LEAFLET NO.7

Interpreting soil tests for calcium, magnesium and Ca:Mg ratios.

It is most unusual in NSW for crops and pastures to be affected by calcium (Ca) or magnesium (Mg) deficiency.

In addition, it is now known that the ratio of exchangeable Ca to exchangeable Mg (Ca:Mg) is not as important as was first claimed, with research results showing a variation between 1 and 20 in Ca:Mg ratios of little consequence in agricultural production.

This *Leaflet* gives a summary of the information that supports these statements.

AVAILABLE CALCIUM (Ca)[1]

Very severe Ca deficiency in crops and pastures will occur when exchangeable Ca in the soil test result is less than 0.5 meq/100g. Calcium levels this low are usually associated with:

- sandy soils that are low in organic matter and with a pH less than 4,
- excessive use of highly acidifying fertilisers, and/or
- very sodic soils

In most situations any one of these three factors will have a greater consequence on plant growth than the Ca deficiency.

The symptoms of a severe Ca deficiency are stubby, weakly branched and discoloured roots similar to symptoms of aluminium toxicity. Above ground the symptoms are shoots dying at the growing point.

Where the soil test reports exchangeable Ca between 0.5 and 0.7 meq/100g Ca deficiency symptoms may occur to a lesser extent, for example, November leaf in bananas. Calcium levels in this range are most likely to occur in a high rainfall environment where the soils are acid with low cation exchange capacity (Bruce 1999).

Where available Ca is marginal (0.7 to 1.0 meq/100g) and growing conditions are most favourable, a Ca deficiency may occur in those parts of the plant that are furthest from the main flow of water within the plant. Examples of the effect of marginal deficiency are poor seed set in peanuts and subterranean clover, and blossom end rot in tomatoes (see Table 1 for details of symptoms).

► *Blossom end rot in tomatoes caused by a marginal deficiency of soil calcium.*

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Left: Magnesium deficiency in Seaton Park subterranean clover. While these symptoms are quite common there is no record of a response to applied magnesium in southern NSW.

Right: Magnesium deficiency in wheat looks similar to nitrogen deficiency.

Frequency of low available Ca in soil. An analysis of the results of testing 6 300 paddocks in southern and central western NSW (A. Fanning, pers. comm.) showed that only 60 of these paddocks had calcium levels in the 0 to 10cm layer likely to cause severe calcium deficiency. Of these 60 paddocks, 43 were sodic with an Exchangeable Sodium Percentage (ESP)[2] of more than 7%. Of those 43 paddocks, 12 had calcium less than 30% of their base cations and all but one of these had either an ESP greater than 10% or some other unexplained abnormality.

Table 1: Summary of the symptoms associated with calcium deficiency.

Soil test result (Ca)	Symptoms
Less than 0.5 meq/100g	Stubby, weakly branched and discoloured roots fresh shoots dying at the growing point.
Between 0.5 and 0.7 meq/100g	As above but less severe
Between 0.7 and 1.0 meq/100g	Symptoms indicate Ca deficiency occurs furthest from the main flow of water.
	Examples are: poor seed set in peanuts and sub. clover blossom end rot in tomatoes.

Note that when the exchangeable Ca falls to less than 45% of Cation Exchange Capacity (CEC)[3], as given on many soil test results, this does not mean that a calcium deficiency will occur. Often in this situation an excess of other cations such as aluminium or sodium has caused the drop in the proportion of Ca in the CEC and that excess is more than likely affecting crop or pasture growth.

AVAILABLE MAGNESIUM (Mg)[1]

Magnesium deficiency has been recorded in seedling crops and pastures in southern NSW where there was less than 0.2 meq/100g exchangeable Mg in the 0 to 10cm soil layer. A sign of Mg deficiency in cereals in the field is yellowing of the oldest leaves and this can be confused with nitrogen deficiency. In clovers, symptoms can include reddening of the oldest leaves (B Scott, pers. comm.). Low levels of exchangeable Mg are rare, with 145 of the 6 300 paddocks referred to above having exchangeable Mg of 0.2 meq/100g or less in the top 10cm.

The likelihood of having a loss in production of a crop or pasture due to a magnesium deficiency is even further reduced with most soils in NSW having ample supply of Mg in the subsoil. The plant normally accesses this supply of Mg as its roots extend into the subsoil.

Where there is a high level of Mg (exchangeable Mg > 50% BCEC[4]) there has been some suggestion that this may cause loss of structure in the soil. Research by the CSIRO in Adelaide (Rengasamy 1986) has shown that Mg in itself has no effect on spontaneous dispersion of undisturbed soil such as subsoil. It can, however, affect dispersion of a soil that has been disturbed.

Where the exchangeable Mg is greater than 30% of BCEC it may enhance the effect of exchangeable sodium in causing dispersion of a soil, provided:

- the Ca:Mg ratio is less than 1,
- the ESP is > 4 %, and/or
- the sum of ESP plus [Ex. Mg % divided by 10] is greater than 6

In practice, this means that contribution of Mg to soil dispersion is of little importance compared to that of sodium. Note that the critical values of Mg and Na for dispersion given above are for a soil with a low electrical conductivity (EC < 0.2 ds/m in 1:5 soil:water). As the electrical conductivity increases, so will the critical value of [ESP plus Mg/10] needed to cause dispersion increase.

Frequency of high levels of Mg in soil. Of the 6 300 paddocks referred to above, 510 (8 %) had magnesium taking up more than 30% of the BCEC in the 0 to 10cm layer and less than 1 % had magnesium taking up more than 50% of the BCEC.

Grass tetany in cattle. The onset of grass tetany is sometimes attributed to a low soil Mg, however Radostitis *et al* (1994) details a number of factors that will influence the onset of this disease. Check with a veterinarian or livestock officer before relying on an application of dolomite to correct the problem. There may be more effective and less expensive ways to reduce the occurrence of grass tetany in cattle.

SIGNIFICANCE OF THE Ca:Mg RATIO IN PREDICTING PLANT GROWTH

Some agronomists use 4 to 6 as a benchmark for the ratio of the exchangeable cations Ca to Mg. They claim that this benchmark must be achieved to ensure a healthy soil and therefore optimum agricultural production. This claim has not been proven. Furthermore, several scientific reports have shown that the Ca:Mg ratio can vary between 1 and 20 with little or no effect on agricultural production.

Moser (1933) points out that the calcium-magnesium ratio hypothesis was first proposed by Loew and May in 1901. He reviewed a number of cylinder experiments using a rotation of barley, red clover, fodder corn and Timothy grass and concluded that there was no significant correlation between the calcium-magnesium ratio and crop yields.

Haby and others in 1993 reviewed the whole question of using the ratios of exchangeable cations to predict plant growth. They found that in New Jersey, F. E. Bear (1945) proposed that an 'ideal soil' is one where the proportion of the exchangeable cations is 65% Ca, 10% Mg, 5% K and 20% H. Again in New Jersey, E. R. Graham (1959) suggested a modification to this standard where the exchangeable Ca could range from 65% to 85% of the CEC. Both Bear and Graham based their benchmark on the analysis of soils sampled from under healthy crops and pastures. They found that all these soils had similar ratios of exchangeable cations and they proposed that cations in these ratios were necessary for the best crop and pasture growth. Apparently neither Bear nor Graham tested their theory by varying the ratios and measuring the effect.

Since then there have been a number of studies in America, New Zealand and Australia that have looked at the effect on plant growth of a wide range of cation ratios on a wide range of soils. For example, in the mid-west of the United States McLean et al., (1983) found poor correlation between yield response of corn, soybeans, wheat and alfalfa to varying Ca:Mg ratios. Eckert (1987) found that a wide variation in Ca:Mg, as well as other ratios of base cations, was of little consequence so long as gross imbalances were not created.

Scott and Conyers (1995), in a review of the effects of varying cation ratios, point out that McLean and Brown (1984) acknowledge that the concept of the set ratios of the cations became a dominant force in shaping lime and fertiliser recombinations in the United States, particularly in the mid-west. However, from their own studies, McLean and Brown concluded 'there is no ideal basic cation saturation or range of saturation where crop yields are maximum'. Simon et al. (1979) reached a similar conclusion for corn and lucerne in the southern states.

Analysis of the results of testing 6 300 paddocks referred to above showed that only 16 paddocks had a topsoil with Ca/Mg greater than 20 and none were greater than 30. In addition, only 88 of the 6 300 paddocks had a Ca:Mg ratio equal to or less than 1, indicating that this situation is not a common problem.

Footnotes

[1] The best indicator of availability of calcium and magnesium is the exchangeable Ca and exchangeable Mg in a standard soil test report. Exchangeable cations, such as Ca and Mg, are positively charged elements that are loosely bound to the negatively charged clay and organic matter. They are not immediately available to the plant but can move easily into the soil solution where they become available. The unit of measurement is usually meq/100g. Most reports give the relative amount of the individual cations as a percentage of the cation exchange capacity (CEC).

[2] Exchangeable Sodium Percentage (ESP) is the percentage of sodium in the CEC.

[3] Cation Exchange Capacity (more correctly, the effective cation exchange capacity or ECEC) is the sum of all the exchangeable cations, that is Ca, Mg, K, Na, [hydrogen (H) when it is given in a soil analysis] and, in strongly acid soils, aluminium (Al) and manganese (Mn).

[4] BCEC is Base Cation Exchange Capacity, which is the CEC less Al and Mn.

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