Areas of Molybdenum Toxicity to Grazing Animals in the Western States

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Highlight: *The geographic distribution of molybdenum (Mo) areas toxic for grazing animals was determined in five western states—Washington, Idaho, Montana, Wyoming, and Colorado. A number of relatively extensive areas producing forage plants with 10 to 20 ppm or more of Mo, levels well within the toxic range for grazing animals, was found. A history of a nutritional problem in animals was found to be associated with most of these areas. The characteristics of these areas are described and levels of Mo in forage plants as well as those of Cu are given. The concentration of Cu in forage plants was nearly the same whether the plants had small or large amounts of Mo.*

Cattle grazed on forage plants with 10 to 20 ppm or more of molybdenum (Mo) exhibit typical symptoms of Mo toxicity (Mo-induced Cu deficiency) and they respond to copper (Cu) supplementation. Faded hair coats, characteristic of Cu deficiency, and profuse diarrhea with foul, smelly feces are common symptoms of molybdenosis (Underwood, 1971). Endemic areas of high Mo are recognized in parts of California (Barshad, 1948), Nevada (Kubota et al., 1961) and Oregon (Kubota et al., 1967) but not in other western states, although livestock are grazed in areas similar to those where Mo toxicity has been observed. This report presents the distribution of such areas in Washington, Idaho, Montana, Wyoming, and Colorado and the soil and geologic factors associated with them.

Plan of Study

Using soil and geologic maps and reports, likely areas in these states were selected for study, focusing on areas with wet floodplains and alluvial fans of relatively small streams draining areas of principally granite and shale. Such areas have been shown to be likely areas of Mo toxicity because they have a rock source of Mo, the Mo in alluvium is deposited

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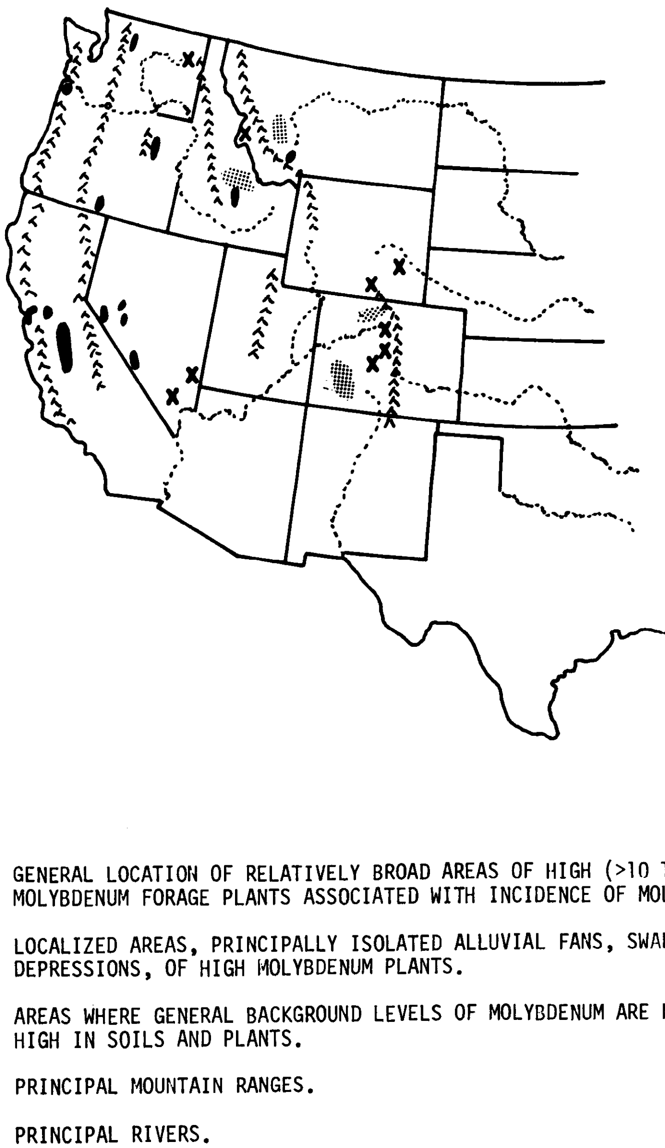

Fig. 1. *Distribution of general areas of molybdenum toxicity in grazing animals in the western U.S.*

Table 1. Principal areas in four western states where forage plants grown on wet parts of alluvial floodplains have toxic levels of molybdenum (ppm) for grazing animals.

Location		Molybdenum (means in ppm)			
State	Stream valley	Soil	Legumes	Grasses	Remarks
Colorado	Blue River incl. 10-Mile Creek	9.2	33.3	2.1	Observations of extension veterinarian.
	Tomichi Creek incl. Quartz and Taylor Creek	1.5	19.8	0.7	Excess Mo has not been associated with poor condition of cattle.
Idaho	Lost River	3.6	18.9	1.2	Poor condition of calves and profuse diarrhea observed.
	Lemhi River incl. 18-Mile Creek	1.8	24.2	1.0	White Muscle disease is recognized but not molybdenosis.
Montana	Willow Creek	9.6	39.6	6.8	Cattle receive injections of Cu.
Washington	Johnson Creek	17.8	29.4	7.4	Calves with faded hair coats.
	Palmer Lake	4.7	24.2	2.3	Calves with faded hair coats.
Overall means		5.8	26.6	3.7	
Number of observations		(31)	(45)	(18)	

with little mixing (dilution) by materials with less Mo from other streams, and have soil wetness that enhances the availability and uptake of Mo by plants (Kubota et al., 1961; 1967). Well-drained soils on floodplains and terraces served as controls within each location. Other areas underlain by mixed rock materials were also included.

The likelihood that high Mo forage plants grow in a given area was established the first year through a study of a few sites within a location. Information gained from the first year of study was used as a basis for a subsequent sampling program of greater intensity.

A level of 10 to 20 ppm or more of Mo in legumes was used as an indicator of problem areas. This criterion was initially developed in Nevada using paired samples of forage species from a wide range of soils (Kubota et al., 1961), and later applied to identify the Mo-toxic areas in Oregon (Kubota et al., 1967). The criterion utilizes legumes as a bioassay tool for estimating the Mo-supplying power of soils. Differences between clovers, alfalfa, and grasses are not consistently evident at low Mo concentrations, but they are evident at concentration levels toxic for grazing animals (10 to 20 ppm).

Each sampling site was located with the assistance of field soil scientists of the Soil Conservation Service, U.S. Department of Agriculture, who have intimate knowledge of soils and geology of given areas. Ranch operators and practicing veterinarians were contacted whenever possible to obtain their observations of nutritional problems in grazing animals. Samples of forage plants were collected by species after the soils were examined and described. The plants were carefully clipped to minimize soil contamination. Soil samples, usually the surface layer (A horizon), were collected from the soil area on which the plants grew. The criterion of soil wetness recognized in the classification and mapping of soils in this country (7th Approximation, 1960) were used. Intensity and degree of soil mottles that reflect soil reducing conditions, thickness and characteristics of surface, organic-rich horizon, and depth to and fluctuations of water table, all measurable soil properties, were used to describe wet soil conditions.

The samples were air-dried at field locations and then shipped to Ithaca, N.Y., where they were oven-dried, ground, and sieved, using a stainless steel sieve. Weighed amounts of the plant material, usually five grams, were dry ashed overnight at 500°C, the ash digested in 1:1 HNO_3, and the silica gently dehydrated and filtered. The filtrate was made to volume and Mo was determined on aliquots of the filtrate by the thiocyanate method. Copper was determined directly on the acid solutions by atomic absorption analysis. The same procedures were used in the determination of Mo and Cu in soils, except that the samples were fused with Na_2CO_3.

General Distribution of High Mo Areas

Areas of Granitic Alluvium

A number of fairly extensive areas of high Mo were identified in Washington, Idaho, Montana, and Colorado that had not been recognized earlier. A summary of Mo in wet soils and forage plants and of animal observations is presented in Table 1. Where 10 to 20 ppm or more of Mo were found in legumes, the amounts in the soil were high, a nutritional problem in cattle was recognized, or Cu supplements were being used. While cattle also graze grasses, the levels of Mo in them were lower than that in legumes. Data for sedges are not presented, but they were essentially the same as those for grasses. The similarities among species of legumes and grasses and differences between the two groups of plants in Mo content were comparable to those reported earlier for similar plants of Nevada and Oregon (Kubota et al., 1961; 1967).

The geographic distribution of the high-Mo areas in the five western states is presented in Figure 1. Problem areas previously identified in California, Nevada, and Oregon and areas identified in this study are shown. This map shows all of the areas of high Mo presently recognized in this country with the exception of the Florida Everglades (Davis, 1969).

Distribution Pattern Within Stream Valleys

The distribution of a high-Mo area within a valley follows a predictable pattern downstream. Results of a detailed study of the Willow Creek floodplain in central Montana are presented in Table 2. Willow Creek is approximately 10 miles long from its head to its confluence with Jefferson River. Forage plants from wet parts of this floodplain contained high levels of Mo, but those from well-drained soils did not. Molybdenosis in cattle has been recognized as a probable nutritional problem, and cattle on two ranches were being treated with Cu glycinate injections. South Willow

Table 2. Molybdenum concentration (ppm) in forage plants and soils of the Willow Creek floodplain, a high molybdenum area, and floodplains of its tributary streams, Madison County, Montana.

Floodplain	Field sites (year/site)	Molybdenum (ppm)		
		Soil	Legumes	Grasses
Wet soils[1]				
Willow Creek	69/16	1.1	20.8	2.7
	68/26[2]	17.4	44.9	6.0
	69/15	5.8	79.4	11.9
	69/19	7.5	32.3	6.8
	68/27[2]	14.1	43.6	1.3
	69/22	9.0	26.2	–
South Willow Creek[3]	69/17	1.3	14.7	1.0
Magpie Creek[3]	69/21	0.6	6.7	2.8
Well-drained soils				
Willow Creek	69/20	1.6	4.2	–
South Willow Creek[3]	69/18	1.5	4.4	–

[1] Sites from head of Willow Creek to its confluence with Jefferson River.
[2] Copper is used on these ranches to treat affected cattle.
[3] Tributaries of Willow Creek.

Table 3. Molybdenum concentration (ppm) of forage plants and soils of the Lost River floodplain, a high molybdenum area, and floodplains of its tributary streams–Idaho.

Floodplain and general location of sampling sites	Field site (year/site)	Molybdenum (ppm)		
		Soil	Legumes	Grasses
Wet floodplain of Lost River[1]				
Lost River	70/3	2.1	14.1	1.7
Chilly (vicinity of 1000 Springs)	69/5	2.9	20.1	0.5
	70/4	1.2	7.1	–
	70/5	1.8	16.2	–
Mackay	69/4	3.2	34.4	–
Leslie	70/11	11.4	15.6	1.6
Arco	70/14	2.7	31.2	1.1
Wet floodplain of tributary streams				
Antelope Creek (enters Lost River south of Leslie)	70/12	1.7	2.1	0.5
Cherry Creek	70/1	4.5	2.5	0.6
Dry Fork (vicinity of Leslie)	70/2	3.2	3.0	1.3
Well-drained floodplain of Lost River				
Leslie	70/13	2.0	4.7	2.0

[1] Sites are arranged in increasing distance downstream.

Creek and Magpie Creek, two tributaries of Willow Creek, do not contribute substantial amounts of Mo to soils on Willow Creek floodplain.

A similar distribution pattern was obtained in a detailed study of the Lost River floodplain in central Idaho (Table 3). With one exception (site 70/4), the Mo concentrations were high in forage plants from the wet soils sampled from the 1000 Spring Area to an area west of Arco, where Lost River disappears beneath permeable volcanic rocks. This distance is about 40 miles.

Alluvium of Antelope Creek and Dry Fork, tributaries of Lost River, appear to contribute Mo to Lost River alluvium, but the plants grown on the floodplains had small amounts of Mo. The wet soils here were faintly mottled but because they are cobbly and have only a thin surficial mantle of fine soil material, they probably are wet only for short periods during spring runoff. The effects of soil wetness on the Mo concentration of plants consequently would be minimized.

In Washington, Idaho, Montana, and Colorado, the Mo-toxic areas mostly occupy wet bottomlands of granitic alluvium in relatively small intermountain valleys. Local pockets of peats and mucks (Histolsols) often occur in the wettest parts. However, not all wet soils formed in granitic alluvium produced molybdenum toxic forage plants and a summary of these nonproblem areas is presented in Table 4. Soils on broad glacial drift plains with a granitic rock source in Wyoming and Montana had relatively small amounts of Mo and amounts in the plants were mostly in the range of 2 to 4 ppm, even though the plants were grown on wet soils.

Forage plants grown on well-drained soils also formed in alluvium had only 2 to 4 ppm of Mo even though some of the soils had as much as 2 ppm of Mo. A summary of Mo for the well-drained soils is presented in Table 5. These observations are consistent with earlier ones made in Oregon and Nevada. Legumes grown on calcareous soils had slightly more Mo than did those grown on noncalcareous soils, but the differences were not large. Grasses grown on well-drained calcareous and noncalcareous soils had nearly the same amount of Mo.

Areas of Shale

Molybdenum toxicity is a problem in northwestern Oregon (Kubota et al., 1967) and in the teart areas of England (Ferguson, Lewis and Watson, 1943) where shale is the rock source of soil-parent materials. Areas of shale-derived soils in Montana and Colorado were investigated and a summary is presented in Table 6. Forage plants grown on soils formed in unconsolidated deposits from Colorado shale in Montana did not have large amounts of Mo. In Colorado, plants grown on soils (Aquolls) of clay and silty clay textures had appreciably more Mo than did those grown on morphologically similar soils of loam texture.

Soils formed in shale cover broad areas of western Colorado, extending from Steamboat Springs in the north to Alamosa in the south. The wet soils in this part of Colorado mostly occupy gentle swales, depressions, and some narrow valleys important for grazing purposes. Because Mo concentrations in soils and forage plants are soil-texture dependent, use can be made of soil-family groupings to predict the probable problem soils. Aquolls of clay texture are members of the fine, montmorillonitic family and loamy soils, fine silty, mixed family.

The soils derived from shales had as much or more Mo than did many formed in granitic alluvium, but the plant concentrations were appreciably

Table 4. Molybdenum concentration (ppm) on some broad areas where forage plants grown on wet floodplains, dominantly granitic, have nontoxic levels of molybdenum for grazing animals.

State and general location		No. field sites	Molybdenum (ppm)		
			Soil	Legumes	Grasses
Alluvial floodplains					
Washington	E. footslopes of Cascades (S. of Okanogon)	9	1.5	3.4	1.0
	Walla Walla area[1]	5	1.5	3.4	3.0
	Okanogon Highlands (N. of Spokane)	6	1.4	2.7	2.2
Idaho	Payette River Valley	2	1.5	1.5	1.0
	Camas Co.	2	1.5	3.1	2.8
Montana	W. footslopes Bitterroot Range	3	0.4	1.8	1.8
Glacial drift plains					
Montana	Big Hole-Wisdom	1	0.4	3.9	–
Wyoming	Jackson-Pinedale	3	0.5	3.6	0.5
No. samples			(29)	(41)	(24)
Mean			1.2	2.9	1.7
SD			0.7	2.2	1.9

[1] Soils strongly influenced by loess.

Table 5. Summary of molybdenum concentration (ppm) in forage plants and in surface horizons (A) of well drained soils of Washington, Idaho, Montana, Wyoming, and Colorado.

Carbonate status of soils	Measurement[1]	Molybdenum		
		Soil	Legume[2]	Grass[2]
Granitic alluvium				
Calcareous	n	7	13	4
	Mean & SE (ppm)	1.3 ± 0.2	3.8 ± 0.4	2.0 ± 0.3
	Range (ppm)	0.3 – 2.0	1.3 – 5.8	2.0 – 4.4
Noncalcareous	n	5	7	4
	Mean & SE (ppm)	1.3 ± 0.2	1.9 ± 0.7	2.3 ± 0.6
	Range (ppm)	0.4 – 1.7	0.4 – 4.1	0.5 – 4.2
Alluvium of mixed rock origin				
Calcareous	n	2	6	4
	Mean & SE (ppm)	1.2	3.1 ± 0.3	1.0 ± 0.4
	Range (ppm)	1.1 – 1.2	0.4 – 4.1	0.5 – 4.2
Noncalcareous	n	5	7	5
	Mean & SE (ppm)	1.3 ± 0.2	1.9 ± 0.7	2.3 ± 0.6
	Range (ppm)	0.4 – 1.7	0.4 – 4.1	0.5 – 4.2

[1] n = number of samples, SE = standard error of mean.
[2] Summary of legumes includes observations for alfalfa and four clover species; of grasses, six species. At relatively low molybdenum concentrations, effects of plant species were not evident, an observation reported earlier (Kubota et al., 1961).

Table 6. Summary of the molybdenum concentration (ppm) in forage plants and wet soils of shale rock origin.

Rock	Dominant texture of soils	No. field sites	Molybdenum[1] (ppm)		
			Soil	Legume	Grasses
Colorado shale–Montana	loam	8	2.1 ± 1.2	1.8 ± 1.2	1.0 ± 0.8
Mancos shale–Colorado	loam	6	0.6 ± 0.4	5.1 ± 3.9	1.8 ± 0.8
	clay and silty clay	10	3.9 ± 2.7	15.2 ± 6.8	1.5 ± 1.5

[1] Means and standard deviations

below 40 to 50 ppm of Mo. A low availability to plants of soil Mo from shale-derived material was observed earlier in Oregon.

Copper Concentrations

Legumes consistently had more Cu than did grasses, but the wide differences noted for Mo were not evident. A summary of the Cu concentrations in forage plants grown on soils formed in granitic alluvium is presented in Table 7, and for those grown on soils derived from shales in Table 8. The largest amount of Cu (23 ppm) was found in red clover (*Trifolium pratense*) from Deer Lodge Valley, a geologically anomalous area of high Cu. The soil on which the plant was grown had 55 ppm of Cu, but as much as 200 to 350 ppm were found in other soils in this general area. Soils formed from shales had appreciably less Cu, but the soil levels were not strongly reflected in the plant.

General Discussion

This study indicates that molybdenosis in the western states may be a more widespread soil-related nutritional problem in grazing animals than had been generally recognized. Greater attention given to Mo may turn up other small areas that were not identified with the selective sampling procedure employed in this study. Recognition of naturally occurring areas of high Mo should be useful in evaluating alternative forage and livestock management practices to minimize the consequences of excess Mo. Since Mo in hay is appreciably less toxic to ruminants than are equally high Mo levels in green plants, the harvesting of hay may be an alternative practice to utilize forage from known Mo toxic areas.

As in earlier studies, plant concentrations of 10 to 20 ppm or more of Mo were found to be indicative of critical cases of molybdenosis. The establishment of definitive levels in plants with subclinical cases may enhance the usefulness of soil-plant techniques in their study. Such needed information may possibly stem from greater attention given to the nutritional importance of Mo and Cu in the western states.

The role of Mo in lowering the biochemical availability of Cu to

Table 7. **Summary of copper concentrations (ppm) in forage plants and soils (wet) formed in granitic alluvium of Montana, Washington, Idaho, and Colorado.**

General location	Copper (ppm)		
	Soil	Legume	Grasses
Montana			
Willow Creek[1]	47.2	8.2	2.9
W. slope Bitterroot V.	25.6	7.9	2.8
Washington			
Johnson Creek-Palmer Lake area[1]	27.7	11.0	3.6
E. slope Cascades (S. of Okanogan)	23.3	9.6	4.9
Okanogan Highlands (N. of Spokane)	20.6	9.3	3.7
Colorado			
Tomichi Creek[1]	40.2	6.0	1.0
Blue R. including 10-mile Creek	38.8	6.1	1.1
Fraser R.	20.4	6.8	2.6
South Park Valley and S. Platte R.	45.9	8.1	1.2
Idaho			
Lost R. Valley[1]	16.4	7.1	4.2
Valleys–trib. streams of Salmon R.	16.4	7.1	1.7
Number of samples	(58)	(3.1)	(2.3)
Overall mean	30.3	8.2	2.9

[1] Areas of high Mo forage plants (see Table 1).

animals remains unclear. The formation of a Mo-Cu complex (lingren) has been suggested as a mechanism in reduced Cu availability (Dowdy and Matrone, 1968). Levels of SO_4-S (sulphur) has also been implicated with molybdenosis (Underwood, 1971) but no difference in S (total) was found in plants with low and high Mo contents when S was determined in the Nevada samples (Kubota et al., 1961). Consequently, no measurements of S were made in this study.

The association of molybdenosis with wet floodplains and alluvial fans should be useful when an undertaking of other soil-related nutritional problems is considered. Selenium (Se) is a case in point. White Muscle disease, a Se responsive disease, is also a nutritional problem in parts of the western states (Muth and Allaway, 1963). Considerations of Se availability in soils indicate that growth of low Se plants may not be necessarily confined to wet lowlands, and attention might be directed towards areas underlain by volcanic ash or areas of acid soils.

The Mo concentration and its range in natural soils provide base levels that might be used to evaluate changes in soil Mo with land use. More Mo might be expected in soils derived from shales and granites than from other kinds of soil-forming rocks, but the variability among soils in their Mo content should be recognized.

Table 8. **Summary of the Cu concentration (ppm) in soils derived from shales and plants grown on the soils.**

Rock	Dominant texture of soils	No. field sites	Copper (ppm)		
			Soil	Legume	Grasses
Colorado shale–Montana	loam	8	18.2	7.2	2.7
Mancos shale–Colorado	loam	6	11.0	7.9	3.4
Colorado	clay and silty clay	10	23.6	7.1	1.7
Overall mean			18.7	7.3	2.4
Standard deviation			14.3	2.9	1.4
Range					
Minimum			5.2	2.4	0.6
Maximum			63.2	14.2	3.2

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