# The Molybdenum Status of Some Indiana Soils[1]

Terry Lavy, Gerald Sands and Stanley Barber, Purdue University

Molybdenum was first shown to be essential for plant growth in 1939 by Arnon and Stout (3). Previous efforts by other workers failed because of molybdenum impurities in the chemicals used in the nutrient solutions. Using tomatoes as the indicator crop, Arnon and Stout found that adding molybdenum at the rate of one part per 100 million parts nutrient solution allowed good plant growth.

The first plant response to molybdenum added to the soil was reported by Anderson (1) in Australia in 1942. He found that molybdenum applications of one ounce per acre produced large yield responses in subterranean clover. Later investigators both in Australia and the United State reported molybdenum response also with non leguminous plants. Bortels (5) had previously shown that the presence of molybdenum was essential in symbiotic nitrogen fixation.

Evans, Purvis and Bear (6) while working with molybdenum deficient plants noticed a nitrate build-up. Upon addition of molybdenum to the growing media this accumulation of nitrates was not found. It was suggested that nitrate build-up may be an indirect effect caused by a lack of molybdenum in a reaction preliminary to nitrate reduction.

In attempting to find molybdenum deficiencies it is first important to understand the different molybdenum forms occurring in the soil. Igneous rocks have been shown to contain less than 1 PPM molybdenum (6). As weathering of the rock occurs molybdenum is released. Being a transition element molybdenum has valence states ranging from +2 to +6, therefore it is capable of being tied up in many chemical compounds.

Barshad (4), in attempting to characterize soil molybdenum, postulated that molybdenum in the soil is present not just as a distinct mineral, but rather partly as a molybdate salt, partly as a component of organic matter and partly as an adsorbed exchangeable anion. This exchangeable anion is the molybdate ion, $MoO_4^{=}$, which is the form available for plant uptake.

Stout (9) points out that the molybdate ion should act like the sulfate ion due to its similarity in charge and size. This ion has been been shown to become less soluble like the phosphate ion as the pH is reduced in clay suspensions (4). This is in contrast with the other minor elements which are all more available at acidic pH levels.

The content of molybdenum in organic matter appears to vary widely. Since soil organic matter decomposes slowly this may be one of the best molybdenum storehouses in the soil.

The exchangeable molybdate ion can be made readily available by liming. Robinson and his co-workers (8) increased the molybdenum uptake of legumes from six to eleven fold by liming the soil.

---

1. Journal paper no. 1679 Purdue University Agricultural Experiment Station. Contribution from the Department of Agronomy. Financial assistance from the Climax Molybdenum Co. is gratefully acknowledged.

The effect of liming on molybdenum uptake depends on the amount of unavailable molybdenum in the soil.

Anderson (2) points out that the small amount of molybdenum which clover plants obtain from molybdenum deficient soils is sufficient for metabolism (nitrate reduction) of the host plant. This indicates that any plant responses to molybdenum usually arise from some beneficial effects on the symbiotic nitrogen fixation mechanism. He has shown that smaller molybdenum responses occur on these soils when adequate nitrogen is present. Thus a primary function of molybdenum to leguminous plants is its aid in supplying nitrogen to the host plant.

The objective of this work was to determine if there are areas in Indiana where molybdenum deficiencies are a limiting factor in crop production.

Where should molybdenum responses be expected?

1. Acid soils tend to tie up molybdenum and may be low.
2. In sandy soils some of the molybdate salt may be lost by leaching.
3. Soils which have been heavily cropped, especially in areas where hay is sold off the farm, would be low because of crop removals.

Foy and Barber (7) reported molybdenum deficiencies in nine of the eighteen soil types studied in the greenhouse in 1956. Alfalfa was grown on these soils which ranged in pH from 4.8 to 7.4. An example of their results is shown in table 1. The treatments used were: no lime; low lime; 250 lbs. Ca $CO_3$ per acre and lime according to soil test. Molybdenum treatments were 0 and 2 pounds of molybdenum per acre. A significant response was obtained on two soils (Tracy and Fox as shown in table 1) using the high rate of lime while six others approached signifi-

TABLE 1

Response of alfalfa to molybdenum on Indiana soils in the greenhouse, 1956.

| Soil | Initial pH | Mo. treatment | Yield (g.dry wt./pot) 3 cuttings No lime | Low lime | High lime |
|---|---|---|---|---|---|
| Tracy loam | 5.3 | O | 0.37 | 7.95 | 10.53 |
| | | Mo. | 0.25 | 8.02 | 12.40 |
| | | Response | —0.12 | +0.07 | +1.87* |
| Crosby silt loam | 5.4 | O | 9.02 | 14.73 | 16.81 |
| | | Mo. | 12.30 | 15.31 | 18.12 |
| | | Response | +3.28* | +0.58 | +1.31 |
| Fox loam | 5.4 | O | 2.90 | 11.09 | 11.43 |
| | | Mo. | 5.18 | 11.69 | 13.39 |
| | | Response | +2.28* | +0.60 | +1.96* |
| Gibson silt loam | 5.6 | O | 0.07 | 2.63 | 16.18 |
| | | Mo. | 0.19 | 7.49 | 14.01 |
| | | Response | +0.12 | +4.86* | —2.71* |

* significance at 5% level

cance. This indicates a lack of both available (soluble molybdate salt) and unavailable molybdenum in these soils. Five soils receiving no lime produced significant yield increases with molybdenum treatments indicating a lack of available molybdate at this pH level. The work of Foy and Barber in the greenhouse suggests that molybdenum deficiencies may be occurring in the field on Indiana soils.

In 1959 a greenhouse experiment was conducted using molybdenum treated seed of red clover, alfalfa and soybeans on eight acid soils. This work failed to show any significant yield increase due to molybdenum treatment. It did, however, show that the soils used contained adequate amounts of molybdenum to prevent deficiencies. Some of the results shown in table 2 indicate that the treated plants took up the added molyb-

TABLE 2

The effect of molybdenum treatment on yield and molybdenum content of red clover and alfalfa grown on a Sidell silt loam at ph 5.2.

| | Hay Yield (g./pot) CUTTING | | | | Mo. Content 1st Cutting | |
|---|---|---|---|---|---|---|
| | 1 | | 2 | | | |
| Crop | Mo.* | —Mo. | Mo. | —Mo. | Mo. | —Mo. |
| Red Clover ..... | 10.66 | 11.80 | 10.40 | 8.68 | 1.9 | 0.9 |
| Alfalfa ..... | 5.25 | 4.85 | 5.58 | 4.55 | 4.3 | 0.6 |

* Molybdenum was applied to the seed at the rate of ¼ ounce per acre.

denum, but failed to give yield increases. Molybdenum applied as a foliar application in the field of soybeans at four locations produced plants containing more molybdenum than the untreated plants, but no significant increase in yield was shown. This indicates once again that the soil on which the plants were grown was high enough in available molybdate. This experiment did show that molybdenum can be taken up by the soybean plant when applied as a foliar application.

In a larger survey, plant and soil samples were taken from five soybean fields on each of nineteen different soil types in Indiana. A molybdenum analysis was made of the above ground portion of the soybean plant. The results are summarized in table 3. The soil was tested for pH, available phosphorus and potassium. The dry weight of ten plants at each location was determined and the maturity stage was noted.

The molybdenum content varied from 0.06 to 21 PPM. A multiple regression analysis of the data using soil pH, available phosphate, potash, color, weight of ten plants and maturity index as the independent variables and molybdenum content of the plants as the dependent variable was made. The results showed practically no correlation of any of these factors with the molybdenum content of the soybean plant.

An analysis for the total molybdenum content of some of these soils was made and the results are shown in table 3. There was little correlation between the molybdenum content of the plant and the total molybdenum content of the soil. However, the molybdenum content of the plant did

TABLE 3

The effect of soil type on the molybdenum content of the soil and the soybean plant growing on the soil.
Total molybdenum content (PPM)*

| Soil Type | Plant | | Soil |
|---|---|---|---|
| | Ave. | Range | |
| Odell silt loam | 0.47 | 0.06–1.12 | 2.08 |
| Vigo silt loam | 0.57 | 0.10–1.19 | 2.48 |
| Chalmers silty clay loam | 0.60 | 0.42–0.67 | 1.52 |
| Fincastle silt loam | 0.65 | 0.37–0.75 | |
| Door silt loam | 0.80 | 0.02–1.60 | |
| Plainfield loamy fine sand | 0.83 | 0.42–1.08 | |
| Newton loamy sand | 0.98 | 0.62–1.75 | |
| Fox silt loam | 1.13 | 0.74–1.58 | |
| Tracy fine sandy loam | 1.24 | 0.44–2.42 | |
| Alford silt loam | 1.25 | 0.82–1.75 | |
| Crosby silt loam | 1.49 | 0.42–1.91 | 1.77 |
| Cincinnati silt loam | 1.59 | 1.08–2.62 | |
| Granby fine sandy loam | 1.77 | 0.28–4.26 | 1.47 |
| Brookston silty clay loam | 1.98 | 0.75–3.86 | |
| Maumee sandy loam | 2.42 | 0.15–8.82 | |
| Hoytville silty clay loam | 3.37 | 1.68–4.85 | 3.05 |
| Nappanee silt loam | 3.57 | 1.45–6.94 | 4.29 |
| Carlisle muck | 5.85 | 0.42–14.34 | 23.20 |
| Genesee silt loam | 6.39 | 1.55–21.25 | 2.56 |

* Plant molybdenum analyses include five samples grown on each soil. Results from soil analyses include duplicates on one to three soils. Only one Carlisle muck sample has been analyzed.

appear to be related to soil type. All five samples from one soil type such as Chalmers, were uniformly low in molybdenum while all five from a soil type such as Nappanee were uniformly high in molybdenum. In general the soils in the northwestern part of Indiana, particularly the prairie soils, appear to be low in available molybdenum while the soils in northeastern Indiana, particularly the lake-bed soils of Allen County, were high in available molybdenum. The soils in the other parts of the state ranged from low to medium. Research is being continued to develop a method for predicting where response may occur.

## Literature Cited

1. Anderson, A. J. Molybdenum deficiency on a South Australian ironstone soil. J. Australian Inst. Agr. Sci. 8 : 73-75.
2. Anderson, A. J. Molybdenum deficiencies in legumes in Australia Soil Sci. 81 : 173-182. 1956.
3. Arnon, D. I. and Stout, P. R. Molybdenum as an essential element for higher plants. Pl. Phys. 14 : 599-602. 1939.
4. Barshad, I. Factors affecting the molybdenum content of pasture plants I. Nature of soil Mo., growth of plants and soil pH. Soil Sci. 71 : 297-313. 1951.

5. BORTELS, H. Molybdenum as a catalyzer in biological nitrogen fixation Arch. Mikrobiol. 1 : 333-342. 1930.

6. EVANS, H. J., PURVIS, E. R., and BEAR, F. E. Molybdenum nutrition of alfalfa. Pl. Phys. 25 : 555-565. 1950.

7. FOY, C. D. and BARBER, S. A. Molybdenum response of alfalfa on Indiana soils in the greenhouse. Proc. S. S. S. A. 23 : 36-39. 1959.

8. ROBINSON, W. O., and EDGINGTON, G., ARMIGER, W. H. and BREEN, A. V. Availability of molybdenum as influenced by liming. Soil Sci. 72 : 267-274. 1951.

9. STOUT, P. R., MEAGHER, W. R., PEARSON, G. A. and JOHNSON, C. M. Molybdenum nutrition of crop plants. Plant and Soil 3 : 51-87. 1951.