

# Isotopic determination of sulfur (S) availability from S coated mono-ammonium phosphate

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## Abstract

An evaluation of three novel elemental sulfur (S<sup>0</sup>) coated mono-ammonium phosphate (MAP) products ((MAP with coarse (75-100 $\mu$ m) S<sup>0</sup> coating (MAP75), MAP with fine (17-24 $\mu$ m) S<sup>0</sup> coating (MAP17), and MAP with 1/3 coarse S<sup>0</sup>, 1/3 fine S<sup>0</sup>, and 1/3 sulfate coating (MAPM)) was undertaken in an intact core pot trial using red clover (*Trifolium pratense*) and compared with single superphosphate (SSP). Sulfur (S) uptake from coated S sources was not significantly different ( $p < 0.05$ ) from SSP after 120 days of growth. Between 34% and 53% plant S was derived from the fertiliser sources. There was no significant difference in % fertiliser recovery between MAPM and SSP at either harvest and at both harvests fertiliser S recovery was in the order MAP < MAP75 < MAP17 < MAPM < SSP.

The key finding was that a MAP coated with 1/3 sulfate and 2/3 S<sup>0</sup> was able to supply clover with the same amount of S, at the same rate, as SSP over 120 days. Under leaching conditions, this availability may result in slower, longer release of S as the coarser fraction slowly meets plant demands and protects added S from leaching.

## Key Words

Elemental sulfur, oxidation, single superphosphate, New England, *Trifolium pratense*

## Introduction

The shift from single superphosphate (SSP) to phosphorus (P) sources with less sulfur (S) such as triple superphosphate has increased the incidence of S deficiency in New England pastures (Blair 2008). Although SSP has historically been the main fertiliser used in the New England, S<sup>0</sup> may be a cheaper more effective alternative S source (Blair 2008). Microbial oxidation is required to convert S<sup>0</sup> to sulfate before plant uptake. The rate of release is largely determined by particle size and factors affecting microbial activity including temperature and moisture (Solberg *et al.* 2005). As climatic constraints reduce S<sup>0</sup> oxidation in the New England, the reduction of S<sup>0</sup> particle size to <150 $\mu$ m is required to provide sufficient sulfate for plant demand (Weir *et al.* 1963). In coarse textured soils, sulfate is susceptible to leaching and hence strategies that may slow the release of sulfate from S<sup>0</sup> may increase the efficiency of applied S. Various models have been developed to calculate a given release of S from S<sup>0</sup> based fertilisers at particular environmental parameters and particle sizes (McCaskill and Blair 1989). This experiment aimed to test the relative availability of S from different sulfate and S<sup>0</sup> coatings on MAP to determine the fraction contributing to S fertiliser release from three novel S fertilisers.

## Methods

### *Pot trial preparation and site background*

A pot trial was conducted at the University of New England's (UNE) glasshouse facility, Armidale New South Wales (NSW). The coarse textured Grey Tenosol (Isbell 2002) (pH: 5.8) used in the trial was sourced from the UNE Newholme research property, approximately 15 km north of Armidale NSW. Twenty four 30 cm ( $\phi$ ) x 30 cm (h) steel, cylindrical undisturbed intact soil cores weighing approximately 40 kg were collected from a perennial, dormant, pasture, with no known fertiliser history. The native pasture composition included *Themeda australis*, *Austrodanthonia* spp., *Poa sieberana* and *Bothriochloa macra*.

### *Soil treatment and application*

Pots were arranged in a randomised factorial design consisting of six treatments with four replicates. Treatments included a control, SSP (contains 12% S as sulfate), MAP (containing 1.6% S as sulfate), MAP75 with 75-100 $\mu$ m S<sup>0</sup> coating (100% S), MAP17 with 17-24 $\mu$ m S<sup>0</sup> coating (100% S) and MAPM consisting of 1/3 75-100 $\mu$ m, 1/3 17-24 $\mu$ m and 1/3 sulfate coating (containing 8.9% S). Reverse dilution methodology was used to label native S as radioactive commercial fertilisers are unavailable. When carrier

free  $^{35}\text{SO}_4$  radioactive S isotope ( $^{35}\text{S}$ ) is applied two assumptions are made. First, the radiotracer, when applied, is distributed throughout the native S pool, hence all native S from which the plant sources S, is uniformly labeled. Second, the application of unlabelled fertiliser S does not affect the movement of tracer S between S pool fractions. 250 mL of  $^{35}\text{S}$  with a half life of 87 days was added to each pot at 596 mCi/ml. Intact cores were allowed to equilibrate for 50 days prior to S fertiliser application. An application rate of 20 kg S/ha was used to adequately provide S to ensure prolonged, non S deficient conditions to evaluate relative S release. Phosphorus (P) and nitrogen (N) application was balanced using AeroPhos (26% P) and urea (46% N) respectively. Potassium (K) was added to each pot at 50 kg K/ha as a KCl solution, molybdenum was added as ammonium molybdate and boron (B) as boric acid at < 1 kg nutrient/ha with the K solution. Red clover (*Trifolium pratense*) seed was broadcasted over each pot at > 20 kg/ha following surface nutrient application. After broadcasting, seed and fertiliser were incorporated into the first 2 cm of soil. Based on pot weight each pot was watered to no more than 90% of maximum field capacity each week.

### Harvest and analysis

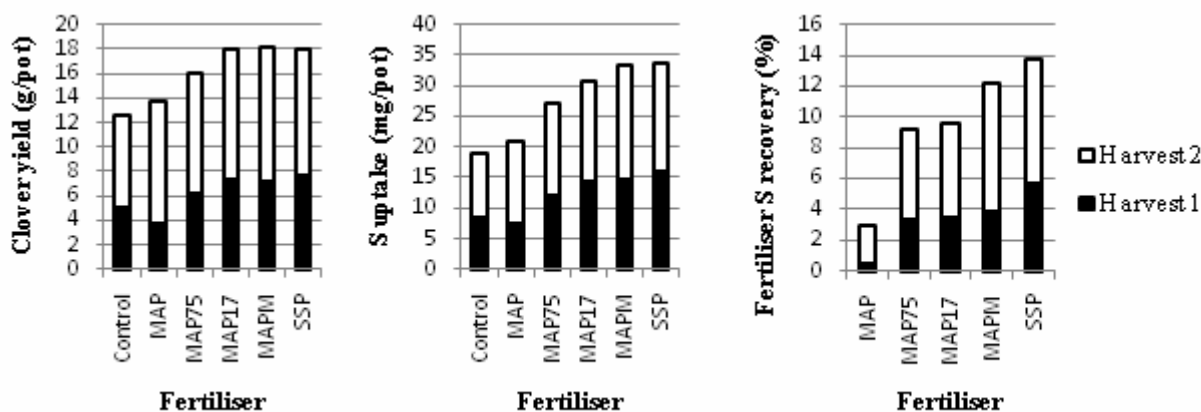
Clover tops were removed at 2cm above the soil surface after 60 and 120 days of growth, placed in paper bags and oven dried at 105°C for 7 days. Samples were digested using the sealed chamber digestion method and nutrient content was determined using inductively coupled plasma-atomic emission spectrometry (ICP-AES), with plant  $^{35}\text{S}$  content determined by liquid scintillation counting following scintillant addition (Anderson and Henderson 1986; Till *et al.* 1984).

### Results

The soil used was responsive to S with significant growth increases to all S additions (Figure 1). All S sources took up more S than the control and MAP treatments at both harvests and there were no differences between MAP17, MAPM and SSP at either harvest.

Less than 40% of the S in the clover in the MAP S treatments was derived from the fertiliser at the first harvest (data not shown) which compares with 50% from SSP. There were no significant differences in the % of S in the plant derived from the fertilisers between the MAP S treatments and SSP at the second harvest.

There was no significant difference in % fertiliser recovery between MAPM and SSP at either harvest (Figure 1) and at both harvests fertiliser S recovery was in the order MAP < MAP75 < MAP17 < MAPM < SSP.



**Figure 2. Dry matter, S uptake and the % of recovered fertiliser S of plant tops in *Trifolium pratense* at 60 days (harvest 1) and 120 days (harvest 2) of growth.**

### Discussion

Tissue S concentrations indicated that 20 kg S/ha met plant requirements for sulfate as either sulfate or fine  $\text{S}^{\circ}$  oxidation. Increasing temperatures over the growing period also provided favourable conditions for microbial oxidation of  $\text{S}^{\circ}$ , increased mineralisation and deeper root growth for S absorption (Solberg *et al.* 2005). Applications of any S fertiliser containing at least 1.6% sulfate and  $\text{S}^{\circ}$  of less than 150 $\mu\text{m}$  particle size at 20 kg S/ha will provide adequate S to meet plant S demand over 120 days. However, the key finding was that MAPM was as available in all facets as the SSP source, despite a 2/3  $\text{S}^{\circ}$  component and less than ideal initial oxidation conditions.

Sulfur recovery values were reduced by 10% in coarse and fine S<sup>o</sup> sources compared with SSP (Figure 1). Coarse S<sup>o</sup> persists longer in soils due to a lower surface area to volume ratio and consequent decrease in oxidation rate (Jones and Ruckman 1966). Sulfur oxidation in the first 60 days of plant growth was also reduced due to lower temperatures and lag times in microbial population growth (Solberg *et al.* 2005).

### Conclusion

There was no difference between a S source consisting of 2/3 S<sup>o</sup> and 1/3 sulfate and a 100% sulfate SSP source with respect to clover growth and S uptake over 120 days. The high (20 kg S/ha) rate of S applied and the closed nature of the trial minimised the opportunity to examine longer term release rates, however there was evidence in this trial that a combination of sulfate and S<sup>o</sup> sources is able to supply equivalent and sufficient S for plant growth under New England conditions.

### References

- Anderson DL, Henderson LJ (1986) Sealed chamber digestion for plant nutrient analyses. *Agronomy Journal* **78**, 937-939.
- Blair GJ (2008) SSP: Single superphosphate, a scenario slowly passing. *14th Australian Society of Agronomy Conference* Adelaide, South Australia.
- Isbell R (2002) The Australian soil classification revised edition. *CSIRO Publishing*.
- Jones MB, Ruckman JE (1966) Gypsum and elemental sulfur as fertilizers on annual grassland. *Agronomy Journal* **58**, 409-412.
- McCaskill MR, Blair GJ (1989) A model for the release of sulfur from elemental S and superphosphate. *Fertilizer Research* **19**, 77-84.
- Solberg ED, Malhi SS, Nyborg M, Gill KS (2005) Temperature, soil moisture, and antecedent sulfur application effects on recovery of elemental sulfur as SO<sub>4</sub>-S in incubated soils. *Communications in Soil Science and Plant Analysis* **36**, 863-874.
- Till AR, McArthur GS, Rocks RL (1984) An automated procedure for the simultaneous determination of sulphur and phosphorus and of radioactivity in biological samples. *Proceedings of Sulfur 84, Alberta, Canada* Sulfur Development Institute Canada (SDIC), Calgary, Canada, 649-660.
- Weir RG, Barkus B, Atkinson WT (1963) The effect of particle size on the availability of brimstone sulphur to white clover. *Australian Journal of Experimental Agriculture and Animal Husbandry* **3**, 314-318.