Greener pastures 5 - Managing sulphur in dairy pastures

Mike Bolland

Ian Guthridge

Bill Russell

Martin Staines

John Lucey

See next page for additional authors

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Messages for farmers

For intensively grazed ryegrass-dominant pastures:

• Apply fertiliser sulfur and nitrogen after each grazing.
• Applying 5-7 kg S/ha after each grazing supplied sufficient sulfur for ryegrass dry matter production.

For traditional clover-ryegrass pastures:

The recommendations below apply to pastures which are not top-dressed with fertiliser nitrogen after each grazing, but instead rely on clover as the main source of nitrogen for pasture production:
• Apply fertiliser sulfur after July each year to supply 25-50 kg S/ha.
What did we learn about sulfur in Greener Pastures?

Soil sampling at Vasse Research Centre

During 1999-2009, soil testing for sulfur (S) was undertaken on 48 paddocks at the Vasse Research Centre (VRC) at Busselton, in the south-west of Western Australia (WA).

Paddocks had been grazed intensively by dairy cows and their young stock over a period of 10 years, as part of the Vasse Milk Farmlets and Greener Pastures farming system projects. Pasture consisted of annual ryegrasses with some subterranean clover. Soils in the 48 paddocks were 1-2 m sand to sandy loam over massive clay, known locally as Abba sand.

For many soils in the region, including Abba sands, the topography is flat and the soils are waterlogged from June to early September in the typical May to November growing season.

The soil sampling program

Samples of the top 10 cm of soil were collected from each paddock in April 1999 and January-February 2000-2009, during the dry period before fertiliser was applied. These are the standard sampling depth and sampling time for soil sampling of dryland pastures in WA.

Soil samples were collected while walking on the same diagonal path across each paddock each year between two permanent markers located on fences. Samples were collected using 2.5 cm diameter metal tubes (10 cm long; known locally as pogos) that were pushed into the soil by foot every 2-3 m, with 50-100 samples collected per paddock, depending on the size of the paddock.
The samples from each paddock were bulked, air dried and sieved through a 2 mm sieve to exclude coarse material. The samples were sent for analysis to CSBP Laboratories in Perth, WA.

Soil test sulfur was measured using the KCl-40 procedure (soil extracted with potassium chloride at 40°C), the standard procedure used in WA and much of Australia.

**What did we find?**

The same critical KCl-40 soil test S value, about 6.5 mg/kg, has been determined for pastures throughout Australia (greater than 560 mm average annual rainfall) and canola grain production on sandy soils in Western Australia. In our own study, soil test S values were always above 6.5 mg/kg (Fig. 1).

Because sulfur mineralised from soil organic matter or dissolved from applied fertiliser can be leached, soil S testing cannot be used to confidently determine fertiliser sulfur requirements of high rainfall pastures in the next growing season.

The extent of leaching of sulfur cannot be predicted so the recommendation for these pastures is to always apply fertiliser sulfur after July each year (ie after the peak of the winter-wet growing season). We suggest to use tissue testing to assess and improve sulfur management.

During the Vasse Milk Farmlet study (2000-2004), fertiliser sulfur was applied twice a year, with 25 kg S/ha applied in autumn and 50 kg S/ha applied late winter-early spring, so a total of 75 kg S/ha was applied in each growing season. During the Greener Pastures study (2005-2009), 5-7 kg S/ha was applied after each grazing and a total of about 34 kg S/ha each growing season. Tissue testing indicated both fertiliser strategies provided enough sulfur for ryegrass production.
Figure 1. Mean and range (minimum and maximum) KCl–40 soil-test sulfur (S) for all 48 paddocks in each year. The critical value for pasture production is about 6.5 mg/kg (dashed line), below which S deficiency is likely to reduce pasture production in the next growing season.
Background Reading
Amino acids are the principal building blocks of plant proteins. Sulfur is a component of two of these amino acids: methionine and cystein. Sulfur is also essential for symbiotic fixation of nitrogen by legumes, where *Rhizobia* bacteria in root nodules use atmospheric nitrogen to produce amino acids and proteins. Sulfur is also used by plants to produce chlorophyll.

Soil sulfur
Most sulfur is derived from minerals in the rocks from which soils are formed. However, in areas near the coast some sulfur (up to 5 kg/ha/year) is also deposited when oceanic cold fronts move across the land. Sulfate sulfur present in sea water is carried from the sea into the atmosphere, to be deposited onto land as the fronts move inland, decreasing with increasing distance inland.

Sulfate sulfur (the form in which sulfur is taken up by plant roots) is sorbed (retained, fixed, bound) by iron and aluminium on the surface of soil constituents (clays, oxides, organic matter), and by iron and aluminium oxides coating sand grains. Sulfate sulfur not sorbed by soil can be leached below the plant root zone.

Leaching occurs in soils with a low capacity to sorb sulfate sulfur, such as uniform deep sands or sandy duplex soils (sand over loam, clay or lateritic ironstone gravel).

Sulfate sorption by sandy and sandy duplex soils
The amount of iron and aluminium oxides coating sand grains varies markedly across the different sandy soils found in the south-west of WA.
The deep, uniform Spearwood sands on the Swan Coastal plain include, nearest the coast, brown Cottesloe Spearwood sands then yellow Spearwood sands and, further inland, pale yellow Karrakatta Spearwood sands. The brown Cottesloe sands have the largest capacity to sorb sulfate sulfur, followed by the yellow Spearwood sands. The pale yellow Karrakatta sands have the lowest capacity.

Bassendean sands are deep, uniform white sands found further inland from the coast than the Spearwood sands and have negligible iron and aluminium oxides.

Leaching of sulfate sulfur is highly unlikely in the brown Cottesloe and yellow Spearwood sands but can occur in the Karrakatta Spearwood sands in wet years and, in most years, in Bassendean sands.

The loam, clay or lateritic ironstone gravel subsoils of sandy duplex soils have larger amounts of iron and aluminium exposed at their surfaces than does the sandy topsoil. Consequently, the subsoils have a larger capacity to sorb sulfate sulfur. As a result, there can be negligible sulfate sulfur in the sandy topsoil but sufficient in the subsoil.

**Recycling of sulfate sulfur by soil organic matter**

Sulfate sulfur taken up by plants, and ingested by animals grazing pasture and crop stubbles, is returned to the soil as organic matter in faeces. Soil organisms (insects, including dung beetles, earthworms, fungi, algae, protozoa and bacteria) physically and chemically process soil organic matter, including faeces, to release nutrients into soil solution. This process is known as mineralisation. Soil organic matter is a major source of sulfur for pastures and crops, particularly in high rainfall pastures. These soils are rarely cultivated, so large amounts of organic matter accumulate through time. However, when these soils are cultivated, organic matter is rapidly broken down by soil organisms, so the organic matter content decreases.
Leaching causes sulfur deficiency

Sulfur deficiency is generally confined to high rainfall (greater than 800 mm annual average) pastures on sandy soils in wet years, as a result of leaching of sulfate sulfur below the root zone. In dry years, the amount of sulfate sulfur mineralised from organic matter supplies adequate sulfur for pasture production through the growing season, so no fertiliser sulfur is required. Fertiliser is only required in wet years. The root zone is shallow, varying from 20 to 40 cm, because our annual pasture species are relatively shallow rooting and because waterlogging is common and plant roots do not grow into waterlogged soils.

In practice, it can be difficult to know if enough sulfate sulfur has leached to induce sulfur deficiency so, as insurance, sulfur fertiliser is often applied after July each year (ie after the peak of the winter-wet growing season).

Symptoms of sulfur deficiency

Both clover and ryegrass have similar sulfur requirements.

Ryegrass cannot symbiotically fix atmospheric nitrogen, so ryegrass on sandy soil is likely to be deficient in both nitrogen and sulfur in wet years. Sulfur is immobile in sulfur deficient grasses, including ryegrass. In deficient grasses, young tillers are lemon yellow in colour and tiller growth is retarded. Sulfur is more mobile in sulfur deficient clover plants. Deficient clover plants are usually small and pale green to lemon-yellow and both young and old leaves are affected. In severely deficient clover plants, leaves tend to fold and stand erect and stems may redden slightly.

Clover can satisfy its nitrogen requirements by either taking up ammonium or nitrate from soil or by symbiotically fixing nitrogen from the atmosphere. Leaching of nitrate nitrogen below the roots of clover plants has no effect on their
nitrogen usage because they can obtain all the nitrogen they require from the atmosphere, assuming functioning rhizobia. However, symbiotically fixing atmospheric nitrogen requires a lot of energy, so legumes take up as much ammonium and nitrate from soil as possible to reduce the energy required for nitrogen fixation.

Sulfur fertilisers

For many years, the most widely used phosphorus fertiliser in WA was locally manufactured single superphosphate, made by adding sulfuric acid—which contains sulfur—to phosphate rock. Single superphosphate contains about 9% phosphorus and 10.5% sulfur. It also contains about 20% calcium. Therefore, use of single superphosphate to supply phosphorus also maintained or increased both the sulfur and calcium status of soil.

Except for high rainfall pastures on sandy soils, experiments conducted on newly cleared soils showed that they contained adequate indigenous sulfur and calcium for pasture and crop production and no sulfur or calcium fertiliser was required. That remains the situation at present—both sulfur and calcium deficiencies remain rare in WA agriculture, except for sulfur deficiency in high rainfall pastures on sandy soils in wet years.

Since the mid 1980s, imported phosphorus fertilisers with lower sulfur levels have increasingly been used instead of single superphosphate. These fertilisers include triple superphosphate and the ammonium phosphate fertilisers MAP and DAP which are sources of both nitrogen and phosphorus. Locally manufactured ammonium phosphate fertilisers are made by adding ammonium sulfate and generally contain more sulfur than the imported versions.
Sulfur fertilisers for high rainfall pastures

Single superphosphate

Single superphosphate has traditionally been the major phosphorus and sulfur fertiliser used for high rainfall pastures. Given that these soils are also prone to potassium deficiency in wet years, single superphosphate is often mixed with potassium chloride (muriate of potash, 50% potassium) and sold as super-potash fertiliser. A range of super-potash fertilisers are available, allowing farmers to apply different rates of phosphorus, potassium and sulfur.

Super-potash fertilisers are typically applied twice a year, at the start of the growing season in autumn and in late winter-early spring. The spring application is important for overcoming sulfur deficiency typically occurring after July.

Gypsum

Gypsum is made up of calcium sulfate containing about 17% sulfur and 21% calcium. It has been used as a sulfur fertiliser for spring application when soil testing indicated there was adequate phosphorus and potassium. Gypsum is now rarely used as a sulfur fertiliser for high rainfall pastures.

Ammonium sulfate

Ammonium sulfate, containing 21% nitrogen and 24% sulfur, is widely used to supply both nitrogen and sulfur to ryegrass-dominant pastures. As explained below, on sandy soils in wet years, both nitrate nitrogen and sulfate sulfur are leached below the roots of ryegrass plants, so both nitrogen and sulfur can become deficient.

All the above fertilisers are equally effective per unit of applied sulfur.
Fertilising clover-ryegrass pastures

Due to leaching of both nitrate and sulfate sulfur in wet years, applying sulfur fertiliser, but not nitrogen fertiliser, after July will benefit the clover but not the ryegrass. However, if nitrogen and sulfur are applied, both clover and ryegrass respond.

Fertilising ryegrass-dominant pastures

Fertiliser nitrogen and sulfur are generally applied after each grazing to ensure ryegrass production is not limited, in the ratio of 3-4 nitrogen and 1 sulfur. This can be achieved by applying a mixture of 60% urea (46% nitrogen, no sulfur) and 40% ammonium sulfate (21% nitrogen and 24% sulfur) so the mixture contains 36% nitrogen and 10% sulfur.

Soil testing for sulfur

Soil testing for sulfur is not reliable for leaching soils in high rainfall areas.

Soil sampling is usually carried out over summer (ie outside of the autumn to spring growing season) when soils are dry and soil test values are invariably high. This invariably finds the soil contains more than enough sulfur for pasture production in the next growing season. The organic matter content of these soils is usually high, with soil organic carbon levels typically ranging from 3 to 6%.

Enough sulfate sulfur is mineralised from the organic matter to meet the sulfur requirements of the pasture early in the autumn to spring growing season, provided that sulfate sulfur is not leached below the plant root zone. Therefore, in drier years enough mineralised sulfate sulfur remains in the plant root zone (typically 20-40 cm) to supply enough sulfur for pasture production through the growing season so no sulfur fertiliser is required.
However, in wet years, little sulfate sulfur mineralised from soil organic matter, or dissolved from fertiliser applied in autumn, remains in the root zone after July, thus requiring applications of sulfur fertiliser.

**Tissue testing for sulfur**

Clover and ryegrass herbage with less than 0.2% (dry weight basis) sulfur is highly likely to be sulfur deficient.
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