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The Available Molybdenum Status of Some West Virginia Soils

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MOST of the knowledge of the chemical status of molybdenum in soils, and of its relationship to plant growth has evolved quite recently. The principal reason for this is the lack of sufficiently refined analytical methods for determining levels of this nutrient in soils and plant tissue. Molybdenum is found in very small quantities in soils and is required only in trace amounts by plants. Nevertheless, when this nutrient is deficient in soils, crop quality and yields suffer just as much as when nitrogen or some other major nutrient is limiting.

Molybdenum-deficient soils have been found in many areas of the world, and in several areas of the United States (8). In West Virginia the importance of molybdenum in crop production was first recognized in the Canaan Valley, Tucker County. Certain varieties of cauliflower grown on these soils exhibited the molybdenum deficiency symptom referred to as "whiptail." This prompted a study of the molybdenum status of West Virginia soils.

Sperow (9) determined the total molybdenum content of some of the agriculturally-important soils of the State. He found total molybdenum content ranges from 0.42 ppm to 11.70 ppm (parts per million). The information resulting from this study is of value in evaluating the potential of soils to supply molybdenum. However, with molybdenum, as with most other nutrients, there is often little correlation between the total amount in the soil and the amount available to plants.

The determination of available molybdenum by chemical methods is difficult because the amounts present in soils are often below that which can be accurately detected.

Many workers have reported poor correlation between chemical test results of available molybdenum and crop growth in the field. Grigg (3) presented a chemical method, which is time-consuming and suffers from ion interference. Purvis and Peterson (7) improved Grigg's method to some degree.

Several investigators have used biological assay techniques to test for available contents of trace nutrients in soils. Mulder (4) and Gerretsen (2), in Holland, and Nicholas (6) and Nicholas and Fielding (5), in England, using *Aspergillus niger* as the test organism, analyzed a large number of soils for available molybdenum. These investigators found that their bioassay results more accurately reflected the availability of molybdenum to crops in the field than did determinations based on chemical extraction and spectrographic methods.

The study reported here was conducted to determine the available molybdenum content of some agriculturally-important West Virginia soils and to relate the results to total molybdenum content. The *Aspergillus niger* method was chosen over chemical procedures because of the intrinsic limitations of the latter.

Experimental Procedures

In the *Aspergillus niger* method, a weighed amount of soil is placed in a flask containing nutrient solution without molybdenum. Flask and contents are then inoculated with *Aspergillus niger* M.[1] The cultures are incubated for six days at 30°C, after which the fungus mycelium is filtered off, dried, and weighed. The amount of mycelium produced is taken to be proportional to the amount of available molybdenum in the soil added to the flask.

A calibration curve is constructed relating mycelium produced to molybdenum contents of a series of cultures containing known amounts of molybdenum. The available molybdenum of a soil is determined by comparing mycelial weights produced in the test sample with those produced in the standard molybdenum cultures. In calibrating this method, values for quadruplicate samples were found to be in the five per cent error range.

Soil samples were collected by staff members of the Department of Agronomy and Genetics of West Virginia University and by soil scientists of the Soil Conservation Service. Samples were selected from areas that had not been fertilized or limed. Samples for analysis were air-dried, ground, and passed through a 60-mesh sieve. Descriptions of these soils are given in the Appendix. Seventy-five soil samples from 30 different soil series were bioassayed for total molybdenum. Results, averages of triplicate samples, are reported in Table 1.

Results

The available molybdenum contents of individual soil samples are given in the Appendix and average values are given in Table 1.

The results indicate a wide variation in availability of molybdenum in West Virginia soils. Available amounts varied from a low of 0.021 ppm in a Mercer County Litz shaly silt loam, to a high of over 1.0 ppm in an Ohio County Westmoreland silt loam. Because the apparent amount in the latter soil was too high to be measured with precision, the exact amount of available molybdenum could not be ascertained. The average available molybdenum content for all soils was 0.141 ppm.

[1]Obtained from H. A. Wilson, Department of Plant Pathology, Bacteriology, and Entomology, West Virginia University Agricultural Experiment Station.

TABLE 1. TOTAL AND AVAILABLE MOLYBDENUM, IN PPM, OF MAJOR WEST VIRGINIA SOILS.

SOIL SERIES	NO. OF SAMPLES	AVERAGE TOTAL Mo*	AVAILABLE Mo RANGE HIGH	AVAILABLE Mo RANGE LOW	AVERAGE AVAILABLE Mo
. Well-drained upland soils of Limestone Valley					
A. *From Limestone*					
Berkeley silt loam	2	1.88	0.067	0.043	0.055
Hagerstown silt loam	4	2.91	0.304	0.127	0.214
Frankstown silt loam	1	1.52			0.069
Frederick silt loam	4	1.81	0.235	0.068	0.180
	11	2.20			0.153
B. *From Shale*					
Berks silt loam	2	6.68	0.270	0.068	0.186
I. Well-drained upland soils of the Ridge and Valley Province					
Ashby silt loam	4	1.02	0.155	0.023	0.100
Belmont silt loam	1	1.17			0.208
Calvin silt loam	3	1.01	0.109	0.091	0.099
Lehew loam	3	0.97	0.057	0.054	0.055
Litz silt loam	2	0.88	0.034	0.021	0.028
Teas silt loam	4	1.22	0.178	0.064	0.114
Ungers loam	1	0.98			0.124
	18	1.04			0.095
II. Well-drained upland soils of the Allegheny Plateau					
A. *From Limestone and Shale*					
Brooke silty clay loam	2	2.34	0.195	0.178	0.186
Westmoreland silt loam	1	2.78			0.260
	3	2.49			0.211
B. *From Sandstone and Shale*					
Clymer silt loam	3	1.36	0.117	0.057	0.096
Dekalb silt loam	4	1.39	0.212	0.068	0.110
Gilpin silt loam	5	1.74	0.213	0.067	0.124
Muskingum silt loam	3	1.28	0.101	0.065	0.079
Upshur clay loam	1	1.93			0.071
Upshur-Gilpin silty clay	1	1.76			0.057
Upshur-muskingum silty clay	2	1.85	0.084	0.0606	0.072
Wellston sandy loam	2	0.90	0.087	0.029	0.058
Wharton silt loam	3	2.15	0.330	0.129	0.220
	24	1.57			0.107
V. Miscellaneous					
A. *Bottomlands*					
Huntington silt loam	3	2.45	0.148	0.063	0.104
Moshannon silt loam	2	1.42	0.114	0.090	0.102
Pope sandy loam	3	1.11	0.126	0.069	0.097
	8	1.69			0.101
B. *River Terraces*					
Wheeling silt loam	2	1.63	0.415	0.088	0.251
Zoar silt loam	2	2.10	0.202	0.091	0.146
	4	1.87			0.199
C. *Slow Drainage Uplands*					
Cookport silt loam	1	0.87			0.063
Tilsit silt loam	3	1.39	0.132	0.041	0.076
	4	1.26			0.073

*Sperow, C. B., *The Molybdenum Content of West Virginia Soils.* West Virginia Uni-
›rsity Agricultural Experiment Station Bulletin 443, August, 1960.

On a group basis, the well-drained upland soils of the Allegheny Plateau, derived from limestone and shale, contained the highest amounts of available molybdenum. Other upland soils derived from limestone or calcareous shales—such as the Hagerstown, Frederick, and Belmont series—were well above average in available molybdenum content. Although not derived from limestone or calcareous parent material, the Wharton and Berks series tested high in available molybdenum. The Wheeling and Zoar soils occurring on river terraces also contained relatively high amounts of available molybdenum.

As a group, the highly-leached and mature soils listed under miscellaneous slowly-drained upland soils contained the lowest amounts of available molybdenum. Some of the well-drained upland soils of the Ridge and Valley Province and some of the soils from the Allegheny Plateau were also low in available molybdenum. These soils, for the most part, developed from non-calcareous sandstone and shales.

Available molybdenum content was not closely correlated with total molybdenum content.[2] This indicates that total molybdenum data alone is insufficient to completely evaluate West Virginia soils from the standpoint of meeting actual crop needs. The data show that soils high in total molybdenum tend to be higher in available molybdenum, but the relationship is not proportionate.

Discussion

Although the bioassay method employed in this work has been found to be dependable by other workers, and was found to be desirable in this study, it can serve only as a general guide for field recommendations. The results must first be correlated with crop growth in the field. Nevertheless, the data obtained can be used to classify the soils investigated with respect to available molybdenum content.

Of the 75 soil samples tested, six would be considered deficient if rated according to standards of Nicholas and Fielding (5), since these six contain less than 0.05 ppm of available molybdenum. They are an Ashby channery loam from Mercer County, a Berkeley clay loam from Berkeley County, a Wellston fine sandy loam from Wayne County, a Tilsit silt loam from Mercer County, and two Litz shaly silt loams, one each from Monroe and Mercer counties.

The Ashby series, developed from gray acid shale and sandstone of Devonian age, are shallow and have very rapid internal drainage. Total molybdenum was also low in the Ashby sample from Mercer County. The low value for available molybdenum content may be related to the mineral composition of the parent material.

Although Berkeley soils are derived from almost pure limestone, which seems to favor higher levels of available molybdenum, only three per cent of the molybdenum in this soil was found to be available.

[2]The percentage of total molybdenum considered to be available for each soil sample is listed in the Appendix.

The deep, well-drained Wellston soils are derived from acid Pennsylvanian sandstone and shale. The profile analyzed was low in total molybdenum. This fact, along with relative mature development of this soil series, explains the small amount of available molybdenum found.

Tilsit soils are similar to the Wellston soils in origin, though more highly leached with planosolic profile development. This may account for the small amount of available molybdenum found in the Tilsit sample from Mercer County. Here again, only about three per cent of the total molybdenum was available.

Both of the samples from the well-drained Litz series are low in total molybdenum, which may explain the low available molybdenum contents found in the samples tested.

Twenty-one of the soil samples bioassayed would be considered slightly deficient in available molybdenum, according to Nicholas and Fielding (5). Three samples from the Lehew series, all from Hampshire County, were in this group. Lehew is a shallow soil derived from red Devonian sandstone. Of the three Teas samples investigated, two were slightly deficient. These soils developed on highly weathered, more or less calcareous Mississippian shales on hilly and steep lands, and contain small amounts of total molybdenum. The Teas soils are also shallow and well-drained. The genesis of these soils and their relatively low amounts of total molybdenum may account for the less than average amount of available molybdenum found.

The soils found to be apparently deficient and slightly deficient might, through intensive cropping, produce molybdenum-deficient plants. This would be especially true where the total molybdenum is also at low levels, and where crops with high molybdenum requirements are grown. However, many of these soils are extremely acid, and proper liming would improve their molybdenum status. The length of time that lime would be effective would be determined by the total amount of molybdenum present in each case. Toxicity due to excessive molybdenum is not likely to occur, except perhaps in the case of the Westmoreland silt loam from Ohio County, and then only under certain cropping practices.

Summary and Conclusions

1. Seventy-five West Virginia soil samples from 30 different soil series were bioassayed for available molybdenum, using *Aspergillus niger* M. as the test organism.

2. The apparent available molybdenum content of West Virginia soils varied widely. The range was from 0.021 ppm in a Litz shaly silt loam from Mercer County to greater than 1.0 ppm in a Westmoreland silt loam from Ohio County. The average was 0.141 ppm.

3. The well-drained upland soils of the Allegheny Plateau contained the highest amount of avilable molybdenum as a group, and the slowly drained upland soils contained the lowest.

4. Above-average available molybdenum content was associated with soils derived from limestone or calcareous parent material.

5. Soils developed from non-calcareous sandstones and shales were below average in content of available molybdenum, the lowest amounts being found in the more highly weathered and well-drained members of the group.

6. Available molybdenum content was not closely related to total molybdenum content.

According to the bioassay, it appears that molybdenum deficiency may occur on certain soils in West Virginia and certain crops grown on them might benefit from treatment with molybdenum. This would be especially true on soils where total molybdenum is also low. According to Rubens (8), liming these soils would improve the available molybdenum status and might prevent the appearance of deficiencies for some time.

Only one of the soils tested appeared to be high enough in available molybdenum to cause toxicity. Unless this is of more frequent occurrence, crop damage because of excessive available molybdenum is not anticipated.

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APPENDIX

Laboratory Number and Soil Type	Total Molybdenum* ppm	Available Molybdenum ppm	Available Molybdenum per cent	County
5 Ashby channery loam	0.42	0.023	5.40	Mercer
6 Ashby shaly silt loam	1.59	0.092	5.76	Pocahontas
7 Ashby shaly silt loam	1.06	0.155	15.60	Randolph
8 Ashby shaly silt loam	1.00	0.128	12.84	Berkeley
12 Belmont silt loam	1.17	0.208	17.78	Tucker
20 Berkeley clay loam	2.32	0.067	2.89	Berkeley
20A Berkeley clay loam	1.43	0.043	3.01	Berkeley
22 Berks shaly silt loam	11.70	0.270	2.31	Berkeley
23 Berks shaly silt loam	1.67	0.101	6.05	Berkeley
30A Brooke silt clay loam	2.64	0.195	7.39	Ohio
32 Brooke silty clay loam	2.05	0.178	8.70	Ohio
41 Calvin silt loam	0.91	0.091	10.00	Greenbrier
41A Calvin silt loam	1.39	0.109	7.83	Greenbrier
42 Calvin silt loam	0.72	0.098	13.57	Tucker
55 Clymer silt loam	1.33	0.117	8.78	Nicholas
56 Clymer fine sandy loam	0.97	0.057	5.91	Greenbrier
57 Clymer silt loam	1.77	0.114	6.42	Upshur
62 Cookport silt loam	0.87	0.063	7.26	Raleigh
69 Dekalb loam	0.59	0.068	11.46	Raleigh
70 Dekalb stony loam	1.00	0.072	7.18	Greenbrier
71 Dekalb channery silt loam	2.40	0.212	8.81	Randolph
72 Dekalb stony silt loam	1.56	0.088	5.65	Preston
95 Frankstown silt loam	1.52	0.069	4.54	Greenbrier
98 Frederick silt loam	1.33	0.068	5.11	Mercer
99 Frederick cherty silt loam	2.25	0.197	8.78	Monroe
100 Frederick silt loam	1.67	0.235	14.05	Berkeley
101 Frederick stony silt loam	1.98	0.221	11.16	Berkeley
102 Gilpin silt loam	1.73	0.213	12.33	Marshall
103 Gilpin silt loam	1.40	0.083	5.91	Nicholas
104 Gilpin silt loam	0.95	0.067	7.03	Raleigh
105 Gilpin silt loam	2.48	0.125	5.04	Upshur
106 Gilpin silt loam	2.14	0.133	6.20	Monongalia
116 Hagerstown silt loam	2.27	0.297	13.07	Pocahontas
117 Hagerstown silt loam	2.30	0.128	5.56	Jefferson
118 Hagerstown stony silt loam	3.12	0.304	9.76	Berkeley
118 Hagerstown subsoil	3.97	0.127	3.20	Berkeley
123 Huntington silt loam	2.56	0.148	5.76	Marshall
125 Huntington silt loam	1.76	0.102	5.80	Mason
801 Huntington silt loam	3.03	0.063	2.07	Berkeley
143 Lehew loam	1.68	0.057	3.40	Hampshire
143A Lehew channery fine sandy loam	0.53	0.054	10.26	Hampshire
143B Lehew loam	0.69	0.055	7.97	Hampshire
148 Litz shaly silt loam	0.92	0.021	2.28	Mercer
149 Litz shaly silt loam	0.84	0.034	4.02	Monroe
169 Moshannon silt loam	1.60	0.090	5.66	Wirt

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Laboratory Number and Soil Type	Total Molybdenum ppm	Available Molybdenum ppm	Available Molybdenum per cent	County
170 Moshannon silt loam	1.25	0.114	9.13	Jackson
174 Muskingum silt loam	1.39	0.101	7.27	Kanawha
175 Muskingum silt loam	1.08	0.070	6.48	Boone
176 Muskingum silt loam	1.36	0.065	4.77	Raleigh
186 Pope sandy loam	0.85	0.069	8.12	Lincoln
187 Pope sandy loam	0.99	0.097	9.80	Upshur
188 Pope gravelly silt loam	1.50	0.126	8.40	Preston
208 Teas silt loam	1.29	0.064	4.95	Summers
210 Teas silt loam	0.93	0.070	7.53	Randolph
210 Teas subsoil	1.15	0.178	15.48	Randolph
211 Teas silt loam	1.52	0.145	9.53	Preston
212 Tilsit silt loam	1.55	0.132	8.52	Mason
213 Tilsit silt loam	1.40	0.055	3.93	Wayne
214 Tilsit silt loam	1.24	0.041	3.32	Mercer
Ungers loam	0.98	0.124	12.63	Tucker
222 Upshur clay loam	1.93	0.071	3.66	Jackson
154 Upshur-Gilpin silty clay	1.76	0.057	3.22	Wirt
155 Upshur-Muskingum silty clay	1.40	0.060	4.32	Jackson
156 Upshur-Muskingum clay	2.30	0.084	3.66	Wayne
233 Wellston fine sandy loam	0.74	0.029	3.92	Wayne
Wellston subsoil	1.07	0.087	8.16	Wayne
235 Westmoreland silt loam	3.14	>1.000		Ohio
237 Westmoreland silt loam	2.78	0.260	9.34	Marion
239 Wharton silt loam	2.44	0.330	13.52	Marshall
240 Wharton silt loam	1.30	0.129	9.89	Nicholas
241 Wharton silt loam	2.70	0.202	7.48	Preston
243 Wheeling silt loam	1.96	0.415	21.16	Wetzel
245 Wheeling silt loam	1.30	0.088	6.76	Mason
251 Zoar silt loam	1.30	0.091	7.02	Wirt
253 Zoar silt loam	2.91	0.202	6.95	Nicholas