Essential Plant and Animal Micronutrients

Molybdenum in Idaho

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Plants require trace amounts of molybdenum (Mo) for normal growth. While animals also require trace amounts, they are more likely than plants to be adversely affected by excessive Mo. Management of Mo in crop rotations should take into account both animal and plant needs.

Molybdenum and Plants

Mo—like boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn)—is a necessary micronutrient for plant growth. Molybdenum is called a micronutrient because plants require it in smaller amounts than the macronutrients—nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). Plants take up Mo in the MoO_4^{2-} ionic form.

Mo has several functions in plant growth. Plants require a constant and continuous supply of Mo for normal assimilation of N. Mo is also a component of the enzyme nitrogenase, which is required in N fixation and plays a role in P utilization. Because of Mo's role in N fixation, legumes require more of it than cereals and are thus more sensitive to low Mo levels in soil (Table 1).

Molybdenum Availability in Soil

Low soil Mo levels in some parts of northern Idaho have been found to limit plant growth in alfalfa, clover, birdsfoot trefoil, peas, and lentils (Fig. 1). In contrast, Mo deficiencies are rare in crops growing on the Snake River Plain in southern Idaho.

Some plants growing in mountain valleys of north-central Idaho have abnormally high Mo levels. Mo fertilizers should not be applied to soils in these mountain valleys unless a need has been demonstrated.

Table 1. The relative Mo requirements of Idaho crops.

Low		High	
Barley	Onions	Alfalfa	Lentils
Bluegrass	Potatoes	Beans	Peas
Corn	Rapeseed	Birdsfoot trefoil	Red clovers
Fruit trees	Sugarbeets	Chickpeas	White clovers
Hops	Vegetable seed crops		
Mint			
Oats	Wheat		

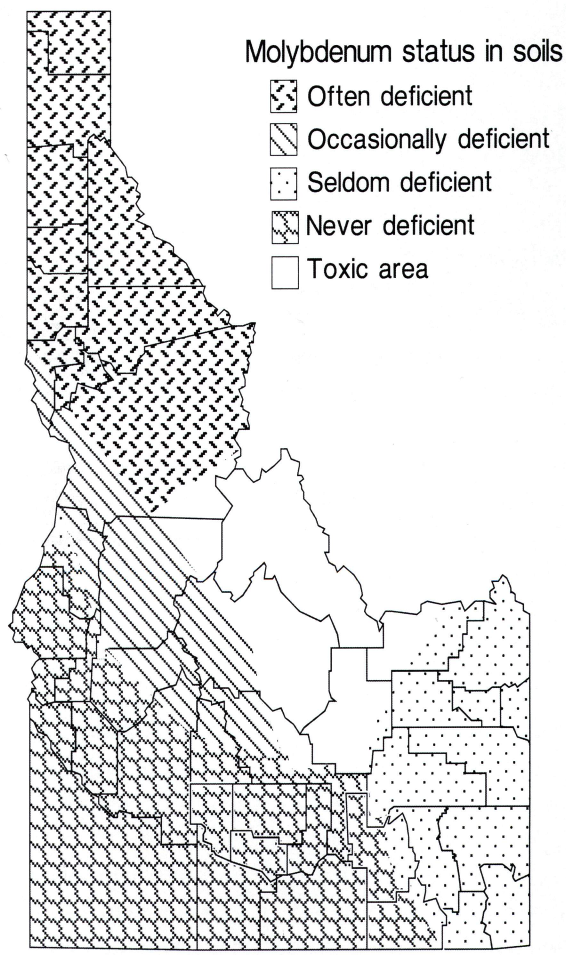

Fig. 1. Idaho soils that may be deficient or extremely high in plant-available molybdenum.

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Fig. 2. Molybdenum deficiency in a crop, such as this soybean field, turns healthy, dark green leaves yellowish-green. This symptom is often misdiagnosed as a nitrogen or sulfur nutritional problem.

Fig. 3. Molybdenum deficiency in white clover. Note the healthy, green leaves on the left, compared to the yellowish-green Mo deficient plants on the right.

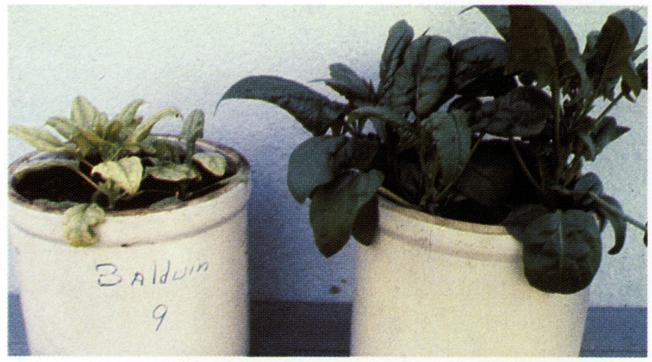

Fig. 4. Molybdenum deficiency in beets. Note the stunted, yellowish-green leaves in the Mo deficient pot.

Mo availability in the soil increases with pH. Mo deficiencies are uncommon in high pH soils (pH 7 or above). That is why Mo deficiencies are rare in southern Idaho. Most Mo deficiencies occur in acidic northern Idaho soils with pH values less than 6.0. In addition, acid, sandy, leached soils or soils high in organic matter (greater than 25 percent organic matter) may be deficient in plant-available Mo.

Most Mo deficiencies in Idaho occur in fields with low pH values and a long-term history of legume production. Soils high in iron may have plants that exhibit Mo deficiencies.

Crop Response

Soils normally contain 0.5 ppm of Mo. However, plants usually require only 0.2 to 5 ppm of Mo in their tissue.

Mo may be harmful when its available form, MoO_4^{2}, is in the soil in excessive quantities. For example, although Mo may be beneficial to plant growth when added to the soil as a seed treatment at rates as low as 0.03 pound per acre, an application of 3 to 4 pounds per acre would be toxic to many plants or to the animals that consume them.

Molybdenum Deficiency Symptoms

When Idaho crops show Mo-deficiency symptoms, economic loss probably has already occurred. In the field, Mo-deficiency symptoms are difficult to distinguish from N and S nutritional problems and often are misdiagnosed. Mildly Mo-deficient plant leaves appear yellow, similar to their appearance when they are deficient in N or S (Fig. 2). Most growers assume yellow peas, lentils, clover, and alfalfa have N or S problems, however, the problem may be Mo deficiency. Mo deficiency symptoms are similar to N symptoms in legumes because Mo is required in the N_2 fixation process—thus when Mo is deficient plants cannot get the N needed for growth. In non-legumes, without Mo plants cannot utilize the N taken up by roots—thus resulting in N deficiency symptoms.

Initially Mo deficiency is characterized by a light green or yellow-green color (Figs. 3 and 4). Under conditions of severe Mo deficiency young leaves wilt and necrotic (dead) tissue appears along their margins (Fig. 5). When a Mo deficiency is suspected, the plant tissue should be sampled and evaluated.

Molybdenum Fertilizer

Several Mo fertilizer materials are commercially available (Table 2). Sodium molybdate ($Na_2MoO_4 \bullet 2H_2O$) and ammonium molybdate [$(NH_4)_6Mo_7O_{24} \bullet 4H_2O$] are the Mo fertilizer materials most commonly used in Idaho. Molybdenum trioxide (MoO_3) is much less soluble (which often means less available to the plant) than sodium molybdate or ammonium molybdate. The molybdenum trioxide form is not widely used in Idaho. Molybdenum sulfide (MoS_2) is a poor source of plant-available Mo and should be avoided in Idaho.

In the frits form, Mo is fused with glass. The glass is then shattered and applied to soils. As the glass slowly dissolves in the soil, Mo becomes available. Molybdenum frits are actually slow-release fertilizers. The amount of Mo can be varied by controlling the amount of Mo fused with glass. Molybdenum frits is an uncommon fertilizer in the Pacific Northwest and should only be applied to acid soils (pH values less than 6.5).

Fig. 5. Molybdenum deficiency in peas grown in northern Idaho. The Mo deficient pea plants on the left are stunted and exhibit severe yellowing of the plant tissue when compared to healthy plants on the right.

Application Methods and Rates

Three principal methods of applying Mo fertilizers are (1) soil application, (2) foliar application, and (3) application directly to the seed at planting time. Mo is applied most commonly as a seed treatment. While foliar applications of Mo are often beneficial, seed and soil applications remain effective much longer. Seed application is the most effective Mo application method followed, in order, by soil application and foliar application.

Optimum application rates of Mo vary. Actual application rates depend on the pH of the soil, the crop to be grown, and the application method. Typical application rates range from 0.03 pound (seed and foliar applications) to 1.0 pound (soil applications) of Mo per acre.

Soil Applications—Differences in soils, the crop to be grown, Mo fertilizer sources, and incorporation techniques lead to differing recommended rates of application. Recommended rates in Idaho range from 0.5 to 1.0 pound of actual Mo per acre. The major problem with applying Mo directly to the soil is that it is difficult to evenly distribute such small amounts. Because of this, soil application of Mo is not recommended in Idaho. If a soil application is desired, the fertilizer Mo should be solubized in water and sprayed directly on the soil. This will allow for a uniform Mo application.

Foliar Applications—Although correcting Mo deficiencies in growing plants with foliar sprays is possible, this method is rarely used. Common foliar spray rates range from 0.03 to 0.14 pound of Mo per acre. Spraying such a small amount of material is expensive and difficult. Also, foliar Mo applications correct only the existing plant deficiency, may not last through maturity, and do not add Mo to the soil for use by subsequent crops because the fertilizer material is intercepted by the plant tissues and not the soil.

Seed Treatments—Most of the time the best way to apply Mo is as a seed treatment. Seed application has distinct advantages over both soil and foliar treatments. Seed treatment results in an even Mo application. Seed treatment also requires lower Mo rates than are used for soil application—0.03 to 0.06 pound per acre. Research indicates that 1/8 ounce per acre of Mo applied as a seed treatment will increase pea yields the same amount as 1 pound per acre of Mo applied directly to the soil.

Avoid treating seeds with more than 1 ounce of Mo per acre. Higher Mo rates can lower seed germination and inhibit the growth of the N-fixing bacteria needed for nodulation on legumes. *Rhizobium* inocula containing Mo is commercially available. Excessive rates also allow plants to take up excessive amounts of Mo. Mo levels are rarely toxic to plants, however, they can be toxic to animals that consume them.

Residual Effects

In neutral to alkaline soils (pH 7 and above), Mo soil applications at rates of 0.5 to 1 pound per acre should remain effective for several crop years. Seed treatments of Mo should supply Mo to plants for 3 or 4 years. Soils that are slightly acid (pH 5.7 to 7.0) may require Mo applications every 4 or 5 years. Soils that are regularly

Table 2. Application rates of common Mo fertilizer materials available for use on Idaho crops.

			Mo rate (lb/acre)			
Fertilizer material	Chemical formula	% Mo	1/8	1/4	1/2	1
			Amount of material to apply (lb/acre)			
Ammonium molybdate	$(NH_4)_6Mo_7O_{24} \bullet 4H_2O$	54	0.23	0.45	0.93	1.85
Molybdenum frits[1]	silicates	2 to 3				
Molybdenum sulfide	MoS_2	60	0.21	0.42	0.83	1.67
Molybdenum trioxide	MoO_3	66	0.19	0.38	0.76	1.52
Sodium molybdate	$Na_2MoO_4 \bullet 2H_2O$	39	0.32	0.64	1.28	2.56

[1]Application amounts of Mo frits depend on the percentage of Mo.

cropped with a legume (peas, lentils, alfalfa, clover, and birdsfoot trefoil) and have pH values less than 5.6 may require Mo applications every 2 or 3 years.

Soil analysis and Plant Tissue Testing

Because plant-available Mo is present in soil in very small amounts, soil Mo analysis is technically imprecise and, therefore, not commercially available. Consequently, a soil test cannot be used to assess the need for Mo. Instead, use plant tissue analysis to determine Mo levels. The need for Mo analysis in plant tissue arises when either (1) you suspect toxic Mo levels in plant material that animals will consume or (2) you observe a suspected Mo deficiency symptom. Little work has been done to establish optimum Mo concentration values in plant tissue, however, plant Mo concentrations between 0.1 and 1.2 ppm are known to be adequate for plant nutrition and safe for animal consumption.

When Should I Apply Mo?

Southern Idaho—Due to high soil pH values (pH 7 or above), Mo levels should be adequate throughout southern Idaho. If a Mo deficiency is suspected (based on visual symptoms), have a plant tissue sample from the field tested for Mo. If the plant tissue contains less than 0.1 ppm consider a foliar application of Mo during the present cropping year, or a soil or seed Mo application to next year's crop.

Northern Idaho—Because a reliable soil test for Mo is not available, Mo should be managed on the basis of crop rotation history and soil pH. Molybdenum is more likely to be deficient if a legume (peas, lentils, chickpeas, alfalfa, clovers, birdsfoot trefoil), canola, or rapeseed is in the crop rotation. Soils with pH values of 5.6 or less are also more likely to be Mo deficient. Based on these facts Mo fertilization recommendations are as follows:

- If soil pH is less than 5.6 and legume or oilseed in rotation:

  ✓ seed treat legume/oilseed once every 8 years
- If soil pH is greater than or equal to 5.6 and legume/ oilseed in rotation less than 50 percent of the time:

  ✓ seed treat legume/oilseed once every 6 years
- If soil pH is greater than or equal to 5.6 and legume/ oilseed in rotation is less than or equal to 50 percent of time:

  ✓ seed treat legume/oilseed once every 4 years.

Molybdenum and Animals

Mo is an essential trace mineral for animals. Mo level in most forages ranges from 0.1 to 3 ppm on a dry matter basis. Beef cattle only require 0.01 ppm Mo in their diet, so a Mo deficiency is usually not of concern. The common symptom of animal Mo deficiency is a blocked urinary tract.

Molybdenum Toxicity in Animals

Many animals cannot tolerate high Mo levels in their diets. Mo can impair utilization of copper (Cu), another essential micronutrient, especially if the diet is also relatively high in suflur (S). A Cu-S antagonism lowers the biological availability of Cu by forming a Cu-Mo or Cu-Mo-S complex in the digestive tract. Forage Mo levels of 3 ppm and above will significantly reduce Cu availability from the diet.

Cu is often deficient in animal diets, and the deficiency generally occurs where plant-available Cu is low, often in high organic matter and poorly drained soils (muck soils). If a muck soil has an abundant supply of Mo, plant Mo uptake increases while Cu uptake is reduced.

Severe Mo toxicity (molybdenosis) occurs in cattle where natural forages contain 20 to 100 ppm Mo. This toxicity causes a condition called "teart" in which cattle develop scours. Scours can be mild to debilitating, resulting in permanent injury to the digestive tract and sometimes death. This condition can be corrected by adding a copper-sulfate supplement to the cattle diet.

For Further Reading

You may order other publications about micronutrients in soils from the University of Idaho Cooperative Extension System office in your county or Ag Publications, P.O. Box 442240, University of Idaho, Moscow, Idaho 83844-2240, or phone 208/885-7982 or email: cking@uidaho.edu

BUL 704, *Soil Sampling*, $2.00

CIS 617, *Essential Plant and Animal Micronutrients: Copper in Idaho*, 50¢

CIS 757, *Nitrogen and Phosphorus BMP: Fertilizer Placement*, 50¢

CIS 882, *Long-Term Effects of Lime on Soil pH in Some Acidic Soils in Northern Idaho*, 35¢

CIS 1085, *Essential Plant Micronutrients: Boron in Idaho*, $3.00

CIS 1088 (formerly CIS 617), *Essential Plant Micronutrients: Zinc in Idaho*

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