Sulphur (S) Version 1.9 11 May 2012

Introduction

Sulphur is an essential plant nutrient required for the production of amino acids which make up proteins. Leaf tissue testing is far more accurate than soil testing for diagnosing and correcting S and other elements for optimum soil, pasture and animal production.

Some have written, “The only way to know if there is sulphur in the soil is to do a soil analysis.” This is so wrong. Soil sulphur tests have been known to be inaccurate for 50 years that I know of. I've attended Ruakura meetings with consultants and MAF (New Zealand Ministry of Agriculture and Fisheries) staff, about faulty S levels in soil tests, and have been told many times that MAF are working on improving the test. There is now two. Both are inaccurate. Pasture analyses are 100% accurate.

The Hill Laboratory September 2008 Newsletter centre double page spread was about the variability of soil sulphur tests. Ask them to post you one, but better still use pasture tissue analyses, and don't waste your time and money studying soil tests, because you'll learn nothing of use. Laboratories have no solutions, nor do they have any for Olsen P’s inaccuracy, nor for inaccuracies in potassium and calcium and other faults in soil tests, such as pH, especially New Zealand ones that go down to only 7.5 cm (3 inches). The rest of the world goes to two or three times this depth.

Legumes need more S than grasses, but all plants and animals need some. Low sulphur levels in cereals cause low protein which affects the quality of the flour and the price received for the grain.

Plants take up sulphur in the sulphate (SO4) form. If single superphosphate (0-9-0-11) is applied the S levels can become too high for a period, and then too low after wet weather leaches the S. Leaching takes potassium, selenium and other elements with it. Elemental sulphur doesn’t leach because it has to be broken down into the sulphate form before it is water soluble. This is done by a bacteria (thiobacillus) which digests the sulphur and excretes sulphate. All soils have this bacteria. It takes a few weeks for elemental sulphur to start to become available so it should be applied before a deficiency shows. In waterlogged soils the bacteria are dormant, so not much elemental sulphur will be released, but sulphate S is still leached, so again, remember that drainage comes first.

Elemental S on its own can be dangerous so must be handled with care. Mixing it with some other items can cause dust and an explosion if more than 20% of the mix is elemental S.

In the 1800s in New Zealand, after farmers had been applying superphosphate for its phosphorus, they discovered that the sulphur in superphosphate was doing nearly as much good as the phosphorus.

Few know this, so some farmers and researchers apply reactive phosphate without elemental sulphur and don't achieve the plant growth that superphosphate achieves. They then wrongly blame the slow reactive elemental phosphate.

Different soils (clays, loams, pumices and peats) require different amounts of S.

Much of the available S in soils is held in humus, so low organic soils tend to be lower in available S than those high in humus, which is decomposed organic matter. **Knowing** this and the above helps more than soil testing.

Sulphur is important

In many soils the application of sulphur is just as necessary as the application of phosphate. This is particularly the case in new pastures after having taken one or more crops off the field, especially if the crops were harvested mechanically, rather than grazed where manure is returned. Mechanical harvesting and cropping reduce the organic matter content of soils substantially, whereas correct fertilising and correct grazing increase it. After years of cropping it can take three or more years for the humus/sulphur/nitrogen balance to return to soils growing grazed pasture. It can help if about 100 kg per ha of Ammo which is 50% urea and 50% sulphate of ammonia is applied every few months until the clovers are working and organic matter has built up. Even one application of pure urea lowers organic matter and the elements held by it which include S, cobalt and boron. It can also halve earthworm numbers.

Dr John Watkinson at Ruakura in the 80s found that the oxidation (making available) rates of elemental sulphur is about ten times faster in New Zealand soils than in those of most other countries because of our high soil micro-organism levels from intensive grazing and the return of fresh animal manure that feeds soil microbes and earthworms.

Soils that have been sealed off by pugging (poaching or trampling) or even by heavy grazing in wet weather, build up sulphur gas in the sealed soil that can kill earthworms and soil microbes because they need fresh air (oxygen). When a pugged soil is opened after a day or two, one can smell the sulphur.

Sulphur -

- Is involved in the formation of chlorophyll, as is magnesium.
- Helps in the synthesis of vitamins like biotin and thiamine.
- In some pasture and crop species aids cold and drought resistance.
- Is essential for the fixation of nitrogen by legumes and soil bacteria.
- Helps improve the structure of soils.
- Is needed by legumes. Deficient clover leaves go yellow.

Elemental S mixed with reactive phosphate makes the P become available more quickly which is important, so should always be done, and provides the S needed in soils and by pastures. Some so called scientists, who should know better, have done reactive phosphate versus superphosphate comparative trials without adding elemental S, which is unfair. The MAF Te Kuiti comparisons were on soil that had not had P for years, which was also not fair on the reactive phosphate. After adding the trial costs to the farmer losses, these and other crooked comparative trials cost the country millions of dollars because they promoted the more expensive, less productive superphosphate which pollutes by fumes and leaching. It is not made in USA now.

Elemental S acidifies soils only slightly, because it is not applied in large amounts (10 to 20 kg per hectare), and usually with reactive phosphate which is alkaline so uses it, whereas Superphosphate has 11% S and 9% P and is applied at 400 kg or more per hectare which gives 44 kg per hectare of S. See Phosphorus.

Elemental S acidifies and flocculates the soil a does gypsum (Calcium Sulphate $CaSO4{\cdot}2H2O$) does, so loosens tight clays by forming small particles which allow air and water to form a more friable soil. When soils are tight and compact because of lacking calcium, adding 15 kg of elemental S helps loosen them. I never recommend straight lime now, because other elements are also usually lacking.

Organic and elemental S are unavailable to plants until converted to sulphate S. Elemental S is gradually converted to plant available sulphate through the mineralisation processes by soil micro organisms, so a dead soil without an abundance of micro organisms will take longer to mineralise S, as will an alkaline (high pH) soil.

Plants needing most S are legumes, Canola and grain crops. Grasses need the least. Brassicas need some, but not too much because they can then use and release too much.

Some people are sensitive to sulphur, so use it carefully and follow all instructions on its use. S dust in the eyes can cause severe damage, so avoid it.

Animal requirements

S is essential for animal health and helps neutralise the effects of prussic acid in sorghums and nitrates in grasses. Adequate S is needed for rumen activity and animal health, especially before calving. In S deficient diets inorganic S can be used by rumen microbes to synthesise amino acids. Sulphate S (inorganic S) in sodium sulphate, potassium sulphate, magnesium sulphate, ammonium sulphate and calcium sulphate are highly digestible while elemental sulphur is not. S acts as a buffer against some toxic elements.

American NCR’s low S optimum of 0.2% (half ours) could be why they have to feed so much to stop milk fever.

Animal deficiencies

When S is low in the diet, toxicities such as high nitrates can affect animal health. S deficiency can

cause reduced feed intake, lower feed digestibility, slower gains, increased metabolic problems and decreased milk production. There is a close association between sulphur and nitrogen, and a deficiency of sulphur is more likely to occur where diets contain high levels of non-protein nitrogen.

There is a possibility that animals are more susceptible to lice infection when S levels are low.

Sulphur is an important anion (positive charge) for cows close to calving when preventing milk fever. The level of sulphur in pasture herbage during the cows' dry period should be very close to 0.4% of the dry matter fed.

Indicators of sulphur deficiencies are reduced feed intake, slower gains, dullness, lower digestibility, and reduced milk production.

Low S levels in pastures and supplements can increase the incidence of nitrate toxicity.

Animal excesses

The S in North American TMR is 0.2%. Some say that 0.2% is toxic, but it depends on whether it is naturally in the feed or added as a sulphate based element, and it depends on the levels of nitrogen, copper and some other elements. Ruminants can tolerate higher levels of S in water and when it is part of the natural feed than when S is added as a dry supplement. High S levels in feeds reduce selenium, copper and zinc absorption. S can be used in supplements and fertilisers to slightly neutralise high molybdenum in pasture, which can cause animals to scour and be deficient in copper, which may then also be necessary to be applied and/or fed. Good farmers will be feeding Solminix which has optimum S with its other 8elements, so animals should not be deficient. Most soluble mineral mixes lack S and sodium.

High levels of S can cause animals to lie down a lot and be restless with twitching muscles and to scour. Internally, they can have darkened kidneys and haemorrhages.

A USA goat farmer did a trial. A sulphur block was given to one mob of goats and not to another. As is known, the sulphur inhibited the absorption of copper so much that the sulphur block mob needed supplementing with copper.

Pasture needs 0.35% for optimum clover growth.

Soil & plant requirements

Sulphur is an essential element for plants. P works in conjunction with sulphur, and vice versa. Winchmore Irrigation Research Farm in 1960 did trials applying only P and only S on separate paddocks and got no responses, while applying them together gave good responses. RP without elemental S gives nowhere near the growth of that with it (NZ National Trials, farmer and my experiences).

Mineralisation (breaking down) of organic S in soils with a high organic content can be a major supplier of sulphate to pastures. A lack of moisture reduces its availability, so deficiency symptoms (clover leaves go pale yellow all over) seen in dry conditions can disappear after rain, showing that although the symptom is there, S is not seriously deficient, however, building up levels before dry periods helps reduce dry period deficiencies.

Levels of sulphur in soils change continuously, depending on the balance between plant uptake, leaching, mineralisation (decomposition), and the amount of organic matter and moisture. These are some of the reasons why measuring S in soils is not of use, whereas measuring plant uptake (tissue analysis) tells us how much the plant is getting out of the soil, and how much the animals are getting. A soil analysis is like a photo, whereas a pasture analysis is like a video film of what is happening in the soil and in plants (the whole system).

A soil scientist or laboratory could say that one needs to know the S reserves in the soil, so just ask them how to build up and keep an element that leaches as fast as sulphate S (in superphosphate) does.

Sulphate ions are extremely soluble, so are easily lost through leaching. This is why it is so important to use elemental sulphur and not sulphate sulphur, except where S requirement is immediate, as when applied with nitrogen which needs it so work, or if the soil is dead and the pH is above 6.3 so elemental S will take longer to become available.

New Zealand AgResearch scientists and Hill Laboratories have acknowledged that measuring S in soils is inaccurate. A Hill newsletter wrote about it covering two pages. Both have been searching for an accurate system for decades, but one wonders why they bother when pasture analyses should be done for

accurate animal feeding and are so accurate. One reason why S cannot be measured accurately in soils is because sulphur ions leach down fairly quickly, so a typical shallow soil test can show low S, while deep rooting plants can still access it.

Pasture tissue should be about 0.4%, but higher pre-parturition so those growing brassica crops which have about 1% S, have almost eliminated milk fever. Temperate climate S seasonal variations are minor with spring 0.41%, summer (dry) 0.37%, autumn 0.40% and winter (wet) 0.41%.

Lucerne and Tonic plantain have about 0.6%. Kikuyu

S in plants helps with protein synthesis, and is necessary in the structure of amino acids cystine and methionine, all part of proteins. Most of the S in plants is present as protein S. This is why it is so important to use elemental sulphurs and not sulphate sulphurs as in superphosphate, except where an S requirement is immediate.

Sulphur contents in soils can vary by ten times, from less than 0.01% to more than 0.1%, or from 250 kg S per ha to 2,500 kg S per ha, so soil tests vary depending on rainfall - and some academics who have never learned about pasture analysing wrongly criticise pasture analyses for varying.

In the same paddock freely drained areas can have adequate sulphate ions (available to plants), while poorly drained, flooded or pugged soils can build up large amounts of unavailable smelly S. Hydrogen sulphide (H2S) is a product of anaerobic decay of organic matter, some of which escapes into the air and can be smelt doing so.

Applying too much nitrogen increases the pastures requirement for S which is essential for the uptake of nitrogen by plants, which is why sulphate of ammonia or Ammo are mostly more effective on an equal cost basis than urea. If you know your pasture levels you'll know which N to use to best advantage.

The amount of organic S in a soil depends on the level of humus, and the level of S applied. Organic S increases in soils and plants as the organic matter increases when pastures are sown.

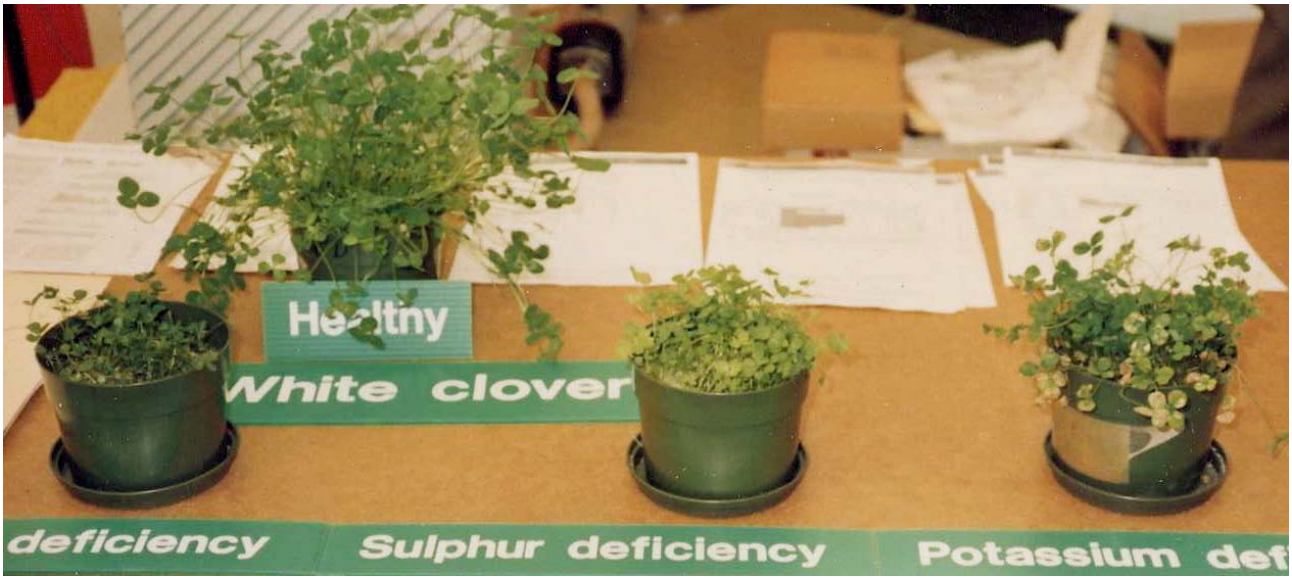
Sulphur is an acidifier so, for this and other reasons, should not be used to excess. S is a fast way to lower a high pH, but can be toxic if overdone.

Lime, which improves soil structure, aeration, drainage and organic matter, increases the production of organic S.

After our wet winters clover growth decreases, partly because available S and other water soluble elements have leached out of our soils during high rainfall. I'm sure this also happens in other countries, and under irrigation.

Mainland USA soils get less S now than when factory smoke pollution was higher. Hawaii gets more when its volcano is erupting, so clover growth increases.

Soil & Plant Deficiencies



MAF stand at Fieldays 1990. The left clover is phosphate deficiency.

A deficiency decreases clover growth and nodulation, hastens the onset of drought affecting pastures,

lowers plant nitrogen levels, and animal production, especially wool. Clovers are yellow as if nitrogen deficient. Clover leaves become sick, dull and yellow, starting with the younger leaves, unlike nitrogen deficiency, where the older leaves go yellow first. With magnesium deficiency, clover leaves go yellow, in thin stripes because the veins stay green.

Nodulation is reduced so there is less N fixation which slows pasture growth. P & N uptake are reduced. Clovers will grow better in urine patches, however this can also be because of low K in the rest of the pasture.

S fixation characteristics in soils are fairly similar to P fixation. See Phosphorus.

In some grass types deficiency shows on the newer leaves while Nitrogen (N) deficiency causes a yellowing of the older leaves. If both N and S are low, yellowing can be on both parts.

Clover leaves can also be small and cupped with scorched and distorted edges.

Clover leaves low in Mn are pale green and/or bright yellow, except for the veins themselves.

Brown spots can then form, and leaves can fall off prematurely.

The chlorosis symptoms develop first on the younger leaves of some grasses too.

Low S levels in pastures can increase the incidence of nitrate toxicity.

Soil & Plant Excesses

High S levels can lower Cu, Mo, Se and Zn uptake. Applying these elements with fertiliser can help reduce the effects of excess S. High levels of S reduce the availability of molybdenum to plants. High S levels seldom occur with correct fertilising using elemental S, but do occur when superphosphate is applied at 300 kg per hectare or more, because that will give 33% S.

Feed quality and palatability can be affected by excess S lowering the above elements. While animals don’t always select pasture with the best feed value in all respects (protein, carbohydrate, energy, mineral and vitamin balance) they do for palatability,

Over time high S can acidify soils which could influence feed quality.

High S and acid soils can be created by industrial smoke. When industrial pollution was high in North America and Europe, less S was needed as a fertiliser, but now more is needed.

Elemental Sulphur

This is converted in an acid (lower than pH 7) soil to sulphate sulphur which is the form that plants use. The conversion is a slow process so S becomes available to plants over a long time and leaching, a problem with water soluble sulphurs, is minimal.

It is usually applied with reactive phosphate which works on it as the S works on the reactive phosphate.

Pastures are best fertilised with elemental sulphur rather than sulphate S because elemental releases S gradually so doesn’t leach and take other elements with it. In some cases deficiencies in pastures (yellowing of clover leaves) can be seen as little as six months after applying superphosphate (0-9-0-11) because water-soluble sulphate S leaches, taking other elements like selenium with it. Elemental S should not be applied if Single Superphosphate (0-9-0-11) has been applied recently because the soil will already have much more S than is necessary, but superphosphate should not be used. None is now made in USA.

The pro Single Superphosphate and anti elemental sulphur group delight in telling that the latter acidifies soils, however, although it is 100% S, it is usually applied at only 10 to 15 kg per ha so doesn’t have a major effect on soil acidity. Twice its weight (20 to 30 kg per ha) of 95% CaCO3 agricultural lime will maintain the pH. However, as elemental S is usually applied with reactive phosphate which has about 33% calcium carbonate, it takes only 60 to 90 kg per ha of reactive phosphate and the rest of the reactive phosphates has a sweetening effect. Anyway, Superphosphate with its 11% S applied at 500 kg per ha applies 55 kg of S per ha, which is about three times more than the normal rate of elemental S, and leaches dreadfully, taking other elements with it.

The major problem of Single Superphosphate is that its water soluble S leaches and takes with it, potassium, sodium, selenium and other water soluble elements. This is very costly, both in lost elements and animals suffering from low selenium.

In 1964 Hogg and Cooper found that mixing Single Superphosphate and potassium chloride (Potassic

Super in NZ) markedly increased potassium leaching. Why is this not publicised, with all the other bad aspects of superphosphate?

Even most scientists recommended that, where sulphur is required, elemental sulphur with reactive phosphate and some other fertilisers should be applied.

Researcher WMH Saunders of Massey University, NZ, pointed out that NZ wide savings on many soil types with pH below 6.3 by using reactive phosphate with elemental sulphur could save between $15 and $50 million a year, compared with using Single Superphosphate.

Sources of water soluble S

Calcium sulphate (Gypsum) 22%.

Copper sulphate 12%.

Magnesium sulphate (Epsom salts) 14%.

Potassium sulphate 17%.

Single Superphosphate 11%.

Sulphate of ammonia 24%.

Triple superphosphate 1.4%.

Zinc sulphate 18% S.

Elemental sulphur is 100% slow release S.

Sulphur sources that are uneconomic or are not recommended are not included.

Sulphate sulphur provides an excess immediately after too much is applied, especially if levels are already adequate. Some of it can be lost by wash down hills and into low areas on flat soils, and/or into drains and rivers and by leaching.

Elemental sulphur

This has 99% elemental S which is not water soluble so doesn't leach until made available, which is at a slow rate so then likely to be used by plants. It is the most important source of S for pastures, provided the soil is acid. It relies on acidity, moisture and soil bacteria, which grazed pasture soils usually have plenty of, to make it available before plants can use it.

Elemental sulphur must be finely ground, to less than 0.5 mm. It can be in a small pelleted form which will dissolve, to be released within a year when more should be applied.

If the pH is 6.4 the figure will be less, and if 6.5 more so, but reactive phosphate will still work, especially if earthworms are active and the soil is live. Earthworms eat reactive phosphate and make it 90% available.

Rain provides about 10 kg per ha near the New Zealand coast, decreasing to 5 kg per ha inland and almost nothing in the centre of large continents. More S is produced from pollution in industrial countries.

Hydrogen sulphide makes the smell in the air in thermal areas. The smell of hydrogen sulphide from cabbages after being frosted, reveals the amount of sulphur in brassicas. Cattle eating some brassicas give off a sulphur odour, so don't graze brassicas before milking because doing so can taint the milk.

80% of the S consumed by animals is returned to the soil, 60% through the urine, mostly in the highly available sulphate form.