MOLYBDENUM RELATIONSHIPS IN SOILS AND PLANTS

G. R. Thibaud
KwaZulu-Natal Department of Agriculture and Environmental Affairs, Cedara College, Private Bag X9059, Pietermaritzburg, 3200
thibaudg@dae.kzntl.gov.za.

ABSTRACT

The essentiality of molybdenum (Mo) for the growth of higher plants was conclusively established by D. Arnon & P. Stout in 1939. At the time, they believed that field cases of Mo deficiency in plants were unlikely to ever occur, owing to the exceedingly low amounts of Mo required. By 1942, however, A. Anderson had identified Mo deficiency in clover production in several South Australian pastures, and had shown phenomenal increases in pasture production through the application of 5 g ha^{-1} Mo. Following on this, Mo deficiency has been found to limit crop and pasture production on millions of hectares of land throughout the world.

In South Africa, several cases of Mo deficiency were identified during the 1960's in maize and lucerne, and also in a variety of fruit and vegetable crops in the winter rainfall area of the Western Cape. The importance of Mo in maize production was further demonstrated during the 1970's and 80's, and Mo re-enforcement of seed has long been a standard practice in the South African maize industry. Prior to 1990, little emphasis was placed on the importance of Mo in soyabean production in South Africa. During the 1990's, however, yield responses of up to 170 per cent due to Mo seed treatment were recorded with soyabean on acid, heavy Hutton soils in KwaZulu-Natal, highlighting the crucial role of this element in ensuring maximum soyabean yields.

Of all the essential trace elements required for the growth of higher plants, Mo is required in the least amount, and leaf Mo contents of 0.1 – 0.5 mg kg^{-1} are typically considered adequate. Molybdenum is required for the functioning of several complex enzyme systems involved in nitrogen metabolism in plants. It is a vital constituent of nitrate reductase, which catalyses the reduction of nitrate (NO_3^-) to nitrite (NO_2^-) as the first step towards the incorporation of nitrogen into protein. In nodulated legumes, Mo is necessary for the reduction of atmospheric nitrogen (N_2) to ammonia by nitrogenase, and in certain legumes such as soyabean and cowpea, for the oxidation of purines by xanthine dehydrogenase. Symbiotic bacteria require about ten times more Mo for N_2 fixation than does the host plant (for protein synthesis). Hence, Mo deficiency commonly occurs in legumes before it does in other plants, when grown in the same soil.

Information on the Mo status of soils in South Africa is noticeably lacking. Data from a soil survey, covering 200 virgin soil profiles in north eastern South Africa, indicated that Griggs ammonium oxalate (pH 3.3) extractable Mo contents varied from 0.003 to 1.5 mg kg^{-1}. Extractable Mo, on average, showed a significant increase with increasing soil depth, but this was not constant across all soil types. Avalon, Griffin and Westleigh soil types showed greater increases in Mo with increasing depth, than did Hutton and Clovelly soil types. Several soil types, including Valsrivier, Rensburg and Arcadia, showed a decrease. Differences in soil parent material and degree of weathering are known to impact on soil Mo status, and soils derived from sandstone, quartzite and granite were found to contain the least amount of extractable Mo (0.07 mg kg^{-1}), while those formed from shale contained between 0.1and 0.14 mg kg^{-1}. Dolerite and diabase derived soils contained approximately 0.1 mg kg^{-1} and were somewhat lower than those formed from basalt, andesite and iron-rich shale and gabbro (0.17 - 0.19 mg kg^{-1}). Soils particularly rich in Mo were those derived from dolomite and chert rich dolomite (0.5 mg kg^{-1}). The amount of oxalate extractable Mo was found to be significantly positively correlated with exchangeable K, AMBIC P, pH, oxalate extractable Fe, and especially with oxalate extractable Mn, and negatively correlated with exchangeable acidity.

The adequacy of Mo for plant growth is determined by a number of soil and plant factors. Soil factors that impact on Mo uptake include the following: level of extractable Mo, clay content and mineralogy, organic matter, redox potential, availability of other nutrients and pH. Poorly drained soils rich in organic matter are very often found to produce crops and pastures with excessively high contents of

Mo, while acid soils containing appreciable amounts of non-crystalline oxides and hydroxides of Fe and Al frequently retain Mo in a non-plant available state. It is widely recognised that liming, by raising pH, increases Mo availability to plants, and it has been suggested that pH elevation is the best way of ensuring adequate Mo nutrition. However, there is evidence to indicate that numerous soils are inherently so low in Mo, that availability is inadequate for optimal growth, even at near neutral pH values. In addition, studies with maize, soyabeans and dry beans on acid, heavy textured soils in KwaZulu-Natal indicate that uneconomically high quantities of lime may be required to ensure against Mo deficiency. Other soil nutritional factors reported to influence Mo uptake are P and S. In spite of several reports indicating that S depresses Mo uptake due to anionic competition between SO_4^{2-} and MoO_4^{2-}, (the forms in which these two nutrients are absorbed by roots), gypsum applications of up to 5 Mg ha^{-1} on kaolinitic clay soils in KwaZulu-Natal were not found to significantly depress Mo accumulation by soyabean. Phosphorus, on the other hand, has been reported to enhance Mo uptake. In the case of soyabean grown on highly Mo responsive soils, this effect is sometimes masked. The dramatic increase in the number and size of nodules with improved P nutrition leads to an accumulation of Mo in the nodules, at the expense of leaves and seed (the plant parts most commonly assayed for Mo uptake effects). In the presence of Mo deficiency, the functionality of the nodules is greatly reduced, and soyabean response to P is adversely affected. Significant negative residual soil N x Mo interactions on yield have also been noted with soyabean, at some locations in KwaZulu-Natal. This suggests that, under conditions of lowered nitrogenase activity (N_2 -fixation), residual soil N may substitute for reduced fixation, provided that NO_3^- loading of the plant is not excessive (adequate nitrate reductase activity). The extent to which crops respond to supplementary Mo may also be influenced by several plant related factors, including species, genotype, and Mo reserves in the seed. Crop Mo requirement typically decreases in the order; legumes > cruciferous crops and cucurbits > grasses. Seed with adequate Mo reserves typically provides sufficient Mo for optimum growth of the plant. However, unless the mother crop is sprayed with Mo, the resultant seed produced usually shows a dramatically lowered Mo content. While many plants can accumulate Mo in concentrations far in excess of their requirement without resulting in phytotoxicity, the indiscriminate use of supplementary Mo can have serious consequences for livestock. The consumption of feed matter containing greater than approximately 5 mg kg^{-1} by ruminants may result in Mo toxicity (molybdenosis), especially if dietary copper intake is low.

Owing to the numerous interactive effects involving Mo, the identification of soils on which supplementary Mo is likely to be beneficial is complex. Although the acid ammonium oxalate method of Grigg has been the most extensively used procedure for estimating plant available Mo in soils, it is insensitive to the positive effect that pH elevation has on plant available Mo, and also to Mo buffering effects in soils. In summary, the commonly held viewpoint which is supported by local findings is that, until the interaction of Mo with other soil properties and nutrients is better understood and characterised, the prognostic value of Mo soil tests alone is likely to remain uncertain. The best approach for identifying Mo-deficient soils at this stage appears to be through simultaneous consideration of soil test values, pH and mineralogy, especially the amount of sesquioxides.