R P 685

Reprinted from Fertiliser News Sept. 1986 Issue Vol. 31 No. 9 (page Nos. 9-16)

Sulphur Research and Development in Indian Agriculture

This paper summarises the salient progress made in the research and developmental aspects of S in Indian agriculture. Deficiencies of S occur in about 90 districts affecting 23-30 m. ha. Yield responses of 31 crops to S have been obtained. In general, such responses are significant and profitable. Fertilisers used at present add about 0.4 mt S/year which is 40 per cent of S taken up by crops. There is very little activity in product development, promotion and extension of S. Sulphur is a master nutrient for oilseed production and deserves greater attention than what it has received so far.

H. L. S. TANDON

Fertiliser Development and Consultation Organisation, C-110, Greater Kailash I, New Delhi-110048.

Sulphur as a plant nutrient is becoming increasingly important for Indian agriculture. During the last two years, a major compilation on sulphur, a regional seminar, a national seminar and now this special issue of *Fertiliser News* on Sulphur are all indicators of the growing interest in sulphur. In his foreword to a recent study on sulphur, Goswami has written "crops, for example require as much S as they do P and it can therefore be rightly called the fourth major nutrient in Indian agriculture" (18). Sulphur deficiencies are scattered in 90 districts and about 23-30 m ha of the cropland in India may be affected. This interest in sulphur is timely because S-deficiencies should not be allowed to develop into constraints in the progress of Indian agriculture. If these are neglected (and not corrected), they can not only lower crop yields but also reduce the efficiency of other nutrients used.

This overview paper aims to briefly discuss the salient features of sulphur research and development in India. Current research output on S is around 15-20 papers/year but for the sake of brevity only a few references are cited here.

RESEARCH ASPECTS OF SULPHUR

Systematic research on sulphur began about 27 years ago. It has gathered momentum but remains largely scattered and uncoordinated. Information on the sulphur status of soils is available from certain areas but lacking in many others. Yield responses of over 30 crops to sulphur have been reported. About two-thirds of such experiments have been conducted in the field and rest in the greenhouses. On-farm trials with sulphur are lacking. Oilseeds account for 50 per cent of the research output and foodgrains for another 30 per cent with the balance to a number of other crops. Information on sulphur in Indian agriculture has been periodically reviewed (4, 5, 7, 9, 12, 15, 16, 18).

Causes of Sulphur Deficiency

The main causes of sulphur deficiency in India are as follows:

* accelerated removal of sulphur by increasing levels of agricultural production (2.5-3 times in 25-30 years).
* dominance of "S-free" fertiliser in the fertiliser-use pattern (N:S consumption ratio of 1.4 in 1963 widening to 11.9 in 1983).
* particularly stronger shifts towards the use of "S-free" materials in the light-textured, intensively-cropped areas of high productivity (N:S consumption ratio of 26 in Punjab against 12 for all-India).
* depletion of soil sulphur due to gap between S additions and S removals.
* forty million ha under pulses and oilseeds which have high requirement of sulphur per unit yield production.
* leaching losses of sulphur.

Sulphur Requirement of Crops

Crops in general require as much sulphur as they do phosphorus but for several legumes and crucifers, S uptake can be more than P uptake (19). As an overall assessment for tropical regions, S requirement per tonne yield production can be taken as 3-4 kg for cereals, 8 kg for legumes and 12 kg for oilseeds (Table 1). Intensive cropping systems can annually remove upto 70-75 kg S/ha. A soybean-wheat-maize cropping system absorbed 49 kg S/ha (11) while a system consisting of legumes and crucifers (mustard—greengram-cowpea) producing 15 t/ha drymatter could remove upto 72 kg S/ha (10). In non-mechanised harvesting, where the total drymatter is removed from the field, crop uptake can be equated with crop removal. In contrast, a

Table 1—Mean sulphur uptake per tonne of yield production

Crop	Kg S/t yield	Source
Cereals	3-4	(8)
Millets	5-8	(8)
Pulses	8	(8)
Oilseeds	12	(8)
Forages	3	(19)

significant proportion of the S absorbed by perennial crops can be tied up in perennial growth and also recycled (Table 2).

Sulphur in Soils

Total sulphur in soils may vary from 19 ppm to about 4000 ppm (5, 15, 18). Sulphur in soils is present both in mineral and in organic forms. Many of the pathways of S transformation are similar to those of N and the mineralisation of organic forms into plant-available sulphate forms is a microbiological process. A recent discussion on the S-cycle in soils and its dynamics is available (14).

Total soil S is apparently of little value in describing the short-term S-fertility of a soil. For the estimation of available S, almost all known methods and extractants have been used in India. Although 10 ppm available S is the most commonly used critical limit below which soils are stated to be deficient in S, this limit obviously varies widely (8-30 ppm) depending upon the soil, the crop, the method of analysis and even the crop variety.

For a given situation, more than one method can be suitable if it is adequately correlated with crop response. Much of this critical level research has been carried out in the greenhouses without any field verification. Since very few soil testing laboratories in India analyse for S, it would be worthwhile to explore the possibility of using the Olsen bicarbonate method (already used for P) for sulphur as well, as it has been found to be promising (20). If found suitable, it could make it easier for the soil testing laboratories to include S in their testing programmes. Of course, it would be ideal if the advice for S application can be based on an integrated approach consisting of soil analysis, plant analysis and S requirements in relation to expected yield levels.

Table 3—Districts where widespread S-deficiency is reported

Andhra Pradesh	:	Kurnool, West Godavari
Bihar	:	Ranchi
Delhi	:	Delhi
Gujarat	:	Amreli, Banaskantha, Junagadh, Kheda, Rajkot, Sabarkantha, Surendranagar
Haryana	:	Bhiwani, Gurgaon, Hisar, Mohindergarh, Sirsa
Himachal Pradesh	:	Hamirpur, Kangra, Una
Karnataka	:	Bangalore, Belgaum, Chickmaglur, Coorg, Dharwad, Hassan, Kolar, Mandya, N. Canara, S. Canara, Tumkur
Kerala	:	All districts
Madhya Pradesh	:	Balaghat, Bhind, Dewas, Dhar, East Nimar, Gwalior, Indore, Jabalpur, Mandsaur, Morena, Ratlam, Sagar, Sehore, Ujjain
Maharashtra	:	Aurangabad, Bhandra, Chandrapur, Kolhapur, Nanded, Osmanabad, Parbhani, Pune, Raigad
Orissa	:	Ganjam
Punjab	:	Faridkot, Ferozepur, Kapurthala, Ludhiana, Patiala, Ropar
Rajesthan	:	Jaipur, Jodhpur, Udaipur
Tamil Nadu	:	Coimbatore
Uttar Pradesh	:	Allahabad, Bulandshahr, Farukhabad, Hardoi, Jhansi, Kanpur, Lalitpur, Mirzapur, Nainital, Sitapur, Varanasi
West Bengal	:	Birbhum, Burdwan, Midnapur, 24-Parganas

Sulphur-Deficient Areas

Although sulphur deficiency is reported to be widespread, systematic delineation of such areas is yet to take place. So far, these have been reported from 90 out of about 400 districts. These do not include districts from Bihar where S-deficiency was reported to be widespread but sampled areas were not clearly indicated. The 90 districts are listed in Table 3.

A S-deficiency map showing these districts has been prepared on the basis of soil analyses and crop responses to S application (18). Information is lacking for a large number of areas and the map is not complete by any means. It is a starting point. Even within an area there can be wide variations. For example, the extent of S-deficiency in different districts of Punjab can vary from 5 per cent to 40 per cent of the cropped area. Apart from soil properties, the management levels, proximity to industrial activity and climatic contributions can have a marked influence on the S-fertility of a soil.

Table 2—Sulphur uptake and removal by tea in south India

Product	Fate	Dry matter kg	S content kg
Made tea	Removed	100	0.25
Foliage	Recycled	120	0.40
Wood	Removed	280	0.36
Total		500	1.01

Source: (2).

Additions of Sulphur

Major sources of sulphur addition to soils are the fertilisers, manures, precipitation, irrigation waters and crop residues. Quantitative data on the S input are available only for the fertilisers. Various N, P, K, NP fertilisers which also contain S are estimated to add about 0.4 million tonnes S annually (Figure 1). If one looks at the nutrient consumption picture as one consisting of NPKS, then in 1984-85, consumption in million tonnes was 5.5 for N, 1.9 for P_2O_5, 0.8 for K_2O and 0.4 for S. Much of this sulphur is however not applied in a pre-planned manner on S-deficient soils but rather S accompanies NPK to the farmers' fields.

Sulphur input through precipitation etc. may range from 2 to 8 kg S/ha per year in areas having 200-800 mm of mean annual rainfall. Certain irrigation waters can bring upto 30 kg S/ha/yr and organic manures may add 1.5 kg S/t manure on gross basis. Information on most of these sources for S is very inadequate.

Removals of Sulphur

Type of crop, level of productivity and leaching are the major determinants of S removal from soils.

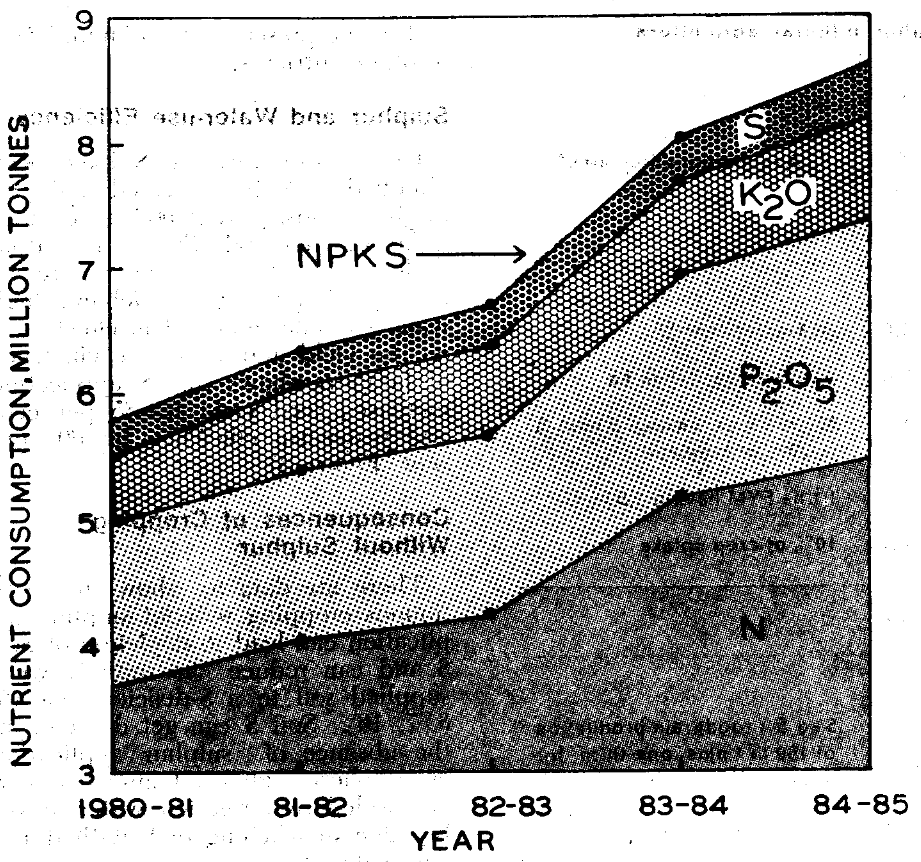

Figure 1—Trends in the additon of NPKS in Indian agriculture (Data source: Fertiliser Statistics, FAI).

Under comparable conditions, a cereal-dominated system may remove 2 kg S|t dry matter while an oilseed-legume dominated system may remove 4-5 kg S/t dry matter produced. Total annual removal of S by harvested crops at present is estimated at one million tonne S (17, 18). This comes to 5.7 kg S/ha of gross cropped area. The figure will vary from one region to another depending upon the cropping pattern, yields and the S status of the harvested materials.

There are very few estimates of S removal through leaching (8) but it is suspected to be an important route of S-exit in coarse-textured, alkaline soils under high rainfall or flood irrigation. That is why the S input via irrigation water cannot be taken as a net addition available for crop use. Crops are known to respond to S application even when the irrigation water carries more S than is absorbed by the crop (3). It would be a worthwhile area of research to estimate the fate of S brought in by irrigation waters, possibly using tagged irrigation water.

Balance Sheet of Sulphur

Due to inadequate data on the S additions and removals through various routes, a quantitative balance sheet of S cannot yet be constructed. A preliminary balance sheet is presented in Table 4. It indicates a net negative balance of S which means the continuing depletion of soil S. Unless corrective steps are taken to bridge this gap, there are chances of S-deficiencies becoming more acute and more extensive.

It would be desirable to generate data on the various sources through which S is added and removed so that any balance sheets to be made are not based on too many assumptions. It would be particularly useful to have such balance sheets separately for irrigated and rainfed farming systems.

Crop Responses to Sulphur

Yield responses of over 30 crops to S application have been reported in India. These include cereals, millets, pulses, oilseeds, forages, tubers and many others. The mean increase in yield due to S application is 27 per cent (wheat), 38 per cent (chickpea), 15 per cent (groundnut), 31 per cent (mustard), 26 per cent (raya), 27 per cent (sunflower), 30 per cent (potato) and 19 per cent (onion), all under field conditions.

At Barrackpore, S application increased paddy yields by 1.2 t/ha (11). Sulphur research on rice has received less attention but may need to be strengthened. Sulphur deficiency is reported to be a major problem in the neighbouring Bangladesh where rice occupies 80 per cent of the cropped area.

Sulphur responses have been documented in detail (this issue of *Fertiliser News*, (18) hence these will not be dealt with in any greater length here. Mention must be made of two aspects: (i) When S-deficiency is corrected, not only the yield but the efficiency of other nutrients also improves. When S application increased wheat yield by 40 per cent, this was accompanied by the increased uptake of N by 58 per cent, P by 41 per cent, K by 27 per cent and of S by 83 per cent and (ii) substantial yield increases have been reported by the application of elemental S as a soil treatment in the calcareous, heavy-textured soils of Rajasthan (7, 13). Prevention of iron chlorosis is one of the major benefits attributed to S in such cases.

Production Yardsticks for Sulphur

On sulphur-deficient soils, response yardsticks of S are generally on par with those for NPK. Some values of sulphur response yardsticks are given in Figure 2. On an average, each unit of sulphur applied increased the yield of wheat by 12 units, chickpea 8 units, groundnut 7 units, mustard 9 units and potato by 78 units. It must be mentioned that unlike for NPK, these production yardsticks for S are based on the results of "on-station" research, primarily due to lack of on-farm trials.

Economics of Sulphur Application

There are actually no established norms about the price of fertiliser sulphur because its presence in fertilisers is either ignored or taken to be of incidental nature tied up with the manufacturing process. For sulphur to be brought into the mainstream of balanced fertiliser use, it is essential

Table 4—A Balance sheet of sulphur in Indian agriculture

Item	Country basis		Hectare basis		Assumptions/Remarks*
	Gross ('000 t)	Net ('000 t)	Gross kg S	Net kg S	
INPUT					
Fertilisers	394	99	2.3	0.6	Actual for 1984-85.
Rainfall	444	111	2.5	0.6	3 kg S/ha for 148 m ha
Irrigation	788	197	4.5	1.1	30 cm water having 5 ppm S to 30% of cropland
FYM	263	26	1.5	0.2	1 t/ha FYM having 1.5 kg S/t
Recycling	100	10	0.6	0.1	10% of crop uptake
Total INPUT	1989	443	11.4	2.6	
OUTPUT					
Crop removal	1000	900	5.7	5.1	5 kg S/t foodgrain production of 150 m t plus one-third for other crops
Leaching	?	?	?	?	
Erosion	?	?	?	?	
Immobilisation	?	?	?	?	
BALANCE SHEET	989	−457	5.7	−2.5	

*Under input, net figures are based on 25% efficiency for the inorganic sulphate forms and 10% for organics

Under output, net figures assume that 10% of S uptake is recycled. This could be negligible for many crops but upto 40% of tea.

Computations for irrigation and rainfall etc. are based on very limited data.

and in the presence of optimum levels of other nutrients.

Sulphur and Water-use Efficiency

Crop responses to S have been obtained both for irrigated and for rainfed crops. Over 90 per cent of grain legumes and oilseeds are raised under dryland conditions where it is very important to achieve high water-use efficiency. The effect of S on the yield and water-use efficiency of taramira shows that S application increased seed yield by 85 per cent and water-use efficiency by 60 per cent (Figure 3).

Consequences of Cropping Without Sulphur

There are data to show that continuous cropping without sulphur application can lead to depletion of Soil S and can reduce an initially well-supplied soil to a S-deficient one (3, 6, 7, 16). Soil S can get depleted in the absence of sulphur application even where significant amounts of S are added by irrigation water, possibly due to leaching of S with drainage water (3).

DEVELOPMENTAL ASPECTS OF SULPHUR

Programmes for the development, promotion and extension of sulphur have been almost non-existent. Fertiliser recommendations do not always include S where proven results of research are available. Areas which were reported to be deficient in sulphur 20 years ago continue to be S-deficient. Yet some signs of change are visible. For the first time, that S received a monetary value tag and given due recognition as a yield-producing input, not as an extra like carbon, or hydrogen or oxygen applied through fertilisers.

As an illustration, fertiliser S may either be priced at Rs. 1.75/kg S (cost of S in gypsum) or at Rs. 2.18/kg S being the price at which S is supplied to the fertiliser industry as a raw material. Taking the price of S at Rs. 1.75/kg, on an average each rupee invested in S generated extra yield worth Rs 11 of wheat, Rs 16 of groundnut, Rs 21 of mustard and Rs 17 of potato. These high levels of profitability have been obtained on fields which were deficient in sulphur

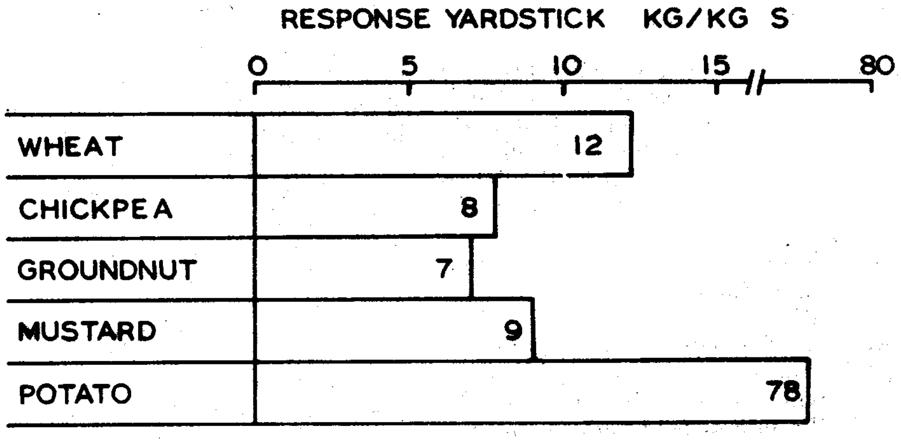

Figure 2—Average yield gains per unit sulphur applied in India under field conditions (Source: 18).

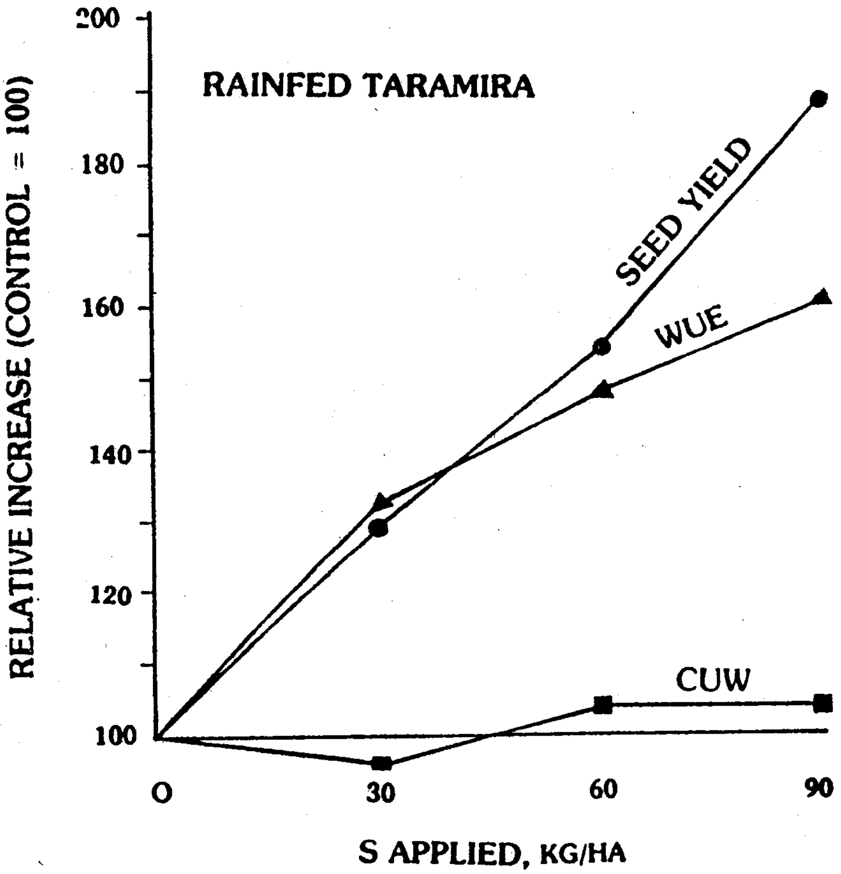

Figure 3—Effect of sulphur on the yiel and water use efficiency of taramira (Data source: Singh, B. P., Indian J. Agric. Sci. 53, 676-680, 1983).

S content of fertilisers was included in the 1984-85 editions of *Fertiliser Statistics*. Special issues such as this one can help to bridge the information gap. Some developmental aspects are briefly discussed below.

Sulphur Requirements

Sulphur requirement of Indian agriculture will depend upon the amounts removed by crops, proportion of removal to be replenished (depletion to be tolerated) and the efficiency of applied sulphur. Exercises in this direction were initiated for the tropical areas by Kanwar and Mudahar (8). Some estimates of sulphur requirement at different degrees of replenishment and over a range of possible efficiencies are presented in Figure 4. To illustrate, at the present S removal of 1 million tonnes, 1 million tonnes S needs to be added if 50 per cent of the removal is to be replenished and the efficiency of added S is also 50 per cent. This is when the total requirements are to be met from fertilisers. A more broadbased picture will emerge if the contributions from manures, residues, precipitation and irrigation are also taken into account along with their efficiency factors.

Sulphur Input through Fertilisers

In the early years of fertiliser use, when AS and SSP dominated the fertiliser scene, more S was added to soils than either N or P. That was a sulphur-plus situation. With the growth in fertiliser use, and advances in technology leading to large scale shifts towards S-free fertilisers, the share of S-containing fertilisers declined. In absolute terms, S added through fertilisers during the past 5 years has increased from 271 to 394 thousand tonnes (Figure 1). This has largely been due to a significant renewal of interest in single superphosphate production and expansion in the production of ammonium phosphate sulphate (Figure 5).

Distribution of Sulphur—Containing Fertilisers

Out of the total annual fertiliser tonnage of 20 million tonnes material, fertilisers containing S account for about 2.7 million tonnes or 14 per cent. This is made up of 1.7 m.t. of SSP, half a million tonne each of AS and APS and a very small amount of SOP. The S component of these fertilisers is probably not yet taken into account while formulating fertiliser distribution plans. It is also not clear whether the locally-available gypsum is readily available in S-deficient areas or how many of the 150 thousand fertiliser sale points are available for its distribution. This would be a suitable subject for study in fertiliser distribution and logistics in relation to soil deficiencies.

Sulphur in Fertiliser Legislation

The existing fertiliser legislation [Fertiliser (Control) Order] lists sulphur as an essential plant nutrient, as in textbooks, but not in the list of materials which can be used to correct sulphur deficiency. To remove this discrepancy between research and development, it would be appropriate that S-fertilisers find a place in the Fertiliser (Control) Order. Gypsum, for instance is widely recommended in India for providing S, particularly to oilseed crops. It would also be educative for fertiliser dealers and farmers if the S content of fertilisers is printed on the fertiliser bags.

Sulphur Recommendations

Some examples of sulphur recommendations approximating near-optimum rates are provided in Table 5. These are generally in the range of 20-50 kg S/ha. In calcareous, heavy-textured soils, where elemental S can be used in its dual role of a fertiliser-cum-amendment, the application rates are in the range of 250-500 kg S/ha. In tea plantations in south India, annual application of 37-49 kg S/ha is suggested to replace crop uptake, leaching etc. (2). In Punjab, 250 kg gypsum/ha is advocated for wheat if "S-free" fertilisers are used.

Generally, the application of materials containing sulphate-S is recommended as a basal, pre-plant application. For groundnut, a delayed or even a split application can be made to ensure adequate S and Ca (SSP; gypsum) at the pod formation stage. Sulphur-deficiency in standing crops can be handled by using a soluble fertiliser such as ammonium sulphate. Materials such as elemental S or iron

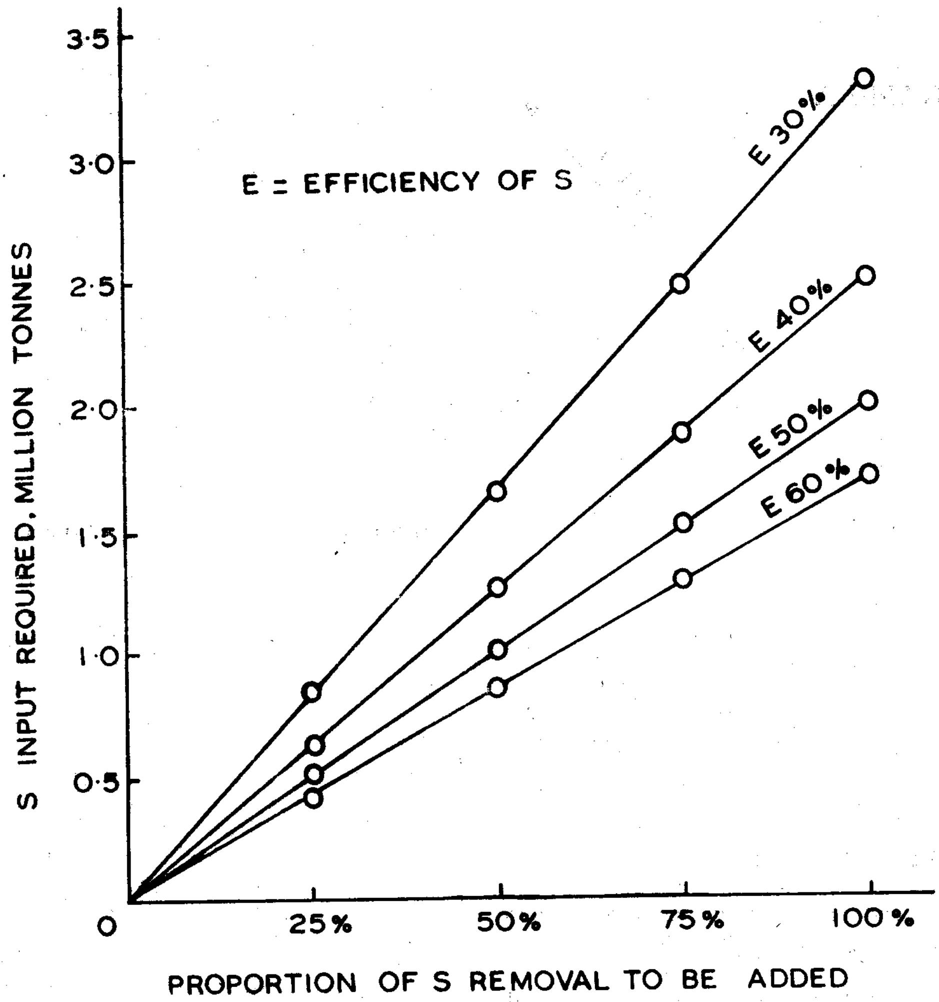

Figure 4—Estimated requirement of sulphur for soils and crops at different levels of replenishment and use-efficiencies.

pyrites are more effective when applied 3-4 weeks ahead of planting to allow for the S to oxidise and convert itself into sulphate form.

Potential Gains from Sulphur Application

Grain yield increases of 250-500 kg/ha from sulphur application on S-deficient soils are common. Assuming that 23-30 million ha of cropland may be suffering from some degree of S-deficiency, each 100 kg increase in yield from S can add 2.3-3.0 million tonnes to foodgrain production. It is therefore desirable to develop area-wise blue prints and action plans for the assessment and correction of sulphur deficiencies.

Sulphur and Oilseed Production

Sulphur comes out as a master nutrient for increasing oilseed yields. Among the field crops, oilseeds have the highest requirement of S per unit yield. Availability of oilseeds in India is far below the requirements with the result that over 1000 crore rupees in foreign exchange are being spent annually for importing oilseeds. The top priority being attached to increasing oilseed production is indicated by the setting up of an oilseed technology mission by the Government of India. When field plans are developed for increasing oilseed production in the 180 districts identified, it is hoped that balanced nutrient application, including S where necessary will receive due attention. Available research shows that on soils which are low in sulphur, each unit of S applied can augment the supply of edible oils by 3-3.5 units. Sulphur can improve the production of edible oils both by increasing seed yields (Figure 2) and by increasing the seed's oil content (Figure 6).

Accounting for Sulphur

Sulphur is neither an extra nor a cost-free appendix attached to fertilisers whether taken out of gypsum mines or offloaded from ships. One consequence of the neglect of S is that fertilisers which contain S are presented as dilute, low-analysis, costly materials because their unit nutrient value is calculated on the basis of N, P or K in them. If the economic value of S is also taken into account, then this picture changes. As an illustration, if the 24 per cent S present in ammonium sulphate is accounted for and this value taken out of the retail price, then cost of N in AS comes out to be Rs 5.4-5.9/kg N as compared to Rs 7.9 when the retail price of AS is attributed only to the 21 per cent N in it. The same thing applies to other fertilisers as well (Table 6).

New S-Containing Fertilisers

There is very little activity towards the development of NP/NPK materials containing S to cater to the needs of specific areas. With S-deficiency being a practical problem in the alluvial soils of the wheat belt,

Table 5—Some indicative optimum rates of sulphur application

Crops	Kg S/ha	Remarks
Cereals	24—40	Wheat, maize, rice
Pulses	20—40	Chickpea, lentil, greengram, blackgram
Oilseeds	10—150*	Groundnut, mustard, rai, sunflower
Tubers	25 - 60	Potato, cassava
Tea	40—50	Under south Indian conditions
Fodders	100	Sorghum for fodder

*Most rates are in the range of 20-50 kg S/ha.

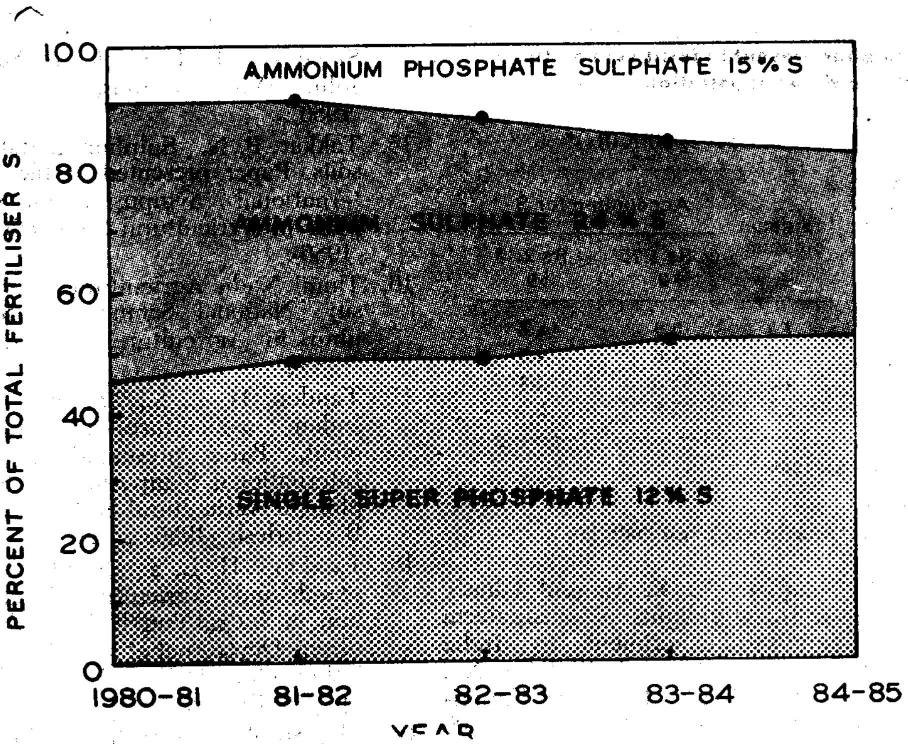

Figure 5—Major contributors of fertiliser sulphur in Indian agriculture (Source: 18).

the existing product pattern could be strengthened by the production of fertilisers containing S (APS, others). For special crops where produce quality is a major factor, production of NPK fertilisers containing K through potassium sulphate could be explored. In general efforts to meet the S needs of S-deficient areas need to be strengthened.

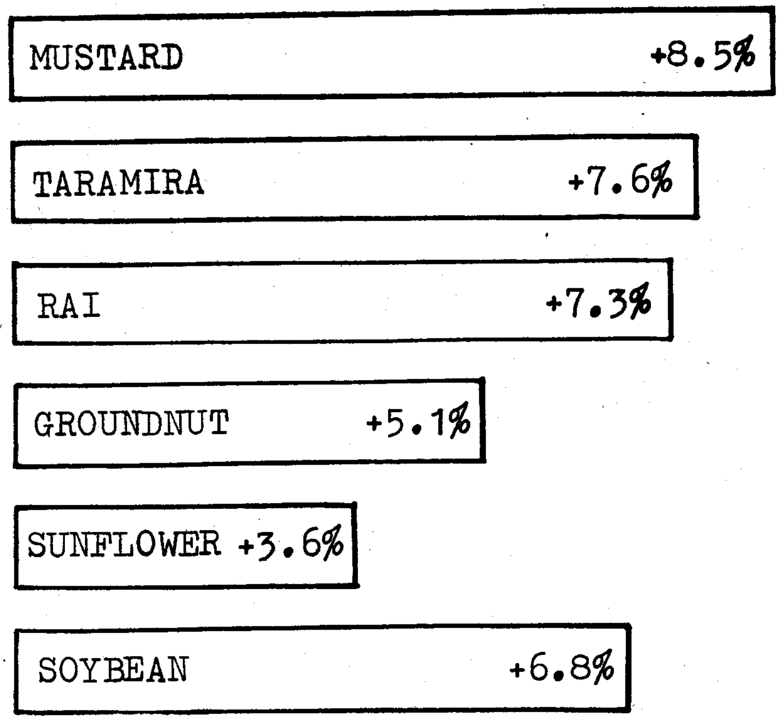

Figure 6—Impact of sulphur on the oil content of oilseeds. Averaged data from several Indian reports.

CONCLUSION

Even if sulphur has traditionally been categorised as a secondary nutrient, it is of primary practical importance for Indian agriculture. Sulphur has much in common with NPK. Its dynamics in soil and reactions in plant are similar to N, it is required by plants in amounts similar to P, and in terms of monetary value, it can be compared with K. A number of areas for research and promotion of S are listed elsewhere (18) and need not be repeated.

What is now required is to (i) delineate S-deficient areas as clearly as possible (ii) develop field based, well-tested S recommendations, (iii) pass on proven results of research to extension networks, T&V system and incorporate them in the package of practices, (iv) take steps to ensure that S-deficiencies are corrected and not neglected, (v) take S-content of fertilisers into account while formulating fertiliser allocation plans, (vi) develop area-wise programme for monitoring S additions and removals through various channels, (vii) strengthen soil and plant analysis programmes for giving sound advice on S management, (viii) development and field testing of new materials containing S and (ix) develop and disseminate educational and training materials on S for field workers.

REFERENCES

1. Aulakh, M. S., Pasricha, N. S. and Dev, G., *Fert. News,* 22 (9), 32-36 (1977).
2. Bhat, S. S. and Ranganathan, V., Planter's Chronicle, 529-531 (1981).
3. Das, S. K. and Datta, N. P., *Fert. News*, 18 (9), 3-10 (1973).
4. Dev, G. and Arora, C. L., Proc. FAI (NRC) Seminar, Jaipur, 135-146 (1984).
5. Dev, G. and Kumar, V., Secondary nutrients, in Review of Soil Research in India (Part I), Indian Society of Soil Sci., 342-360 (1982).
6. Ghosh, A. B., *Fert. News,* 25 (12), 36-39 (1980).
7. Jain, G. L., Sahu, M. P. and Somani, L. L., Proc. FAI (NRC) Seminar, Jaipur, 147-174 (1984).

Table 6—Effect for accounting for the sulphur present in fertilisers on the per unit retail price of N, P and K—an illustration

Fertiliser	Nutrients (kg/tonne)	Retail price (Rs./tonne)	Cost/kg NPK (Rs)*		
			Ignoring sulphur	Accounting for S	
	N — P_2O_5 — K_2O — S			@ Rs 1.75/kg	@ Rs 2.18/kg
AS	210 — 0 — 0 — 240	1650	7.9	5.9	5.4
SSP	0 — 160 — 0 — 120	950	5.9	4.6	4.3
SOP	0 — 0 — 500 — 180	2100	4.2	3.6	3.4
APS	200 — 200 — 0 — 150	2600	6.5	5.8	5.7

*Fertiliser retail prices are as revised on January 31, 1986.

Price of S @ Rs 1.75/kg S is as in gypsum.

Price of S @ Rs 2.18/kg S is as given to fertiliser industry as a raw material.

8. Kanwar, J. S. and Mudahar, M. S., *Fert. News,* 30 (11), 37-54 (1985).

9. Kanwar, J. S. and Randhawa, N. S., Micronutrient research in soils and plants in India (A review), Tech. Bull. No. 50, Indian Council of Agril. Research, pp. 185 (1974).

10. Nad, B. K. and Goswami, N. N., *Indian J. Agric. Sci.,* 54 (7), 569-572 (1984).

11. Nambiar, K. K. M. and Ghosh, A. B., Highlights of a longterm fertiliser experiment in India (1971-82), Research Bulletin, No. 1, Longterm Fertiliser Experiments Project (ICAR), pp. 100 (1984).

12. Shinde, D. A., Agronomy of Sulphur in Madhya Pradesh (manuscript).

13. Singh, H. G., *Indian Fmg.,* 21 (1), 212-213 (1971).

14. Stevenson, F. J., Cycles of Soils, John Wiley & Sons, pp. 380 (1986).

15. Takkar, P. N. Sulphur in Indian soils. Paper presented at the International Symposium on Sulphur in Agricultural Soils, Dhaka (1986).

16. Tamil Nadu Agricultural University. National Seminar on Sulphur in Agriculture, Abstracts (1985).

17. Tandon, H. L. S., Sulphur in Indian agriculture—an assessment. Paper presented at the International Symposium on Sulphur in Agricultural Soils, Dhaka, Bangladesh (1986a).

18. Tandon, H. L. S., Sulphur Research and Agricultural Production in India (2nd Edition), Fertiliser Development and Consultation Organisation, New Delhi, pp. 80 (1986b).

19. The Sulphur Institute, Sulphur—The fourth major nutrient, The Sulphur Institute, Washington, DC., pp. 52 (1982).

20. Tiwari, K. N., Nigam, V. and *Sci.,* 31 (2), 245-249 (1983). Pathak, A. N., *J. Indian Soc. Soil Sci.,* 31 (2), 245-249 (1983).