Nutri-Facts

Agronomic fact sheets on crop nutrients

Molybdenum

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Molybdenum (Mo) is a trace element required in very small amounts for the growth of both plants and animals. Crop deficiencies of Mo are fairly uncommon, but when diagnosed, various soil and foliar fertilizers can be used to correct this condition. Deficiencies have been reported from acid, sandy soils and can be exacerbated under minimum disturbance cropping systems.

Molybdenum in Plants

Molybdenum, although required in very small amounts, is essential for normal plant growth and development. Molybdenum's primary function within the plant is to produce enzymes. These Mo-enzymes are involved in the regulation of nitrogen (N) nutrition. In non-legumes, nitrate reductase regulates the conversion of nitrate into bioactive forms. The Mo requirement of legumes is greater than that of grasses and other crops as an additional Mo-enzyme (nitrogenase) is required by the root nodule bacteria for N fixation. Canola also has a relatively high demand for Mo, requiring 5 to 6 times more Mo than cereals.

Molybdenum toxicity in plants is rare but special care should be taken to monitor for toxicity in fodder crops. Sheep and cattle feeding on plants with a high Mo concentration may suffer from a condition known as molybdenosis. This condition is a result of high Mo concentrations suppressing the availability of dietary copper (Cu) in these animals.

Molybdenum in Soils

Molybdenum is released from solid minerals through normal weathering processes before undergoing various reactions in the soil to become its plant-available anion form MoO_4^{2-} (molybdate). Once it is dissolved, MoO_4^{2-} anions are subject to adsorption processes on clays, metal oxides of iron (Fe), aluminum (Al), and manganese (Mn) as well as organic compounds, and carbonates.

The solubility of MoO_4^{2-} is greatly influenced by soil pH and

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Soybeans showing Mo deficiency in the foreground.

there is increased availability with higher soil pH. Molybdate solubility increases approximately 100 times for every unit increase in soil pH. Therefore, the use of lime to increase the pH of acid soils is an important management tool to improve Mo availability. Where soils have a pH_{Ca} of 5.0 or greater, it is uncommon to encounter Mo deficiencies.

Addition of sulfate (SO_4^{2-}) fertilizer tends to decrease MoO_4^{2-} uptake, as they both compete for root uptake sites. The addition of phosphate can result in the release of Mo that is adsorbed on soil, leading to greater Mo uptake and accumulation in plants.

Diagnosing a Molybdenum Deficiency

Because Mo is required in such small quantities, the diagnosis using soil or plant testing is analytically challenging, expensive, and is not reported as reliable in predicting Mo deficiencies over a wide range of soils[1].

Soil pH is an important determinant of the amount of plant available Mo in the soil. Molybdate adheres more readily to other elements in the soil when the pH is 4.5 or less, increasing the

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likelihood of Mo deficiency. Australia's soils under agriculture will acidify with time, therefore, if soil pH is not monitored and kept at a reasonable level, the amount of plant available Mo declines[2]. However, soil acidification can also increase the risk of potassium (K) deficiency and aluminium (Al) toxicity, so the diagnosis can be difficult[3].

Plant tissue tests can be used but, like soil tests, they are expensive and reliability is relatively low.

Molybdenum Deficiency Symptoms

Molybdenum is mobile within plants and deficiency symptoms can appear on the entire plant.

Non-legumes: Since adequate Mo is essential for proper N metabolism, deficiencies commonly appear as stunted plants and failure of leaves to develop a dark green color. In more severe deficiencies, the leaves may develop a pale green or yellow area around the edges and between the veins. Advanced symptoms of insufficient Mo may appear as burning (necrosis) around the leaf edges and between the veins. The most severely affected plants can show empty heads (similar to Cu deficiency or frost) and delayed maturity.

Legumes: The symptoms of insufficient Mo include a general stunting and yellowing, typically seen as a result of insufficient N supply. Root nodules are green and small.

Fertilizing with Molybdenum

In many soils, application of a liming material to increase pH will release Mo from insoluble forms. For example, a study showed that addition of lime alone resulted in the same soybean yield as when Mo fertilizer was added to unlimed soil. However, the chemical release of soluble Mo following lime application may take weeks or months to occur.

If lime is not required for crop growth or when the Mo concentration of the soil is low, it may be useful to fertilize with additional Mo in the following ways:

Soil. Molybdenum fertilizers can be banded or broadcast on the soil. It is commonly added in small amounts, ranging from 250 to 900 g/ha. It is often mixed with other fertilizer materials to help with uniform application or it may be dissolved in water and sprayed on the soil before planting. Molybdenum trioxide (MoO_3) is only suitable for soil application due to its low solubility. The use of MoO_3 at 150 g/ha has been shown to have a residual activity of up to 5 years[4].

Foliar. Soluble Mo sources, such as sodium or ammonium molybdate, are used for foliar application to plants. Foliar application of dilute solutions of Mo is generally most effective when applied at earlier stages of plant development. Foliar applications are beneficial for immediate correction of Mo deficiency symptoms, compared with soil applications, which have a longer residual benefit.

Seed. Seed treatment with Mo fertilizer ensures that each seed is uniformly provided a small, but adequate amount of Mo for healthy growth. Rhizobia inoculants for legume crops are sometimes amended with small amounts of Mo to promote vigorous N fixation. Excessively high application rates can lower seed germination or cause Mo accumulation to concentrations that may be harmful for grazing animals. Selecting seed from a crop with a good Mo history or from an alkaline soil can also reduce the risk of deficiency[5].

The selection of a specific Mo fertilizer depends largely on how the material will be applied. Some common fertilizer products containing Mo are given in **Table 1**.

Table 1. Some common fertilizer products containing Molybdenum.

Name	Chemical formula	Mo content	Solubility
Sodium Molybdate	$Na_2MoO_4{\cdot}2H_2O$	39%	653 g/L
Ammonium Molybdate	$(NH_4)_2Mo_7O_{24}4{\cdot}H_2O$	54%	400 g/L
Molybdenum Trioxide	MoO_3	66%	3 g/L

Crop Response to Molybdenum

The benefit of supplying adequate Mo most commonly relates to boosting the ability of plants to utilize N, therefore the crops response to adequate availability of Mo is generally similar to that of adequate availability of N.

Table 2 shows some examples of Mo responses, all which come from situations where soil pH is very low, either from Western Australia or on the slopes in New South Wales. For example, canola yield responses to applied Mo have been measured in Western Australia[2] on sites where $pH_{Ca} < 4.8$. Where Mo is lacking, supplemental fertilization has resulted in large increases in plant growth and yield.

Table 2. Responses to supplementary molybdenum for a range of species.

Crop	Soil pH_{Ca}	Control	Plus Mo	Mo rate, g Mo/ha	Reference
Canola	4.6	1.75 t/ha	1.99 t/ha	40 (avg. of 3 sites)	2
Wheat	<4.4	1.25 t/ha	1.60 t/ha	70 (avg. 3 sites)	5
Subclover	4.5	4.60 t DM/ha	5.70 t DM/ha	80	6
Wheat	4.4	1.63 t/ha	2.42 t/ha	120	7
Wheat	4.3	5.1 g/pot	9.7 g/pot	120	8
Phalaris	4.3	10.0 g/pot	3.7 g/pot	-	8

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