In acidic soils (pH below 6.8) where effective legume nodulation was not occurring because of low Mo levels, applying optimum quantities of LimeMagPlus corrected low Mo and low Calcium (Ca) which are often associated. After correct applications of lime, based on ryegrass analyses aiming for Ca 0.8%, the clover grew well, nodulated normally, and did not grow any better after Mo was applied.

The first thing to learn about Mo is that dry soil conditions make it difficult for plants to take up Mo, but in wet conditions plants can take up excessive amounts, especially if Copper (Cu) is low.

Legumes require Mo to fix atmospheric nitrogen (N). Mo helps make iron (Fe) available within plants which alleviates plant injury that could be caused by excessive Cu, boron (B), cobalt (Co), manganese (Mn) (common in NZ and in under-drained and under-limed acid soils) and/or zinc (Zn).

Mo is essential for the utilisation of ammonium and nitrate nitrogen, and helps reduce nitrates (indigestible toxic protein) within plant tissues. The toxic nitrate content of plants on Mo deficient soils is higher than when there is adequate Mo of at least 1.5 mg/kg. However, there are top producing peat farms with Mo pasture levels of 8 mg/kg without animal health problems, provided Cu and S levels are correct, and provided that, when necessary, Cu is supplemented directly to the animals through the drinking water in a good soluble mineral mix. However, if possible, such high Mo levels should be avoided. Levels of 3 or 4 with Cu at 12 mg/kg are no problem.

Most farmers, agricultural consultants and the establishment (AgResearch, DairyNZ, LIC, and their so-called scientists) spend too much time advising about the main (N, P, K.) elements, except calcium, and not enough on minor ones, with Mo and Co at the bottom of their lists. They then wonder why their legume nodules are small and white, so not making N, or even non-existent, why pastures lack clovers and then need artificial N.

Calcium application in many countries has decreased substantially (see Calcium), because of the powerful promotion of companies' very profitable urea, phosphate and potash.

In New Zealand since about 1990 the establishment's solution to declining clovers caused by insufficient LimeMagPlus (see the Calcium chapter for information) has been to apply urea. The cost of this could pay for 1,000 to 2,000 kg of lime per hectare, depending on the source and distance.

Many farmers and scientists apply urea to grow more grass when Ca, Mg and/or Mo are low. Thus applying LimeMagPlus containing all deficient elements can improve soil, earthworm, pasture and animal health, followed by pasture and animal production much more than urea can, and for a lot longer. Read Elements > Calcium and Cobalt, because lime increases Mo levels, and ruminants and clovers can't grow and do well without Co.

In 1945 it was found that Mo was deficient in some countries and in parts of New Zealand. Some New Zealand soils have sufficient, thanks to lime applied for good pasture and animal growth and production.

Squash growers sometimes rent peat land from animal farmers and apply high amounts of Mo to achieve good crops. They cause very high Mo levels for the animal farmers who sow pastures again. It is easily fixed with copper sulphate at 8 kg per hectare and with correct elemental sulphur (S) levels for a few years to make pastures healthy for animals. Too much Mo causes scouring just like insufficient Cu does.

Optimum levels

Mo 1.5 mg/kg, Cu 0.13 mg/kg and S 0.4% are optimums for most animals and fine for plants. Mo in clover nodules can vary between 3 and 10 mg/kg. Low Mo levels yield less N.

For most sheep (breeds vary) Cu should be about 8 mg/kg, which is too low for cattle. Where pasture Mo exceeds 5 mg/kg and Cu is 8 mg/kg or lower, cattle may develop clinical Cu deficiency and scour. Feeding Solmin or Liquimin with added magnesium through drinking water will help cattle, and not adversely affect sheep because they drink so little. Mo is not toxic at 5 mg/kg if Cu is at least 13 mg/kg for cattle and 10 mg/kg for sheep and S is at least 0.35%. In USA many good farmers are unconcerned with Mo at 2.5 mg/kg, while some have 5 mg/kg. In NZ some veterinarians and others recommend levels under 0.5 mg/kg which is much too low, causing white nodules which don't make N, so clovers don't thrive. The problem is Cu and S are too low. Very roughly, Cu should go up by about 2

mg/kg per 1 mg/kg that Mo goes up, so Mo at 5 mg/kg requires Cu to be 16 mg/kg which is not easy to achieve, so Cu feeding is needed. See Elements > Copper.

Wet winter Mo levels can be up to double dry summer levels in the same paddock. Nothing can be done about it, except what has been written above.

A problem some New Zealand farmers have is a loss of clovers caused by misinformation from the establishment. Clover root weevils get blamed for loss of clover even when there aren't any present, or their damage is only slight. It is disgraceful that the establishment which includes their laboratory which does pasture analyses and wrongly claims Mo 'Normal Range' in pasture should be 0.15 ~ 0.2, which is ridiculously low.

Animal deficiencies

Very low Mo in ruminants' diet can cause loss of appetite, Cu toxicity and scouring. Sheep grazing pastures with very low Mo content (less than 0.1 mg/kg) had Cu accumulate in their livers, leading to chronic Cu poisoning and subsequent deaths. High Cu and S levels in pastures reduce the amount of Mo retained by the animal.

When Mo is deficient in diets, nitrate levels in forages are higher. Mo is necessary for conversion of nitrates into amino acids and helps animals convert surplus nitrates into uric acid so they can be expelled. When Mo is deficient **or** excessive, nitrates are more dangerous to animals and can kill them. 15% of cows in a 200 cow herd died within hours of grazing a high nitrate crop and its short yellow regrowth. Many others aborted. I was called in and found that this normally safe forage grass type crop had been grown on peat without sufficient lime, so crop Mo levels were very low.

Nutrifeed and Japanese Millet have no prussic acid, so, unlike sorghums, are safe to graze at any stage. However, like most fast growing grasses, if forced with N under low Mo, B and/or low S levels, they can have toxic nitrate levels which can kill cows. Especially when back grazing short yellow re-growth after rain following a dry period.

Animal excesses

Feeds high in Mo (and S) can cause Cu to be insoluble and not absorbed, causing Cu deficiency in animals even if pasture Cu levels are optimum. Animals' immune systems can then be adversely affected. High Mo symptoms include scouring, bleached hair, reduced growth, low blood iron levels (anaemia), lameness, joint abnormalities, arthritis and osteoporosis. The first three symptoms are similar to low Cu symptoms.

Toxicity (molybdenosis) in ruminants is caused by a diet high in Mo combined with low Cu, rather than just one being too high or too low. It can cause teeth to grow too long, especially on peat where there is no grit in it to wear teeth, more so in sheep. High Mo can also contribute to long hoof growth.

Feeding a soluble mineral mix (with extra Cu if necessary) daily through an on-line dispenser is a good way of avoiding Mo scours in cattle. During cold wet periods even cattle may not drink much, especially if given wet pasture in the mornings and no hay. Sheep may not drink at all when pasture is moist.

Avoid supplementing with DRY Cu sulphate (as opposed to the same amount in a day's drinking water). A slight excess of dry Cu in concentrates has killed cows in USA.

Red and Alsike clovers are higher in Mo than white clovers and can lower animal Cu levels, so aim for balanced mixed pastures.

When Mo is excessive (or deficient), nitrates have more adverse affects on animals.

Small fine bubbles in their dung can be from excess Mo or Cu deficiency, but if also smelly can be caused by salmonella.

Soil & plant requirements

In 1930 Bortels discovered Mo is essential for legume N fixing bacteria, yet there are still many areas where Mo levels are inadequate, and sometimes not even measured. So what do farmers and some AgResearch staff do when pastures show nitrogen deficiency symptoms? Apply artificial N, without checking the pasture tissue Mo level.

Trials in Scotland with ryegrass showed that on poorly drained soils ryegrass contained more Mo, Co and Mn than ryegrass growing on a similar well drained soil. Pasture levels should average about 2 mg/kg Mo over the year, but are higher during winter rainfall and early spring than in summer dry

weather. Mo deficiency is not usually found in perfectly limed soils, unless other levels are out of balance such as high Cu, S and Mn. Don't apply Cu when Mo is too low.

Liming increases Mo uptake and decreases Co uptake (until soil organic matter increases under correct pasture farming which lime helps achieve). Applied N lowers the Mo herbage content where Cu levels are low and increases the herbage content where Cu levels are high.

Legumes require more Mo than non-legumes for normal growth. 175 grams/ha of sodium molybdate gave 400% increase in lucerne yields where the pH and Ca levels were adequate. In some cases it is necessary to fertilise with both Mo and lime for maximum yields. Sodium molybdate on its own has had no effect on yield, whereas with phosphate it did. Under arid conditions Mo can remain fixed, so unavailable to plants. Mn and sulphates (in superphosphate, gypsum, sulphate of ammonia, etc.) lower Mo uptake.

Clovers need Mo right from germination, so if Mo is low, use coated seeds with Mo, or if unavailable Mo may be applied effectively as a seed treatment. The most suitable Mo compounds that are harmless to the nodule bacteria are Mo trioxide, ammonium molybdate and molybdic acid. To apply a recommended 84 gm molybdenum/ha, either 125 gm Mo trioxide or 153 gm ammonium molybdate or 157 gm molybdic acid must be thoroughly mixed with the amount of lime necessary to pellet the seed for 1 ha.

Soil & plant deficiencies

Low Mo (under 0.5 in mixed pasture tissue) limits clover nodulation, N fixation substantially, and vitamin C production. Low vitamin C in animals reduces their ability to excrete surplus nitrite.

A frequent cause of poor pasture growth is low Mo of 0.4 mg/kg or less in pasture tissue.

Slight deficiency symptoms in legumes are pale yellow leaves without leaf spotting. Greater deficiency symptoms are oval, pale brown spots on some leaves, poor growth with pale yellow foliage, and pale nodules instead of having pink haemoglobin pigment. Chronic deficiency causes yellow or orange mottling of most leaves with oval, pale white clover leaves and stems, or parts thereof, giving leaves a brownish appearance. Symptoms usually appear in older leaves first, then show up regularly in younger leaves, until the growing point is killed. Other element deficiencies at the same time can mask or change the symptoms. The only certain way of deciding is an accurate pasture herbage analysis.

When pH is about 5.7 and Mo is deficient, it is better to apply lime to increase the pH to a maximum of about 6.1. Lime is much more effective long term in increasing the Mo than applying sodium molybdate, however in some soils it takes 7 t/ha of lime cultivated in or over three years to increase Mo adequately.

When phosphorus (P) and S are low, responses to Mo can be low or nil. In acidic conditions, Mo can be unavailable to the plant. Mo requirements are affected by high aluminium (Al), Cu, Mn, phosphate, S, Fe, Zn and nickel (Ni) levels. If Ca and/or phosphate are low, applying Mo may not give a response. Mo may not increase if P is low and Fe is high. Low S limits the response from Mo, however high S decreases Mo uptake. Where raising the pH releases Mo, but Mo reserves are low, a Mo deficiency can occur again, once the Mo that was made available has been used.

The Mo in some soils rises following lime applications, but in other soils it will only rise following the application of Mo. In some soils both lime and Mo are required to raise Mo in herbage. In one area of Australia, applying 140 grams Mo per ha (2 ounces/acre) gave the same increase as applying 3,000 kg of lime/ha. 70 g/ha of sodium molybdate has given striking pasture improvement in NZ and other countries, but sometimes a capital amount of double this is required initially. Higher rates can be toxic to nodule bacteria, and should be avoided.

A farm in NSW greened up and grew more clover and then grass after applying 70 g/ha of Mo.

Liming, when required to increase Ca levels or pH, is the best way of increasing Mo levels. Don't apply more than 2.5 tonnes/ha (1 ton/acre) on the surface at any one time, or within two years [is this figure still correct -only 2.5T/ha over 2 years? SR] or Mo levels can rise excessively on the surface.

Where Al is high, lime has a greater effect on increasing pasture and animal production than Mo, so Mo should not be applied if Al is high or if pH or Ca are low. Mo should **not** be used before adequate lime has been applied. Most mineral soils and peats have low Mo pasture levels unless limed adequately. Several farmers who were wrongly advised by the Ministry of Agriculture (MAF) in the 60's to apply Mo instead of more lime, and then had to apply lime to correct the low Ca levels ended up with pasture Mo levels of over 10 mg/kg. Once up it is very, very difficult to reduce. Deep cultivation

helps, as well as the points previously mentioned such as Cu and S.

Mistakes in fertiliser mixes can cause problems. Keep dated accurate samples (half a dozen handfuls from different parts of the load or heap) from all fertilisers. Mistakes can be made at fertiliser depots and if subsequent pasture Mo levels increase, or problems occur, the fertiliser kept can be analysed. One farmer I know had the wrong fertiliser spread on his farm.

When Co stocks sold out in NZ, a large supplier kept supplying and charging for fertiliser with Co. When discovered, the organisation had to spread the Co on the farms concerned at 1 kg/ha. So, buyer beware. Check all fertilisers when they arrive.

Soil & plant excesses

The main concern with high Mo is animal health, in which increases increase the Cu level to 13 on cattle farms and 9 on sheep farms. Some apply Mn sulphate to reduce Mo, however, if too high it reduces legume nitrogen fixation and stresses animals. See Elements > Manganese. Elemental S is better.

Green growing plants with high Mo have a worse effect on animals than hay with the same level.

RP Sechura contains about 30 mg/kg of Mo, so RP Gafsa, which has under 5 mg/kg, or another reactive phosphate should be used when Mo levels are above 6 mg/kg. Levels in processed fertilisers (Superphosphate, Triple Super, etc.), depend on the phosphate used.

Ensure that Mo, Cu, S and Mn levels are optimum.

Soy herbage can have Mo of 20 mg/kg which is dangerous except that very little is usually fed. S and Cu at normal levels in Soy are not high enough to counter the bad effects of the extremely high Mo. Avoid feeding other high Mo level feeds with Soy and ensure that Cu and S levels are adequate.

Red clovers take up more Mo that can lower animal Cu, so aim for correct pasture levels. However, as red clovers grow in summer when dry, they should not cause a problem on peat.

Excessive amounts of lime in one application to the soil surface, especially when soils are poorly drained, increases pasture tissue Mo levels. Smaller amounts of lime more often don't increase Mo levels as much, but spreading costs more. Mo levels can change by up to 100% between dry and wet conditions, so don't worry about a level of 6 mg/kg in wet conditions, provided Cu is correct. You can use gypsum which is Ca and S because it doesn't increase soil Mo levels, but is very expensive in areas away from the sources, and should not be used if S is already high.

Sources

Sodium molybdate, but don't apply it if calcium is needed because the good effects of lime are so vast. Read Elements > Calcium which shows 50 benefits.

Agricultural lime applied to most soils, especially peat that is low in copper, releases Mo and increases pasture Mo levels.