# The effectiveness of alternative sources of fertiliser sulfur for plants

Nguyen Tien Hai[1], **Graeme Blair**[2], Chris Guppy[2] and Michael Faint[2]

[1] Institute of Agricultural Sciences for Southern Vietnam, Ho Chi Minh City, Vietnam
[2] Agronomy and Soil Science, University of New England, Armidale NSW, Australia. gblair@une.edu.au

**Abstract**

Sulfur (S) can be added to fertiliser either during, or post manufacture of the primary fertiliser. The easiest way to add S is as prills of elemental S/bentonite. Several processes are available to prepare these and the question arises as to their effectiveness in supplying S to plants.
This was evaluated using a range of commercially available products and comparing the S release rate from them with that from mono-ammonium phosphate (MAP) coated with both elemental and sulfate S, and from sulfate S from double superphosphate either alone or supplemented with S/bentonite prills. The results show that no form of uncrushed S/bentonite tested could supply S to plants in the short term. Crushing the prill resulted in a 10-fold increase in apparent fertiliser S recovery by the plant. Adding S/bentonite to double superphosphate resulted in an approximate 5% recovery of the added S.Coating or a mixture of elemental and sulfate S on the surface of the MAP granule was agronomically acceptable.

**Key words:** sulfur, sulfate, elemental sulfur, bentonite fertiliser

## Introduction

Freight and spreading costs make up an increasing proportion of on-ground pasture fertiliser costs. Because of this there has been a move away from single superphosphate to fertilisers with higher nutrient density such as double and triple superphosphate, monoammonium phosphate (*MAP*) and diammonium phosphate (*DAP*) (Blair 2008).
Sulfur (S) bentonite potentially offers a convenient way to add S to fertilisers but previous work has shown its effectiveness in supplying sulphate to plants to be questionable. Commonly S bentonite prills contain 10% bentonite but Boswell and Swanney (1986) found that prills with 40% bentonite provided S to plants for a considerably longer period than those with 10%. Bentonite adds considerably to the cost of the prill and those with high quantities of bentonite are difficult to store because of swelling and dispersion during storage, so manufactures keep quantities added to a minimum.
This glasshouse study was undertaken to compare the performance of a range of S/bentonite products with a range of elemental S/double superphosphate based products and an experimental S coated MAP.

## Materials and Methods

Soil of granitic origin (Tenosol) was collected from the Kirby Experimental Station of the University of New England, Armidale, Australia. The soil was collected from the 0-30 cm horizon, dried, ground, and passed through a 2.0 mm sieve. The characteristics of the soil are presented in Table 1**Error! Reference source not found.**.

**Table 1. Kirby soil characteristics**

| Soil characteristic | Value |
|---|---|
| pH (1:5 water) | 6.04 |
| Clay (% oven-dry weight) | 45.3 |
| Silt (% oven-dry weight) | 23.3 |
| Fine sand (% oven-dry weight) | 22.5 |
| Coarse sand (% oven-dry weight) | 8.9 |
| Total S (µg/g) | 204.2 |
| KCl-40 S (µg/g) | 1.3 |

PVC plastic pots with an inside diameter of 15 cm and 12 cm deep were filled with 1.3 kg of soil in a plastic bag to prevent leaching and the solid fertiliser treatments shown in Table 2 were mixed with 200 g of soil and placed on top of the 1.3 kg soil. All treatments received 20 kg S/ha based on pot surface area. N, P, K and Mg were applied to all treatments at rates of 80, 70, 20 and 5 kg/ha, respectively as ammonium nitrate, DAP, KCl, and $MgCl_2$. N was balanced between treatments.

The WF SB was sourced from Wengfu (WF) PastureKing fertiliser which is double superphosphate supplemented with S/Bentonite prills.

DEVCO NutraGold is an S/Bentonite pastille containing sulfur particles in the 20-500 micron range.
The MAP modified treatment is MAP coated with 2 S sources (1/3 as sulfate, 1/3 as elemental <75µm, 1/3 elemental 75-100µm).

*Crop management*

Four day old-germinated seeds of maize were sown in each pot to a depth of 2-2.5 cm. The pots were watered to near field capacity within one week. After one week plants were thinned to two healthy plants per pot. The moisture content was adjusted to field capacity and maintained with tap water until the harvest 21 days after planting. The temperature of the glasshouse was maintained at 20-30$^{o}$C throughout the experiment. Additional urea at 50 kg N/ha was applied after 14 days.

For the second crop three, four day-old germinated seeds were sown on the day after the first crop was harvested and after one week the plants were thinned to two per pot. No additional S was applied and an additional 50 kg N/ha was applied after 19 days and again after a further 12 days. The temperature and soil moisture was maintained as in the first crop. The plant tops harvested 40 days after sowing.

*Sampling and analytical techniques*

The plant tops were cut approximately 1.5 cm above the soil surface, dried at 60$^{0}$C until a constant weight and ground to pass a 1 mm sieve. A 0.2 g subsample was digested in a sealed container with a mixture of 70% perchloric acid and 30% hydrogen peroxide (Anderson and Henderson, 1986). Total sulfur in plant digests was determined on an Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES).

*Statistical analysis*

The data were analyzed by analysis of variance (ANOVA) at a probability level of 5% using the NEVA analysis of variance program (Burr, 1982) and means were separated using the Duncan's Multiple Range Test (DMRT) at $P<0.05$.

**Table 2. Composition of fertilisers evaluated**

| Fertiliser | Analysis (%) | | | | |
|---|---|---|---|---|---|
| | N | P | S | Sulfate | Elemental S |
| Control | 0 | 0 | 0 | 0 | 0 |
| WF SB | 0 | 0 | 90 | 0 | 90 |
| DEVCO Nutragold | 0 | 0 | 90 | 0 | 90 |
| DEVCO Nutragold crushed | 0 | 0 | 90 | 0 | 90 |
| WF PastureKing | 0 | 15.7 | 4.6 | 4.6 | 0 |
| WF PastureKing 17 | 0 | 13.0 | 3.9 | 3.9 | 13.1 |
| MAP modified | 12.9 | 11.9 | 9.7 | 3 | 5.9 |

## Results

*Harvest 1*

There was no significant difference in shoot dry matter yield or apparent S recovery among the two sole S/bentonite sources (WF SB, DEVCO Nutragold) (Table 3) and these were not significantly different from the control. Crushing the DEVCO Nutragold resulted in a significant increase both parameters.

In harvest 1 yield and % apparent S recovery with WF PastureKing 17, which contains both elemental and sulfate S, was equal to DEVCO Nutragold crushed and MAP modified.

The shoot dry matter yield in the crushed DEVCO Nutragold treatment was not significantly different from the PastureKing treatments which did not differ from each other and were significantly higher than the control. The S content and the apparent S recovery were higher in the DEVCO Nutragold crushed treatment than in the PastureKing treatments (Table 3). The highest yield, S content and apparent S recovery was recorded in the MAP modified treatment.

**Table 3. S content and % apparent S recovery at harvests 1, 2 and total**

| Fertiliser | Harvest 1 | | Harvest 2 | | Total |
|---|---|---|---|---|---|
| | Shoot DM (g/pot) | % apparent S recovery | Shoot DM (g/pot) | % apparent S recovery | % apparent S recovery |
| Control | 3.76 b* | | 0.35 f | | |
| WF SB | 3.95 b | 0.6 d | 1.23 cde | 2.1 de | 2.8 d |
| DEVCO Nutragold | 4.27 b | 0.0 d | 0.95 def | 2.2 de | 4.1 d |
| DEVCO Nutragold crushed | 6.90 a | 26.5 a | 4.25 a | 16.9 a | 43.4 a |
| WF PastureKing | 8.20 a | 16.5 b | 1.49 cd | 10.5 c | 27.0 c |
| WF PastureKing 17 | 7.87 a | 19.0 b | 1.60 cd | 12.8 bc | 31.7 b |
| MAP modified | 8.13 a | 28.7 a | 3.47 a | 14.3 ab | 42.9 a |
| lsd | 1.18 | 4.7 | 0.76 | 3.4 | 6.6 |

* numbers within a column followed by the same letter are not significantly different at $p=0.05$

***Harvest 2***

All treatments except the DEVCO Nutragold produced significantly higher shoot dry matter yields than the control at harvest 2 (**Error! Reference source not found.**) and, as in harvest 1, crushing the DEVCO Nutragold resulted in a significant increase in tops dry matter yield and the yield in this treatment was higher than in all other treatments. There was no significant difference between the two S/bentonite treatments in either S content or % apparent S recovery. As in the first harvest crushing the DEVCO Nutragold resulted in a significant increase in both S content and % apparent S recovery. There was a significantly higher % apparent S recovery in the WF PastureKing 17 treatment than the other PastureKing treatment which most likely reflects the release of some S from the elemental component of this product.

When data for % apparent S recovery is considered over 2 harvests DEVCO Nutragold crushed and MAP modified have the highest values, which exceeded 40%. The high value for the DEVCO Nutragold crushed treatment indicates that elemental S oxidation is proceeding rapidly and suggests that the low recoveries in the un-crushed S bentonite products is due to either a lack of oxidation in the concentrated zone in and around the prill or insufficient contact between the roots and the prill. At an S application rate of 20 kg/ha, as made in this experiment, only 2 prills are added/pot. This is a similar problem in field applications at the commonly used 10 kg S/ha as shown in Table .

The 11.1% higher % elemental S recovery in the WF17 product than in PastureKing indicates that roots have accessed oxidized elemental S. The higher than expected recovery of elemental S based on the WF SB treatment suggests that the presence of the sulfate in the products allowed the development of a root system capable of accessing the S oxidized around the prill. When all the S is applied in an elemental form in the prill such development of a root system appears not to take place hence the low S uptake.

In addition to the poor S oxidation from the S/bentonite products the on-ground granule distribution is poor because of the concentration of the S within the small granule. The difference in density is illustrated in Table 4.

**Table 4. Distribution of S fertiliser when applied at 10 kg S/ha**

| | Broadcast (granules/$m^2$) | Drilled (granules/m row) |
|---|---|---|
| S bentonite | 25 | 5 |
| SSP or PastureKing | 250 | 50 |

These results are supportive of the findings of Degryse et al. (2016) found that the half-life of oxidation for powdered ES at 25°C was around 35 days, 140 days for MAP+ES granules, and around 1150 days for ES prills.

## Conclusion

This experiment was conducted on a very sulfur deficient soil which required the fertiliser to provide a rapid supply of S to the growing plant. It showed that when the S bentonite prills were applied alone the S they contained was not available to the plant either because of lack of access by the soil bacteria to the S in the prill or to the spatial distribution of the S in the pot. When S/ bentonite prills were added to PastureKing as in WF 17 the plant was able to access the elemental S in the prill indicating that root growth was stimulated by the presence of sulfate resulted in contact between the growing root and the S oxidized from the prill. Coating of a mixture of sulfate and elemental S onto the surface of MAP, as in MAP modified, was shown to be an effective means of providing short and long term S.

## References


Anderson DL and Henderson LJ (1986). Sealed chamber digestion for plant nutrition analyses. Agronomy Journal, 78**,** 937-939.

Blair G (2008). Single Superphosphate, a Scenario Slowly Passing. Proc 14th Australian Agronomy Conference, Adelaide.http://agronomyaustraliaproceedings.org/index.php/11-2008/78-2008-concurrent-papers-plant-nutrition

Boswell CC and Swanney B (1986). Alternative sulphur fertilisers in New Zealand. Proceedings of the New Zealand Grassland Association 47: 233-242.

Burr EJ (1982). NEVA User's Manual. Analysis of variance for complete factorial experiment: The University of New England Computer Centre, Armidale, NSW, Australia

Degryse F, Babasol A, Baird R, da Silva RC and McLaughlin M (2016). Oxidation of Elemental Sulfur in Granular Fertilizers Depends on the Soil-Exposed Surface Area. Soil Science Society of America Journal 80:294–305.