material in fertilizers rose to 2.3 million tonnes in 2007/08, the country's production of S-carrying fertilizers fell. (Table 1)

This downturn is thought to be the result of the spike in energy and raw materials prices that year, which forced many Indian fertilizer producers to scale back production and conserve cash flows. In 2003, the Indian government incorporated sulphur in the Fertiliser Control Order. This required the sulphur content of S-carrying fertilizers to be printed on the fertilizer bags as part of the product specification. Further policy changes were implemented in 2008.

However, the declining production of SSP in India has caused concern. For long, sulphur was excluded from the subsidy provisions made to N, P and K fertilizers, thereby raising its relative price, but this anomaly has now been removed with the inclusion of S in the subsidy programme. The new policy of nutrient-based pricing is intended to encourage the greater use of complex fertilizers.

As in India and China, other countries in Asia have likewise acknowledged the importance of sulphur in more balanced fertilizer nutrition regimes. To that extent, a key hurdle has been crossed. Nevertheless, the transformation of agricultural systems throughout the continent and the incorporation of sulphur as a primary nutrient will require continuing substantial investments in local education, training and promotion by all stakeholders, including government extension agencies and fertilizer manufacturers and dealers. This will be a long haul, but a highly worthwhile one. ■