Pasture fertilisation with sulfur enhanced fertilizer

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Abstract
An evaluation of a Sulfur Enhanced Fertilizer (Thiogro) fertilizer (MAP12) was undertaken on a native pasture oversown with clover near Armidale, NSW, Australia from August 2007 to November 2008. Fertilizers (Single superphosphate (SSP), mono-ammonium phosphate (MAP), pastille DAPS (pastille) and Sulfur enhanced mono-ammonium phosphate 12 (MAP12)) were top dressed onto the sward and four harvests taken over the period. SSP and MAP12 produced higher clover yields than MAP and pastille DAPS. MAP12 was superior to SSP, particularly at the later harvests.This is an important result as clover growth is essential in the pasture both to contribute fixed N and for animal protein. Addition of S fertilizers increased the uptake of S in all treatments, except pastille DAPS. Highest uptake was with MAP12. Calculation of apparent fertilizer recovery (S uptake in S treatment - S uptake in MAP treatment)/ S applied) showed a recovery of 16% from SSP, 32% from MAP12 and no recovery from DAP pastille. The increased yield resulting from S application resulted in an increase in the apparent recovery of fertilizer P.

Key Words
Single superphosphate, elemental sulfur, oxidation, leaching.

Introduction
Elemental S is an almost ideal fertilizer as it contains 100% nutrient. The elemental S must be oxidized to sulfate (SO_4) before it is available to plants and since microorganisms carry out this process it is moisture and temperature dependent; as is crop demand for S. The rate of oxidation is also dependent on the particle size of S. This means that there is great scope to manage the release rate of SO_4 to the plant to maximize plant uptake and minimize losses by surface runoff and leaching. Research carried out by Blair *et al.* (1971) has shown that plants require S and P early in growth and that S oxidation rates are enhanced by intimate mixing of P and elemental S (Lefroy *et al.* 1995), which makes S inclusion into P containing fertilizers attractive. Shell invented the "Thiogro" process in 2001 to include microfine elemental S into DAP and MAP and a patent for this was filed in 2003 (International Publication Number WO 2004/043878 A1). A significant feature of the process is that the elemental S is finely divided and is distributed throughout the fertilizer granule. Sulfur oxidation from Thiogro SEF has been determined in plant growth chambers at the University of New England, Armidale using a carrier free $Ca^{35}SO_4$ reverse dilution technique. Ryegrass (*Lolium perenne*) and Rhodes grass (*Chloris gayana*) were grown at temperatures of 22/14 °C and 34/26 °C (14 hour day/10 hour night) respectively, for 9 weeks. At the end of the 9 week growth period an average of 23.6% of fertilizer S was recovered in the plant tops from DAP and MAP based Thiogro with no significant effect of temperature. This compares with 73.2% from gypsum in Rhodes grass and 54.1% in ryegrass. These results demonstrated the metered oxidation of the microfine elemental S at the start of growth, leaving more S for uptake at a later stage of development. However field studies were necessary to confirm release and potential benefits of Thiogro SEF.

Methods
Site and Preparation
The field trial was conducted at the University of New England Newholme Field Research Station approximately 15 km north of Armidale. The site (Smiths Rd) had little history of fertilizer application and as a consequence, native species (eg. *Bothriochloa macra* (Redgrass), *Austrodanthonia spp.* (Wallaby Grass) *Dichanthium sericium* (Queensland bluegrass), *Themeda australis* (Kangaroo Grass)*, Poa sieberana* (Tussock Grass)) dominated the pasture composition. The native grasses on the site were mowed to approximately 30 mm and glyphosate (Roundup®) applied to initiate a chemical fallow prior to topdressing the fertilizers. Initial soil analysis indicated that S (KCl-40 S - 2.1 mg/kg) and Colwell P (3.7 mg/kg) concentrations were limiting. Soil pH was 6.1 in water.

Experimental design and fertilizer treatments
The 2m x 4m plots were marked out in a randomised block design with 4 replicates. The replicates were

blocked down the slope to allow lateral movement of nutrient to be removed as a blocking factor if necessary. There were 4 different fertilizer treatments (Table 9).

Table 9. Analysis of fertilizers used

Fertilizer	N	P	Total S	Sulphate S	Elemental S
Single superphosphate (SSP)	0	8.5	11.0	11.0	0
Mono-Ammonium Phosphate (MAP)	11.0	18.2	1.6	1.6	0
Pastille DAPS (pastille)	16.2	16.6	11.3	1.3	10.0
Sulphur Enhanced Mono-Ammonium Phosphate 12 (MAP12)	11.7	15.1	11.6	3.8	7.8

Sowing and sampling

Applications of basal rates of fertilizer were applied to the plot at the time of sowing to attempt to alleviate the plant nutritional constraints allowing only S response to be observed. N and P in the forms of urea and di-ammonium phosphate (DAP) were added to the S fertilizer treatments to ensure equal amounts of both N (20 kg/ha) and P (15.9 kg/ha) were applied to each plot. Potassium (or molybdenum or boron) deficiency was suspected by day 86 of the trial, so basal applications of all suspected nutrient limitations were applied. Potassium was applied at 50 kg K/ha (as KCl), molybdenum was applied at 0.2 kg Mo/ha (as ammonium molybdate) and boron was applied at 1 kg B/ha as boric acid. Nusiral white clover (*Trifolium repens cv.* Nusiral), Seaton Park subterranean clover (*Trifolium subterraneum cv.*Seaton Park) and USA red clover (*Trifolium pratense cv.* USA) were broadcast sown over the plots at 4 kg/ha, 8 kg/ha and 8 kg/ha respectively. Water was applied to initiate germination.

The fertilizers were applied on August 21, 2007 and four harvests were carried out when there was sufficient harvestable material in the the mono-ammonium phosphate treatment which occurred 119, 153, 211 and 343 days after fertilizer application. Preceding each harvest, the pasture composition of each plot was visually estimated by three different assessors and averages were used to estimate the proportion of clover.

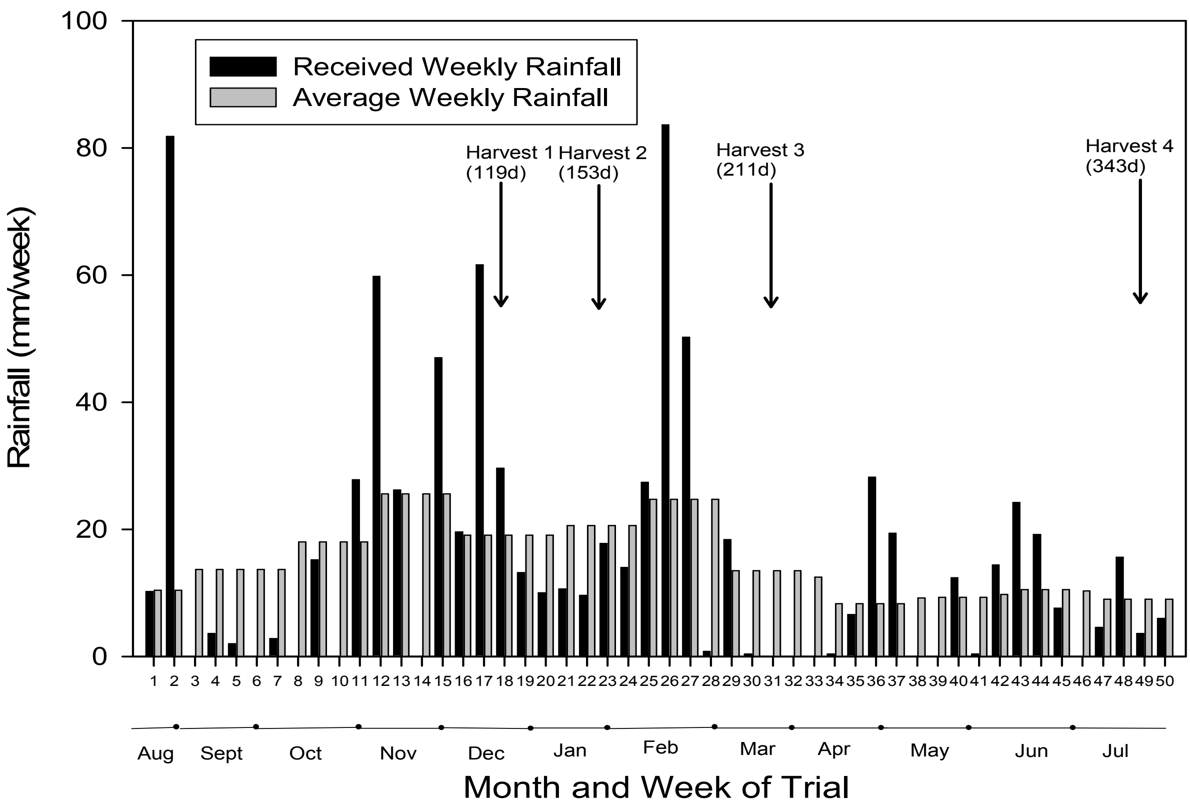

Figure 1. Actual and average rainfall (mm/week) for the trial period.

Climatic conditions
The observed weather conditions were comparable to long term averages recorded for the area and moisture was not thought to be limiting to pasture growth (Figure 1). The high volume rainfall events combined with the coarse textured soil created the potential for leaching of nutrient into the sub-soil or down the slope (Figure 1).

Results
There was a significant S fertilizer treatment effect on total dry matter production (P>0.05) with the clover component contributing most of this variation, especially in later harvests (Figure 2). Addition of S fertilizers increased the uptake of S in all treatments, except DAP pastille (
Table 10). Highest uptake was with MAP12. Calculation of apparent fertilizer recovery (S uptake in S treatment - S uptake in MAP treatment)/ S applied) shows a recovery of 16% from SSP, 32% from MAP12 and no recovery from DAP pastille (
Table 10). Apparent recovery of P reflected that of S, with plants that were less limited by S deficiency displaying greater P recovery. When totalled over the period of the trial, MAP12 produced more clover growth than SSP; however, SSP displayed more rapid early dry matter production (Figure 2).

Table 10. S uptake (kg/ha) and apparent fertilizer recovery (S or P uptake in S treatment – S or P uptake in MAP treatment)/ S or P applied) from the S fertilizers applied.

Treatment	S uptake (kg/ha)	Apparent % fertilizer S recovery	Apparent % fertilizer P recovery
DAP past	3.44 a	0 a	34.7 a
MAP	3.65 a	0 a	35.7 a
SSP	5.05 b	16 b	40.4 b
MAP12	6.38 c	32 c	50.8 c

Numbers followed by the same letter are not significantly different according to DMRT.

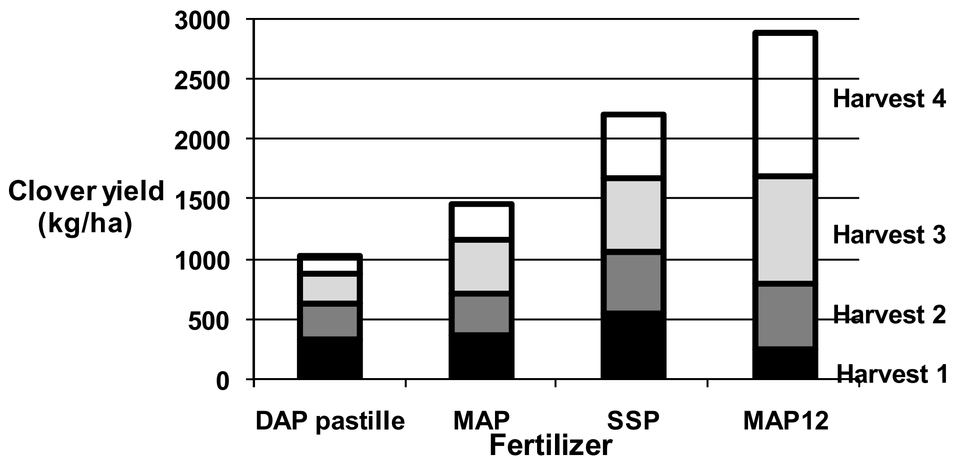

Figure 2. Effect of fertilizer on clover yield at each harvest. Treatments are di-ammonium phosphate with S° pastilles (DAP pastille) mono-ammonium phosphate (MAP), single superphosphate (SSP), and mono-ammonium phosphate with S in granule (MAP12).

Discussion
The relatively rapid dry matter production by the SSP treatment in early harvests declined with time. In contrast, the MAPS treatment continued to increase harvestable dry matter resulting in greater total dry matter production (Figure 2). Total S uptake was also higher from MAP12 than SSP most likely due to leaching of SO_4 from the SSP treatment two weeks after application (Table 2, Figure 1).The predominant reason for the greater cumulative uptake by clover in the MAPS treatment was that the SO_4 ion, as it exists in SSP, is susceptible to leaching (Blair 1971). It is thought that the MAPS treatment displayed twice the apparent fertilizer S recovery as SSP due to its leaching resistant or slow release properties (Table 2). The coarse textured soil, low adsorption capacity and high initial rainfall of this experimental environment

resulted in the potential for losses laterally and vertically down the soil profile. In leaching environments, SO_4 sources have commonly produced high yields in the early stages of trials, with little residual value, whereas S° sources have been observed to have modest initial yields but greater residual value. On the Northern Tablelands, Jones *et al.* (1969) reported gypsum treatments (44.8 kg S/ha) were S deficient after 11 months. In the present trial S deficiency symptoms were observed in the SSP treatment (applied at 10 kg S/ha) after 4 months. The findings of this experiment are complemented by the literature in reporting greater S uptake from S° fertilizer sources in comparison to SSP under leaching conditions.

The S° pastilles are large particles, with a smooth surface. They are formed from molten S° and are designed to resist water infiltration and dusting during transport. As a result the pastilles have a very low specific surface area and subsequently low oxidation rates (Germida and Janzen 1993). This is because the oxidising microbes require direct contact with the S° surface to enable oxidation (Vogler and Umbreit 1941). The total S uptake data indicates that very little, if any S° was oxidised and made available to the plant during the trial period (Table 2) with implications for total clover dry matter production (Figure 2). It is therefore concluded that due to the low S° specific surface area, S from the pastille treatment was relatively unavailable during the growing period of the trial. The pastille treatment is therefore not recommended for application in the field.

Increased availability of S in limiting conditions allows for improved utilisation of available P.
The increased yield resulting from S application resulted in an increase in the apparent recovery of fertilizer P (
Table 10).

Conclusion

The advantages of S° fertilizers over SO_4 sources has been clearly demonstrated in soils where there is potential for leaching to occur. The present trial indicated that apparent fertilizer recovery can increase from 16% to 32% over a 15 month period when S° is used instead of the industry standard SSP. However, not all S° fertilizers achieve these benefits. The DAP pastille treatment tested was not observed to be any different from the control due to the large particle size of the S° (low specific surface area). The results indicate the potential for increased fertilizer efficiency and increased production with the use of S° fertilizers in leaching environments.

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