

Sulfur availability from elemental S coated fertilisers

Joachim Pitala¹ and Graeme Blair²

¹ PNG University of Natural Resources and Environment, Agriculture Department, PMBS, Kokopo, East New Britain Province Papua New Guinea

² Agronomy and Soil Science, School of Environmental and Rural Science, University of New England, Armidale, NSW 2350, gblair@une.edu.au

Abstract

A glasshouse study was undertaken on an sulphur (S) deficient soil to examine the availability of S to flooded rice when elemental S (S⁰) was coated by various means onto the surface of triple superphosphate. The experiment consisted of a factorial combination of 6 sources of fertiliser S materials [Goldphos10 (GP10), UNE1, UNE2, TSP+S⁰f, TSP+S⁰m and TSP+S⁰c, and a control] with 3 replications. A straw and grain yield response was recorded for all fertilisers. Among the fertilisers GP10 produced a significantly lower grain yield, tops S content and fertiliser S recovery than the other fertilisers. Although no significant difference in straw or grain yield was recorded between the different S particle size coatings there was a lower S content and % fertiliser S recovery in the coarse treatment compared to the fine and medium. The lower yield with GP10 compared to the fertilisers coated with a similar particle size elemental S (TSP+S⁰f, TSP+S⁰m) suggests that the chemical binding used to produce GP10 inhibited S oxidation.

Keywords

Oxidation, rice, sulphur, TSP.

Introduction

There is a growing demand worldwide for sulfur (S) containing fertilisers because of the increasing incidences of S deficiency caused by extensive and popular use of high analysis fertilisers such as mono-ammonium phosphate (MAP), triple superphosphate (TSP) and di-ammonium phosphate (DAP) that contain little or no S (Blair 2002). Crop responses to applied S have been reported in all regions from temperate to tropical climates (Blair 1979; Eriksen 2008; Liu et al. 2014). Sulfur may severely limit crop yield and impair the quality of agricultural products (Blair et al. 1994; Fageria et al. 2011). However, increasing freight and spreading costs have focused attention on fertiliser manufacturers to produce products with high nutrient density (Till 2010).

Producers of fertilisers such as MAP, DAP and TSP are often reluctant to alter the manufacturing process in their large plants to include nutrients such as S and Zn and coating of the finished fertiliser is an alternative. The high nutrient density of elemental S (100%) compared to gypsum (16% S) makes it an ideal source to add to fertiliser. However its use has been limited because of the risk of explosion during its preparation which involves dry grinding needed to produce fine particles. Recent advances in wet grinding technology (e.g. US Patents 4372872A, US8679219 B2) have reduced this hazard and it is now feasible to safely prepare fine elemental S. This can either be added during the manufacturing process or later to the finished fertiliser. The objective of this experiment was to investigate the availability of S to plants from elemental S coated on to finished fertilisers.

Methods

The surface layer (0-15 cm) of the soil was collected from a native pasture site about 100 m from the New England Highway at Uralla, NSW and dried. The Colwell P test was 17.3 mg/kg and KCl-40 S was 4.5. The soil was sieved through a 2 mm sieve prior to potting to obtain a uniform soil particle size.

The experiment was conducted from January to May, 1997 in a glasshouse at Agronomy and Soil Science, University of New England, NSW, Australia. The experiment consisted of a factorial combination of 6 sources of fertiliser S materials [Goldphos10 (GP10), UNE1, UNE2, TSP+S⁰f, TSP+S⁰m and TSP+S⁰c, and a control] with 3 replications. Details of the fertilisers used are presented in Table 1. These treatments were arranged in a randomized complete block design. UNE1 was made using 10% sodium lignosulfonate as the binder and UNE2 was made using the same binder and the coat was hardened during the drying process by blowing warm air into the drum. GP10 is a commercial S coated TSP (Goldphos10) which was

manufactured by Hi-Fert Pty Ltd, Australia. Information booklet (No.8) on Goldphos by Hi-Fert Pty Ltd (undated) states that “GP10 is made by milling elemental S to <250 µm and chemically bonding it onto TSP granules”. Liquid ammonium sulfate was used as the binder. To obtain the different particle sizes of 53-154 µm (fine), 154-263 µm (medium) and 263-328 µm (coarse), S^o was sieved through the required sieve sizes by wet-sieving. TSP (20% P) and GP10 granules between 2.0-2.8 mm in diameter were used in the experiment. The TSP granules were coated with the S^o by mixing 20 g of S with 10 mL of 10% calcium lignosulfonate to make a paste. To obtain a good coated fertiliser the mixture was transferred to a rotating drum and a slightly warm air current blown over the granules as they were being coated.

The S and P concentration of the coated fertilisers (Table 1) was determined using the combined phosphorus and sulfur digest method for soils and fertilisers of Till et al. (1984). The S and P rates used in the experiment were 10 kg S/ha and 46 kg P/ha. P was balanced between treatment by adding TSP where necessary.

Prior to potting into 15 cm diameter pots each 1.85 kg of soil was labelled with 0.893 MBq of carrier free ³⁵S. Immediately after the application of the radioactive solution, 50 mL of deionized water was added and mixed thoroughly with the soil. The labelled soil samples were then stored to incubate for 3 weeks which allowed the equilibration of ³⁵S with the native sulfate and rapidly turning over organic S in the soil (Dana 1992). This allowed the reverse dilution calculation method of Shedley et al. (1979) to be used to determine fertiliser S uptake. The pots were placed in a glasshouse, watered with deionized water to field capacity and basal nutrients equivalent to rates of 100 kg N/ha and 10 kg K/ha applied as Urea and KCl applied one day later.

After one week the fertilisers were applied by placing the granules uniformly on the soil surface. Flooding was imposed by adding deionized water to a depth of 4 cm above the soil surface and maintained at that level until during the ripening period, when watering was terminated. Nitrogen was reapplied as urea at 40 kg/ha at 30 and 45 days after transplanting (DAT) and 20 kg K/ha reapplied as KCl at 35 DAS.

Table 1 P and S concentration and method of making the fertilisers added.

Fertiliser	% P	% S	Elemental S particle size (mm)	Binder
GP10	18.0	10.0	<250	Chemical
UNE1	20.0	10.0	10	Lignosulfonate (LS)
UNE2	17.4	9.7	10	LS+heat
TSP + S ^{of}	20.7	10.3	53-154	LS
TSP + S ^{om}	20.3	11.3	154-263	LS
TSP + S ^{oc}	20.3	11.6	263-328	LS

At maturity the plants were cut 1 cm above the soil surface and grain and straw separated and dried at 80° C for 48 hours and after cooling, their dry weights were recorded and ground to pass a 1 mm screen. Plant analysis were undertaken using HClO₄ / H₂O₂ sealed chamber method of Anderson and Henderson (1986). Total S was measured by Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) and ³⁵S content was measured by Liquid Scintillation Counting (Till et al. 1984). The reverse dilution technique of Shedley et al. (1979) was used to calculate the recovery of fertiliser S by the rice plants. In this technique the specific radioactivity (SR, MBq/mgP) data is converted to specific radioactivity ratio (SRR). SRR is the ratio of the treatment to the control SR. The proportion of S in the sample derived from the fertiliser is estimated as (1-SRR) × 100%.

The data were analyzed by the analysis of variance using the NEVA Version 3.3 computer program (Burr 1982). Mean separation for each treatment was determined using the Duncan's Multiple Range Test (DMRT), where treatment effects observed at a probability level of 5% or less are considered significant.

Results and Discussion

A straw and grain yield response was recorded for all fertilisers (Table 2). Among the fertilisers GP10 produced a significantly lower grain yield, tops S content and fertiliser S recovery than the other fertilisers.

Similar results were found by Dana et al. (1994) and Blair et al. (1994), who found that the application of GP10 resulted in significantly lower plant and grain yields than other S containing fertilisers. Sulphur is required early in the growth of rice plants and if it is limiting during early growth the final yield is reduced (Blair et al. 1979). Dana et al. (1994) and Blair et al. (1994) found that the application of UNE1 prepared using calcium lignosulfonate as the binder generally gave consistently higher yields than other coated fertilisers prepared using polyvinyl alcohol binder.

No significant difference in straw or grain yield was recorded between the different S particle size coatings however there was a lower S content and % fertiliser S recovery in the coarse treatment compared to the fine and medium. The lower yield with GP10 compared to the fertilisers coated with a similar particle size elemental S (TSP+S[°]f, TSP+S[°]m) suggests that the chemical binding used to produce GP10 inhibited S oxidation.

Table 2. Dry weight (g/pot), S content (mg/pot) of straw and grain and % total fertiliser S recovery.

	Dry weight (g/pot)			S content (mg/pot)			Fertiliser S recovery (%)
	Straw	Grain	Total	Straw	Grain	Total	
Control	6.9 a	7.1 a	14.0 a	3.0	5.0	7.9 a	
GP10	11.7 b	8.3 a	20.0 b	6.0	5.8	11.8 b	17.8
UNE2	12.6 b	12.1 b	24.7 c	7.2	10.5	17.7 c	49.2
UNE1	13.4 bc	11.7 b	25.1 c	10.2	12.1	22.2d	73.6
TSP+S [°] f	13.3 bc	12.7 b	26.0 cd	9.2	12.3	21.5 d	68.8
TSP+S [°] m	12.8 b	12.2 b	25.0 c	9.6	12.0	21.6 d	70.2
TSP+S [°] c	13.2 bc	12.0 b	25.2 c	7.4	10.6	18.0 c	50.4

The rapid oxidation of elemental S observed in this flooded soil study contrasts to earlier studies (Janzen and Bettany 1987; Nevell and Wainright 1987) which demonstrated that S[°] oxidation is favoured at field moisture capacity. However, Dana et al. (1994), found that oxidation of S[°] was rapid under both flooded and non-flooded conditions. Within a flooded soil, there are aerobic and anaerobic zones, therefore, oxidation and reduction reactions can occur at the same time in the different parts of the flooded soil (Blair and Lefroy 1987). Rice plants generally occupy a large volume of the planted soil so that oxidized zones occur which allow for the growth and metabolism of aerobic microorganisms (Freney et al. 1982). In the present experiment, flooding of the soil favoured the dispersion of the elemental S into the surrounding soil making it accessible to S oxidising microorganisms.

Conclusion

The method of binding elemental S to finished fertilisers has been shown to have a bigger effect on S oxidation, and hence plant S uptake, than particle size over a wide range of particle sizes.

References

- Anderson DL and Henderson LJ (1986). Sealed chamber digestion for plant nutrient analyses. *Agronomy Journal* 78, 837-839.
- Blair GJ (1979). Sulfur in the Tropics. Technical Bulletin. IFDC-T12, International Fertilizer Development Center, Muscle Shoals, Alabama, USA.
- Blair GJ. (2002). Sulphur fertilisers: a global perspective. In: Proceedings of the International Fertiliser Society No. 498, pp. 1-36. The International Fertiliser Society, Cambridge, UK, 16-17 December 2002.
- Blair GJ, Dana M and Lefroy RDB (1994). A glasshouse evaluation of sulfur fertiliser sources for crops and pastures. II. A comparison of sulfur coated triple superphosphates and gypsum. *Australian Journal of Agricultural Research* 45, 1517-1523
- Blair GJ and Lefroy RDB (1987). Sulphur cycling in tropical soils and the agronomic impact of increasing use of S free fertilizers, increased crop production and burning of crop residues. In: Proceedings of the Symposium on Fertilizer Sulphur Requirements and Sources in Developing Countries of Asia and the Pacific. Bangkok, 26-30 Jan., 1987. pp 12-17 FADINAP, FAO, The Sulphur Inst., ACIAR.

- Blair GJ, Momuat EO, Mamaril CP (1979). Sulfur nutrition of rice. II. Effect of source and rate of S on growth and yield under flooded conditions. *Agronomy Journal* 71, 477-480.
- Burr EJ (1982). NEVA User's Manual. Analysis of variance for complete factorial experiments. The University of New England, Armidale, NSW.
- Dana M, Lefroy RDB and Blair GJ (1994). A glasshouse evaluation of sulfur fertiliser sources for crops and pastures. I. Flooded and non-flooded rice. *Australian Journal of Agricultural Research* 45, 1497-1515.
- Eriksen J (2008). Soil Sulfur Cycling in Temperate Agricultural Systems. In: Jez J (ed) *Sulfur: A Missing Link between Soils, Crops, and Nutrition*. Agronomy Monographs, Vol 50. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America, Madison, WI, pp 25-44.
- Fageria NK, Baligar VC and Jones CA (2011). *Growth and mineral nutrition of field crops*. 3rd edition. CRC Press, Boca Raton, FL, USA.
- Freney JR, Jacq VA and Baldensperger FJ (1982). The significance of the biological sulfur cycles in rice production. In Dommergues, Y.R., and Diem, H.G. (eds.), *Microbiology of Tropical Soils and Plant Productivity*. pp 271-317. Martinus Nijhoff/Dr W. Junk Publisher, The Hague.
- Janzen HH and Bettany JR (1987). Oxidation of elemental sulfur under field conditions in Central Saskatchewan. *Canadian Journal of Soil Science* 67, 609-618.
- Liu S, Huang D, Chen A, Wei W, Brookes PC, Li Y and Wu J (2014). Differential responses of crop yields and soil organic carbon stock to fertilization and rice straw incorporation in three cropping systems in the subtropics. *Agriculture Ecosystems and Environment* 184, 51-58.
- Nevell W and Wainright M (1987). Influence of soil moisture on sulphur oxidation in brown earth soils exposed to atmospheric pollution. *Biology and Fertility of Soils* 5, 209-214.
- Shedley CD, Till AR and Blair GJ (1979). A radiotracer technique for studying the nutrient release from different fertiliser materials and its uptake by plants. *Communications in Soil Science and Plant Analysis* 10, 737-745.
- Till AR (2010). *Sulphur and Sustainable Agriculture*. International Fertilizer Industry Association. Paris.
- Till RA, McArthur GS and Rocks RL (1984). An automated procedure for the simultaneous determination of sulphur and phosphorus and of radioactivity in biological samples. In: *Proceedings of Sulphur-84*, Alberta, Canada, 3-6 June, pp. 649-660. Sulphur Dev. Inst., Canada (SUDIC), Calgary, Canada.