THE DISTRIBUTION CF MOLYBDENUM
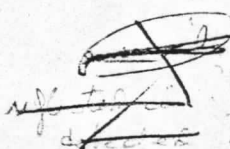
IN RED ALDER AND FIVE CTHER

NORTHWESTERN TREES

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ABSTRACT

Molybdenum, a necessary metallic coenzyme for nitrogen fixation, was measured in six northwest tree species. Concentrations in leaf-branch samples were lowest in Alnus rubra, a nitrogen fixing species, and highest in Pseudotsuga menziezii. The highest concentrations, measured in seeds of Alnus rubra, may be an adaptive mechanism allowing seedlings to rapidly begin nitrogen fixation. Alder ~~frequently comes up on~~ is typically an early invader on cut-over Douglas fir stands. The high concentration of Mo in Douglas fir litter may contribute to the success of these alder invasions.

INTRODUCTION

Of the twenty-four elements known to be essential to plant and microorganism growth, molybdenum is one of the eight so-called trace elements or micronutrients, and is required in very small amounts. Molybdenum nutrition of agricultural plants has justly received considerable attention, yet its utilization by forest ecosystems has recieved little study. This paper reports results of an initial study of the molybdenum distribution in various Pacific northwest trees.

World-wide interest in molybdenum began in 1942, when it was discovered that as little as 1/16 oz Mo per acre (4 g/ha) applied to unproductive clover pasture resulted in significant increases in clover production (Anderson 1946). Subsequently molybdenum has been shown to be essential in nitrogen-fixing and other plants, and to be part of several enzymes including nitrate reductase and nitrogenase (Anderson 1956). Insufficient molybdenum in nitrogen-fixers is first perceived to be a nitrogen deficiency.

The molybdenum content of most soils is low, averaging around 2 ppm, and is very uniform in its distribution (Rubins 1956). The availability of molybdenum for plant uptake is strongly influenced by soil pH. Below a pH of 5, molybdenum is almost completely bound to colloidal surfaces and becomes unavailable (Jones 1957).

The average molybdenum content of plant leaf tissue is

reported to be 0.10 ppm (Epstein 1965). It is known that some plants can highly concentrate specific elements, but no known accumulators of molybdenum have been found. Young and Guinn (1966), in one of the few intensive studies of micronutrient content of forest trees, found an average concentration of 3.5 ppm Mo in organs of seven tree species growing in Maine. Molybdenum occured in roots, bark, leaves and woody tissue in order of decreasing concentration.

To initiate a study of the role of molybdenum in the ecology of northwestern forests, two studies were carried out. In the first, concentrations of molybdenum were determined in six common northwest forest trees to look for differential distribution. In the second, various tissues of Alnus rubra were analyzed to determine if molybdenum is concentrated in specific organs.

Red alder (Alnus rubra Bongard) was chosen as the focal point of this study because of its importance in northwestern forest ecology and the possibility of its susceptability to molybdenum deficiency. It is a successful successional tree because of its ability to fix nitrogen, its very fast growth (as much as 5 ft./yr.) and its ability to tolerate and utilize high   light intensities. It appears quickly on moist soils after conifers have been removed by fire or cutting. Red alder has a large biomass of nodules and a high fixation efficiency of 814 mg N/g dry wt. nodules (Meyer 1966). Zavitkovski and Newton (1968) reported a rate of over 300

* as compared with 513 mg N/g dry wt. nodules for Pisum sativum and 258 mg N/g dry wt. nodules for Soja sp.

kg N fixed/ha yr in young dense stands. The average annual
rate is probably 100-200 kg/ha.

METHODS

Samples were collected from a wooded area of The Evergreen
State College campus, Olympia, Washington. The soil in the area
is a sandy loam with a pH range of 4-5.

Using special precautions, due to the nature of working
with trace quantities, a forty year old red alder was felled
and various organs sampled. Leaf-branch samples from _Alnus_
rubra, _Tsuga heterophylla_, _Thuja plicata_, _Pseudotsuga menziezii_,
Taxus brevifolia and _Acer macrophyllum_ were also collected.
Alder samples, except seeds, and all other samples, except
Douglas fir, were collected and analyzed in May and June 1975.
Local alder seed and Douglas fir samples were collected and
analyzed in November 1975. An alder seed sample from Blue Lake,
Humbolt Co., California was purchased and analyzed in June 1975.

In the lab these samples were partially dried and ground
to a powder in a Wiley Mill and then fully dried overnight at
110°C, prior to being weighed for digestion.

The analytical technique utilized involves a perchloric
acid digestion followed by a newly developed technique using
graphite furnace atomic absorption and a standard addition
method-ology to overcome interferences. A full description of
this method can be obtained from the author.

Due to time required to perfect the technique and certain
time limitations, only one analysis was conducted on each sample

except alder nodules. Some idea of the accuracy of the technique can be gained from two lines of evidence.

1.) Analysis of two subsamples from the alder nodule sample gave reasonably replicable readings of 0.40 and 0.45 ppm.

2.) According to the standard additions method the accuracy of an analysis is indicated by the degree of linearity acheived when absorbance is plotted against standard addition concentration. Four different standard additions were added to aliquots of each sample. In eleven of thirteen samples, the coefficient of correlation was ≥ 0.98, in one sample it was 0.95, and in the other 0.87.

RESULTS AND DISCUSSION

The concentrations of molybdenum in leaf-branch samples ranged from less than 0.04 ppm in Acer macrophyllum, Alnus rubra and Taxus brevifolia to 1.02 ppm in Pseudotsuga menziezii (table 1-1). Alnus rubra, despite its dependance on molybdenum for nitrogen-fixation had the lowest concentration.

The concentrations of northwest trees average about 0.40 ppm dry wt. and are similar to the average plant tissue estimate made by Epstein (1965). On the other hand, concentrations for northwestern trees are an order of magnitude lower than the average of northeastern trees of 3.5 ppm (Young and Guinn 1966). Whether this is a function of site is not presently known.

The Douglas fir sample contained a suprisingly high concentration of molybdenum, almost three times higher than

the nearest species. This relative accumulation of molybdenum
by Douglas fir may have considerable ecological significance.
Alder regeneration is often very aggressive on cut over Douglas
fir sites. Increased concentrations of molybdenum on the
forest floor resulting from years of Douglas fir litterfall
may be a factor in promoting aggressive alder growth. At any
rate, the relative content of soils underlying various aged
Douglas fir stands should be investigated.

The distribution of molybdenum in various tissues of
red alder ranged from 0.01 ppm dry wt. for leaves and branches
to 2.02 for one seed sample. ~~The distribution in regard bark~~ *The distribution of molybdenum was such that roots*
~~leaves, branches and trunk wood~~ *mained higher amounts than bark and; leaves, branches and trunk wood contained lesser quanti* roughly parallels the findings
This finding
of Young and Guinn (1966) for northeastern trees, although
total amounts are much lower.

The molybdenum concentration in nodules is approximately
double the highest concentration in any vegetative tissue.
This suggests that nodules have a capacity to concentrate the
element. This is to be expected because nitrogenase, located
in the nodule, requires molybdenum.

The most surprising finding was the high concentration
of Mo in red alder seeds, 2.02 ppm dry wt. in northern Cali-
fornia seeds and 1.33 in local seeds. This concentration is
approximately 15X the average for vegetative tissue and 4X that
of nodules. Similarly Lavy and Barber (1963) observed molyb-
denum accumulation in the seeds of soy beans. Investigations
of this phenomena should be carried out to determine whether
a physical phenomena or a
accumulation is simply physiological ~~or a functional~~ adaptation.

The relatively high concentrations in seeds may be important
in the ecological strategy of red alder. A stockpile of
molybdenum in alder seeds may allow rapid establishment of
the seedlings nitrogen fixing capacity independent, initially,
of soil concentrations.

Many important questions remain unanswered and deserve
discussion and research, especially that of the interactions
of pH, Mo availability and growth response. It has been shown
that alder actually acidifies the soil down to the soil pH
range of 3.8-4.8, approximately one pH unit lower than conifers
(Ugolini 1968). Contrary to what one might expect, mature red
alder seems to lack nitrogen or molybdenum deficiency symptoms.
This suggests that the trees are able to obtain an adequate
supply. Perhaps Mo becomes available through mycorrhizal
associations or alder is capable of altering soil chemistry
so that Mo becomes available. Neal et al. (1968) state that
ectotrophic mycorrhizae on red alder increase nutrient absorb-
ing capacity and alter soil chemistry and microbial populations
in the rhizosphere. Hatch (1937) showed that pines with
mycorrhiza absorbed significantly higher amounts of phosphorus
than other nutrients in relation to non-mycorrhizal pines.
The chemical activity and availability of phosphorus in acid
soils is similar to molybdenum. Mitchell (1964) states that
uptake of Mo from acid soils can occur if the organic matter
content is high. Presumably organic chelation protects Mo from
entry into insoluble compounds. Another possible source of
molybderum is from decomposition of carbonaceous plant remains

in anaerobic soils which can lead to increased solubilization
of trace element complexes of Zn, Co, Mo, Cr, and Cu on
waterlogged land (Ng and Bloomfield 1961, 1962).

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Table 1-1. The concentration of molybdenum in ppm dry weight of leaf-branch samples of six northwestern trees and specific tissues of red alder.   (* estimate only)

SAMPLE	CONCENTRATION
Leaf-Branch Samples	
Alnus rubra	0.01
Acer macrophyllum	0.03
Taxus brevifolia	0.03
Tsuga heterophylla	0.20
Thuja plicata	0.37
Pseudotsuga menziezii	1.02
Alnus rubra Samples	
bark	0.14
branches	0.01
large roots	0.19
leaves	0.01
fresh litter	0.19*
nodules (subsample A)	0.40
nodules (subsample B)	0.45
seeds I (Calif. sample)	2.02
seeds II (local sample)	1.33
trunck wood	0.01*
Control	0.04 [1.]

1. Data below the control concentration represent analytically insignificant amounts.