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Mineral Nutrition and Growth of Eastern Redcedar in Missouri

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INTRODUCTION

Although optimum levels of most soil nutrients are now well established for most agricultural crops, relatively little is known about the nutrient requirements of most forest trees, particularly those species which had only secondary economic value in the past. Furthermore, little is known about the nutrient requirements of the less valuable tree species which occur on a wide variety of site conditions. Eastern redcedar (*Juniperus virginiana* L.) is one such species.

Eastern redcedar grows and develops best on rich, moist, well-drained sites, although it tolerates extremes ranging from swampy land to dry rock outcrops (Figure 1). It seems to be able to withstand the competition of hardwoods on the thin soils of dry limestone outcrops in Missouri, where definite redcedar communities occur (Brown, 1950; Beilman and Brenner, 1951). The physical nature of such rock-outcrop sites may limit the develop-

Fig. 1—Eastern redcedar coming in on dolomite "glades" in Taney County, Mo. (U. S. Forest Service photo.)

Fig. 2—Eastern redcedar under a girdled post oak (Quercus stellata, Wang.) on an "old-field" in southern Phelps County, Mo. (U. S. Forest Service photo.)

ment of associated hardwood species, whereas the chemical nature of the thin soils on these sites may directly affect the growth of eastern redcedar. (Read and Walker, 1950; Spurr, 1950).

When there are seed trees nearby, eastern redcedar is a characteristic tree species in early stages of forest succession on many old-fields (Figure 2). Young trees also are becoming increasingly prominent on grassy dolomite "glades" and outcrops, and on ridges and "post oak flats" of the Ozarks region. King et al. (1949) considered eastern redcedar as a desirable management type within much of the 492,000 acres of land classed as a cedar-hardwood cover type in Missouri.

Of the several soil factors affecting growth of eastern redcedar, soil fertility, as measured by chemical analyses, is of fundamental importance. This study was undertaken to evaluate certain nutritional aspects of eastern redcedar. It was hoped that mineral composition of the twigs and foliage, when compared with mineral composition of the soil on which given plants grew, would throw some light upon the growth of eastern redcedar in response to various levels of soil nutrient availability. It was assumed that the concentration of mineral nutrients in the above-ground parts of the plant would reflect the relative "uptake" of these elements from the soil.

OBJECTIVES

The primary objective of this study was to determine how much the mineral composition of eastern redcedar foliage and twigs varied with soil, season, age, and sex of the tree. The secondary objective was to determine the influence of the principal nutrient elements on seedling growth of this species. It was hoped that this study might reveal several promising leads for further research.

PROCEDURES

Field Investigation

Duplicate composite samples of foliage and twigs were collected from two male and two female trees of about 10 to 15 years of age growing on a wide range of soils at 13 locations in the Ozark and Ozark Border regions of Missouri. (Figure 3) Repeated collections were made during the spring, summer, and fall of 1951 from trees growing on two soil types within the Ashland Arboretum and Wildlife Experimental Area in Boone County.

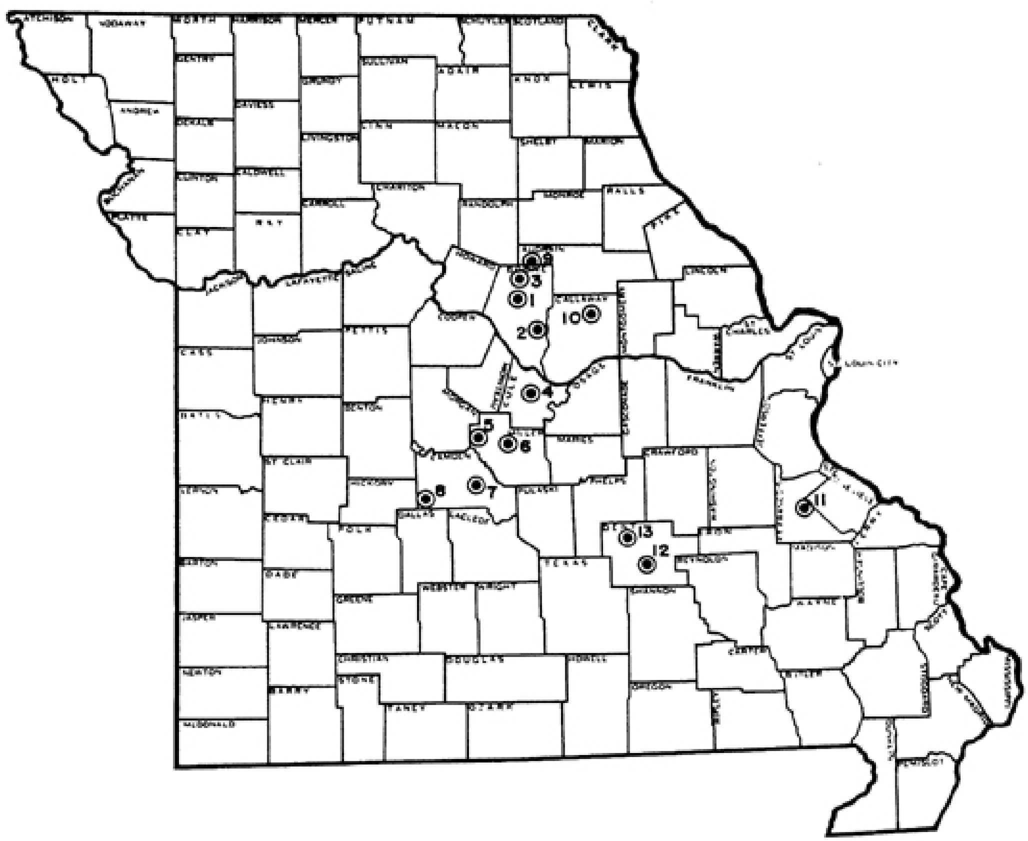

Fig. 3—Map of Missouri showing location of the sampling areas.

Small terminal twigs were cut from all sides and all heights of each tree, bagged separately, and air-dried at room temperature. Subsequently, the foliage and twigs were separated by rubbing, ground to pass a 2 mm. sieve, oven-dried in silica crucibles at a temperature of 100° C., weighed, dry-ashed at 500° C., and reweighed. The ash was then brought into solution, filtered, and the residue was dried at 110° C. and expressed as silica according to the method outlined by Piper (1950). Aliquots of the original solution were employed in making the calcium and potassium determinations, using the modified Lundegardh's flame method reported by Mitchell (1948), which employs spectrophotometric equipment. Other aliquots of the original solution were used for the phosphorus and magnesium determinations. A modification of the official micro-chemical method developed by Sterges *et al.* (1950) was used for determining the phosphorus content, while the magnesium determination was made in accordance with the standard micro-chemical method of Sterges and McIntire (1950).

Loose soil samples were taken by means of a soil auger at several spots at each collection location and bagged separately by soil horizons. After air-drying, these soil samples were lightly crushed, and a composite sample from each horizon was taken from the material which passed through a 2 mm. sieve. Soil tests were made on each sample, using "rapid" methods developed by Graham (1950) for testing Missouri soils. Soil reaction was determined by a line operated pH meter using a glass electrode, and soil organic matter by photoelectric colorimeter. Photoelectric methods were also used in determining soluble phosphorus and exchangeable calcium, potassium, and magnesium.

Nursery Investigation

About 8 cubic feet of soil were collected in the spring of 1951 at each of four different locations in Missouri, and mixed with an equal volume of coarse, sterile quartz-sand so that soil structure would not be the factor limiting plant growth. Twenty-four, uniformly graded, year-old eastern redcedar seedlings were transplanted into each of eight wooden boxes containing the sand-soil mixtures and mulched with an inch of year-old white oak header shavings. These boxes were placed outdoors, bedded in coarse sand, and periodically watered with distilled water throughout the growing season when rainfall seemed inadequate.

The trees were removed from the boxes in November, 1951, by washing the roots with a stream of water (Figure 4). After measuring shoot and root length, the plants were air-dried, the foliage was separated from the stems, and the stems were severed from the roots. Foliage, stems, and roots were then oven-dried at a temperature of 100° C., weighed (Table 2), ashed, reweighed, and finally analyzed for their content of silica, calcium, potassium, magnesium and phosphorus (Table 3).

Fig. 4—Representative 2-year-old eastern redcedar transplants after one growing season on various Missouri soils. The two plants at left were the largest and the two plants at the extreme right were the smallest of the total of 192 plants. The latter are about the size of the one-year-old seedling stock planted in April, 1951. Soil number and soil series: 87, Union (glade); 13, Riverwash; 27, Union (glade); 71, Putnam (surface); 74, Clarksville; 104, Putnam (subsurface).

A composite sample of soil was taken from each box and analyzed for reaction and content of organic matter, soluble phosphorus, and exchangeable calcium, potassium, and magnesium (Table 1).

RESULTS AND DISCUSSION

Seedling Growth

The growth of 192 eastern redcedar seedlings on several Missouri soils appeared to be markedly influenced by the amount of certain available mineral elements in the soil:

1. Fastest growth in weight and length, most foliage and branches, most extensive root system, and healthiest appearance characterized seedlings grown on rich, calcareous "glade" soil having the highest pH and calcium content, high organic matter and soluble phosphorus content, and adequate to high amounts of potassium and magnesium. On the other hand, the poorest growth and color, made on the leached Putnam subsurface soil, was associated with a low pH, lowest organic matter content, and low amounts of calcium, potassium, and phosphorus (Tables 1 and 2).

TABLE 1 -- DESCRIPTION OF THE SOILS ON WHICH EASTERN REDCEDAR SEEDLINGS WERE GROWN

Soil Series Horizon Depth Remarks	Union Surface Glade	Clarksville Surface Unimproved Pasture	Putnam Surface Agricultural Field	Putnam Subsurface Gray Layer (A_2)
Soil Number	87, 27	74	71	46, 104
pH	7.8	4.7	5.0	4.9
Organic matter, %	6.0+	1.2	1.8	0.8
Exch. Ca, % Sat.	88.1	16.9	37.3	22.0
Exch. Mg, % Sat.	10.4	19.2	2.5	11.0
Exch. K, % Sat.	1.6	2.3	0.2	1.0
Sol. P_2O_5, Lbs.	66	17	26	8

TABLE 2 -- GROWTH OF EASTERN REDCEDAR SEEDLINGS IN SEVERAL MISSOURI SILT-LOAM SOILS DURING THE 1951 GROWING SEASON

Soil	Union Surface	Clarksville Surface	Putnam Surface	Putnam Subsurface
Number of Plants	48	24	24	48
Growth, Length, cm.				
Shoot	16	8	10	1
Root	23	20	11	10
Total	39	28	21	11
Fresh wt., gm.	12.9	8.8	10.2	2.2
Oven-dry wt., gm.				
Foliage	3.9	2.6	3.4	1.1
Stem	1.1	0.7	1.0	0.2
Root	1.7	1.1	1.7	0.5
Total	6.7	4.4	6.1	1.8

2. Soils which were rich in nutrients produced the largest bulk of plant material, but a unit of this bulk contained the least amount of ash. The concentration of ash in stems, roots, and foliage of seedlings, particularly stems, was inversely related to the oven-dry weights as shown in Table 3. It also appeared that sharp increases in silica content occured after the ash content of seedlings exceeded the 5 percent level, particularly for samples of foliage and roots.

3. The percentages of total seedling weight in root, stem, and foliage remained almost constant regardless of the size of plant or kind of soil in which the plant grew. In general, the foliage comprised 54, the roots 28, and the stem 18 percent of the total oven-dry weight of seedling plants, as shown in Table 2. It would be interesting to determine whether this surprisingly constant relationship holds for mature trees.

4. The amount of exchangeable calcium in the soil had a direct influence on growth of the root, stem, and foliage of seedlings. It appeared that high pH, other things being equal, signified high calcium content of the soil, which in turn promoted an extensive root system and vigorous stem with healthy foliage.

5. There was a direct relationship between the weight of seedling roots and the amount of phosphorus and potassium contained in the foliage.

TABLE 3 -- DRY WEIGHT AND MINERAL CONTENT* OF EASTERN REDCEDAR SEEDLINGS GROWN IN SEVERAL MISSOURI SOILS DURING THE 1951 GROWING SEASON

Soil	Union Surface	Clarksville Surface	Putnam Surface	Putnam Subsurface
Oven-dry weight, gm.				
Foliage	4.2	2.9	3.7	1.4
Stem	1.3	0.9	1.2	0.4
Root	2.1	1.5	2.1	0.9
Total Plant	7.6	5.3	7.0	2.7
Ash				
Foliage	5.11	5.35	7.35	5.44
Stem	4.00	4.47	4.85	5.08
Root	5.54	6.39	7.23	6.43
Calcium				
Foliage	0.51	0.53	0.72	0.71
Stem	0.88	0.96	1.09	1.26
Root	0.79	0.61	0.68	0.74
P_2O_5				
Foliage	0.58	0.34	0.52	0.40
Stem	0.26	0.23	0.20	0.16
Root	0.35	0.39	0.33	0.28
Magnesium				
Foliage	0.10	0.16	0.12	0.13
Stem	0.08	0.05	0.05	0.01
Root	0.11	0.02	0.03	0.03
Potassium				
Foliage	0.85	0.85	0.67	0.62
Stem	0.39	0.36	0.31	0.35
Root	0.47	0.50	0.46	0.47
Silica				
Foliage	0.81	1.16	3.41	2.94
Stem	0.53	0.68	0.84	0.94
Root	1.72	2.70	3.69	1.77

*Expressed as percent of oven-dry weight.

6. Growth in length and weight of seedling shoots and roots was directly related to the amount of soluble phosphorus in the soil up to about 26 pounds per acre furrow-slice[1], but beyond this point there was little or no effect on seedling growth. Considering percentage of ash as a measure of uptake and utilization, the lowest percent of stem ash (but greatest growth) occurred on soil having 62 pounds P_2O_5 per acre, whereas the highest percentage of ash (but least growth) occurred on soil having 8 pounds P_2O_5 per acre (Figure 5). The importance of phosphorus in the growth and development of plants has been emphasized by many investigators. It follows that site quality for a given tree species should be correlated with the amount of soluble phosphorus in the soil. In this connection, Lutz (1949) reported that Schuetze (1896), Nemec (1929), and Hackmann (1930) found

[1]An acre furrow-slice is considered to be the surface 7 inches of soil on an acre of land.

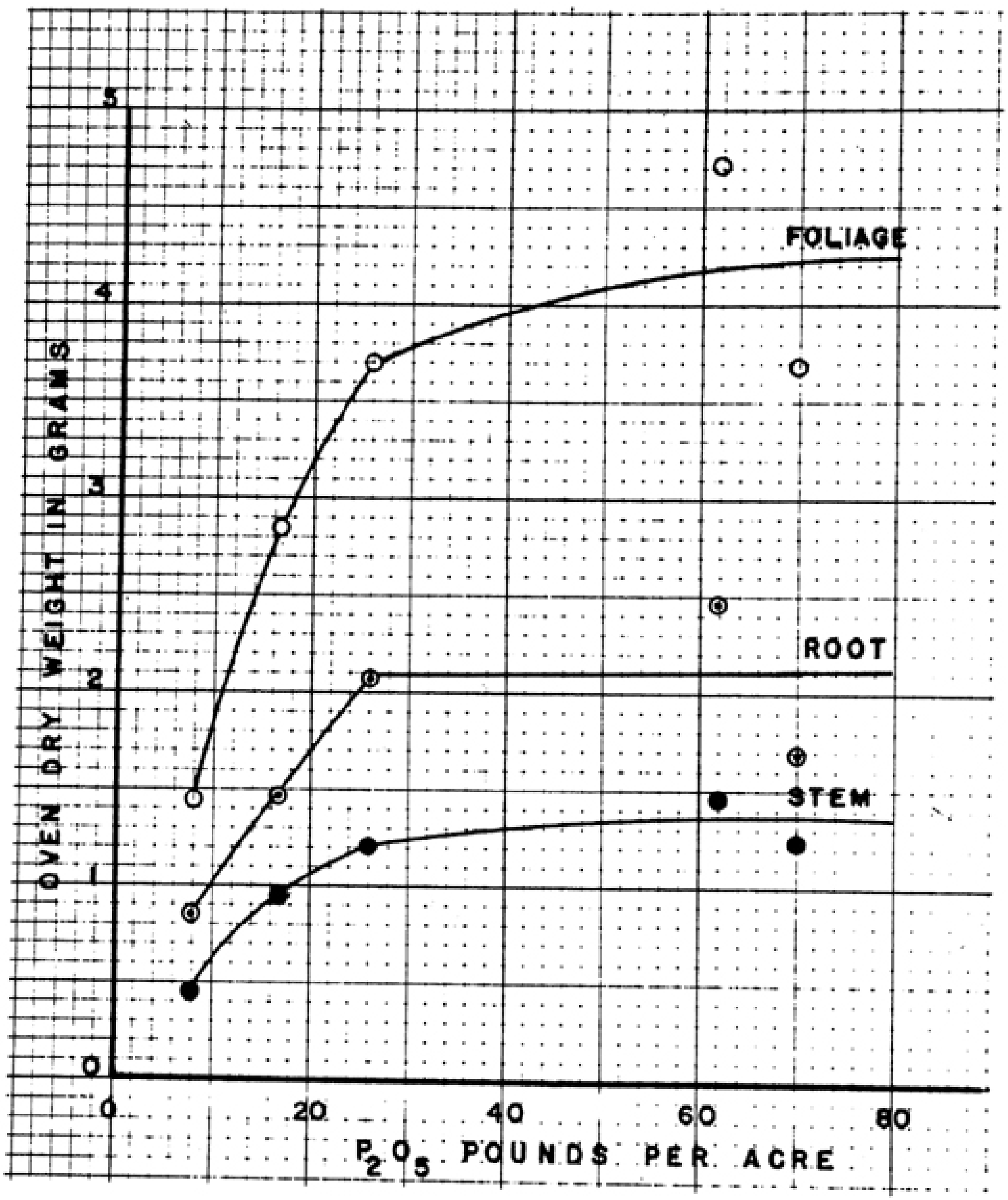

Fig. 5—Relationship between amount of P_2O_5 in the soil and oven-dry weight of foliage, stem, and root of eastern redcedar seedlings.

higher yields of pine and better site quality for spruce on central European soils with a relatively high phosphoric acid content. However, he also pointed out that Hennecke (1935) was unable to establish any clear relation between the phosphoric acid content of sandy German soils and site quality for trees.

Mineral Nutrition

The concentration of certain mineral elements in the foliage and twigs of eastern redcedar appeared to vary as follows with the—

1. Kind of soil:

a. There was a direct and significant relationship between the amount of soluble phosphorus in the silt-loam soils studied and its concentration in the foliage of both seedlings and mature trees (Figure 6).

b. There was a definite relationship between the concentration of calcium, potassium, and magnesium saturation of the soil and the concentration of these elements in the foliage, stems, or roots of seedlings or mature trees.

2. Advance of the growing season and sex of mature trees (Tables 4 and 5):

TABLE 4 -- EFFECT OF SEASON ON THE CONCENTRATION OF CERTAIN MINERAL CONSTITUENTS IN THE FOLIAGE AND TWIGS OF 10-16 YEAR OLD OPEN-GROWN EASTERN REDCEDAR TREES

Month of Collection	March-May		Aug.-Sept.		October		Weighted Averages	
Number of Samples	16		12		6		34	
Mineral Constituent	Foliage	Twigs	Foliage	Twigs	Foliage	Twigs	Foliage	Twigs
Ash	5.16	5.49	5.69	5.34	6.39*	5.45	5.65	5.43
Ca	1.41	1.78	1.39	1.62	1.65	1.83	1.45	1.74**
P_2O_5	0.27	0.20	0.34	0.20	0.37**	0.15	0.31	0.19**
Mg	0.22	0.13	0.24	0.15	0.20	0.09*	0.22	0.13**
K	0.49	0.33	0.76	0.44	0.74**	0.32	0.63	0.37**
SiO_2	0.47	0.51	0.23	0.27	0.30*	0.34	0.36	0.39

*Significant (2% level)
**Highly significant (1% level)
Note: Seasonal test of significance was computed by the "t" test for differences between means for March-May and October. Similarly, weighted averages were tested for differences between values for foliage and twigs.

TABLE 5 -- EFFECT OF SEASON AND SEX ON THE CONCENTRATION OF CERTAIN MINERAL CONSTITUENTS IN THE FOLIAGE AND TWIGS OF EASTERN REDCEDAR TREES GROWING ON UNION SILT-LOAM SOIL

Date of Collection		May 4		Sept. 6		Oct. 13		Average	
		Male	Female	Male	Female	Male	Female	Male	Female
Ca	Foliage	1.65	1.11	1.63	1.42	1.69	1.91	1.66	1.48
	Twigs	1.70	1.62	1.71	1.83	1.76	2.18	1.72	1.88
P_2O_5	Foliage	.34	.47	.39	.40	.41	.45	.38	.44
	Twigs	.15	.15	.22	.26	.15	.16	.18	.19
Mg	Foliage	.19	.12	.23	.21	.21	.20	.21	.17
	Twigs	.08	.10	.13	.14	.04	.10	.08	.11
K	Foliage	.48	.52	.71	.73	.57	.64	.58	.63
	Twigs	.30	.34	.45	.43	.31	.31	.35	.36

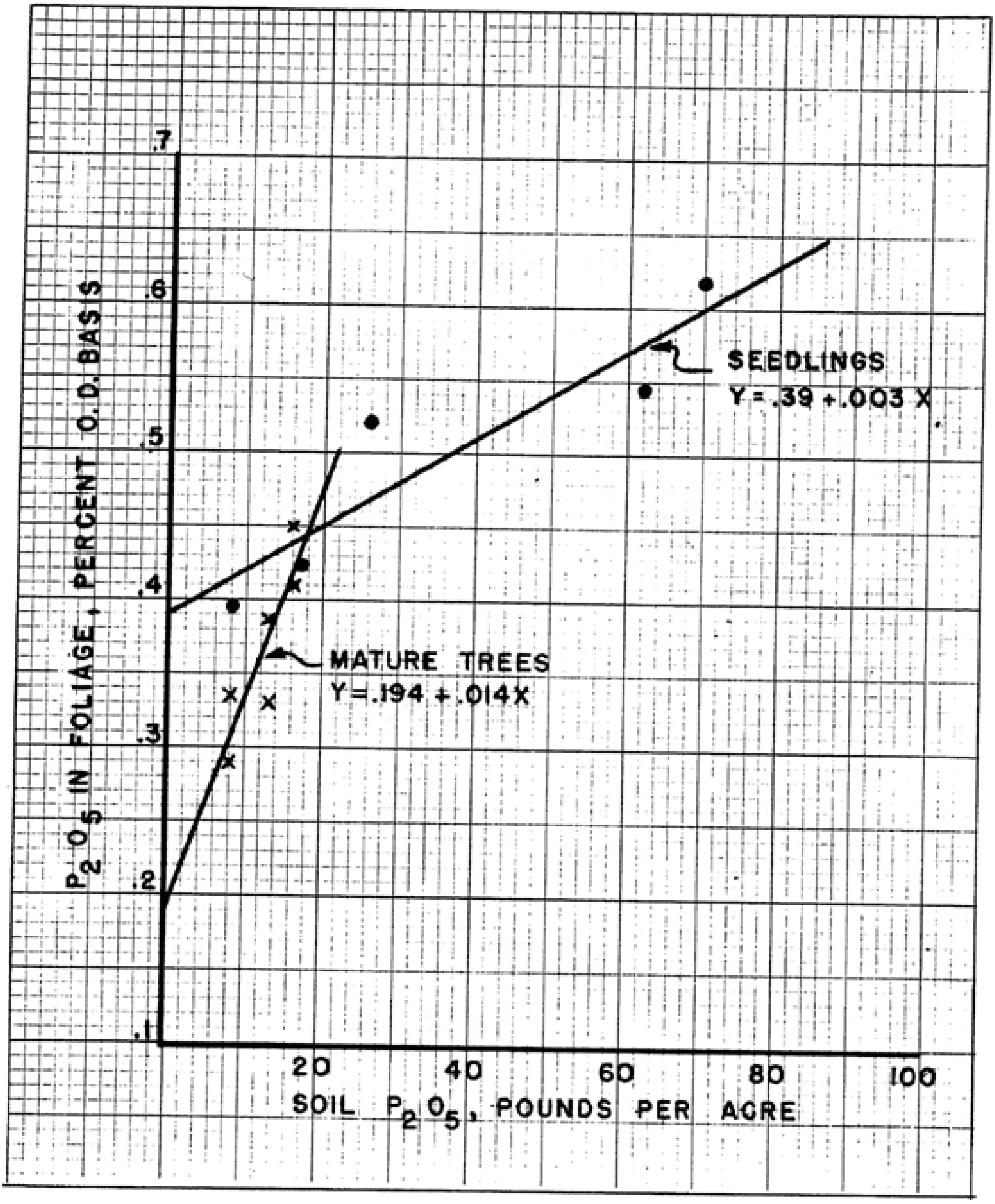

Fig. 6—Relationship between amount of P_2O_5 in the soil and its concentration in the foliage of seedling and mature eastern redcedar trees.

a. As the growing season advanced, the concentration of phosphorus in the foliage of both male and female trees increased. This is at variance with the results for nine hardwood tree species reported by Lutz (1949). It is possible that cedar foliage undergoes metabolic processes during the growing season which differ materially from those of hardwood leaves.

b. The foliage of female trees had a higher phosphorus content than the foliage of male trees. Furthermore, the amount dropped in mid-summer and then increased in the fall.

c. The phosphorus content of twigs remained relatively constant throughout the growing season, but dropped sharply in October.

d. The calcium content of male foliage was generally greater than that of female foliage, but remained relatively constant during the growing season. The calcium content of female foliage, however, definitely increased as the summer advanced. Lutz (1949) included eastern redcedar in the group of trees whose mature leaves usually contain more than 2 percent calcium on the oven-dry basis. In the present study, however, the concentration of calcium in foliage samples was less than 2 percent in most cases, averaging in the autumn about 0.6 percent for seedling foliage, and 1.65 percent for foliage of trees 10 to 15 years old. With respect to seasonal changes in the calcium content of foliage, Lutz (1949) found a progressive increase from June 1 to October 1 for both eastern white pine and eastern redcedar. In the present study, only a slight increase occurred, during the late summer months, and this increase was not found to be statistically significant. On the other hand, the calcium content of foliage from female trees rose progressively as the season advanced, whereas the calcium content of male foliage remained relatively constant. Insomuch as the sex of eastern redcedar trees has not heretofore been recorded in the investigations of other workers, it is possible that the progressive seasonal increases which have been reported in the literature were for female trees only.

e. The amount of silica in the foliage and twigs dropped in the late summer but rose in October, the fluctuation being significant for foliage but not for twigs. The specific role which silica may play in the life of a plant is not yet fully understood. Most workers consider silica as "doubtfully essential," despite its relatively high concentration in grasses and tree bark. Meyer and Anderson (1949) reported that silica appeared to influence phosphate metabolism in plants. Others have proposed that silica increases the availability and assimilation of phosphates in the soil. (Miller, 1938, Meyer and Anderson, 1949). Barton-Wright (1933) mentioned that Nemec (1927) found that the amount of phosphoric acid which is taken up by plants is proportional to the amount of water-soluble silicate in the soil. The results of this study support Nemec's conclusion.

The sharp decrease in phosphorus in the twigs during the late summer, when the silica content increases, may be explained as follows: Phosphorus is known to be heavily used in the autumn maturation of fruits and seeds; it is readily distributed from tissue to tissue within the plant, especially when the supply in the soil is low; in late summer, then, phosphorus moves into the foliage and fruit from the twigs, whereas silica builds up in both foliage and twigs in the process of "hardening" for the winter. The concentration of P_2O_5 in eastern redcedar seed was found to be 0.515 percent oven-dry weight, which is considerably higher than its autumn concentration in twigs of about 0.151 percent.

f. The potassium content of the foliage increased with the advance of the growing season. However, no significant differences could be established between male and female foliage or twigs.

g. The magnesium content in the foliage and twigs decreased in late summer. Like phosphorus, magnesium is rather mobile in plants and redistribution from older to younger plant tissues may occur rapidly and frequently. Magnesium is also believed to play an important role as a carrier of phosphates. It is the only known mineral constituent of the chlorophyll molecule. According to Frey-Wyssling (1945), it occurs in two different combinations as chlorophyll A ($C_{55}H_{72}O_5N_4Mg$) and as chlorophyll B ($C_{55}H_{70}O_6N_4Mg$).

3. Age and part of the tree (Table 6):

TABLE 6 -- THE EFFECT OF AGE AND PART OF TREE ON THE CONCENTRATION* OF SEVERAL MINERAL CONSTITUENTS

Mineral	Nursery Seedlings			Mature Field Trees	
Constituents	Foliage	Stems	Roots	Foliage	Twigs
Ash	5.67	4.55	6.20	5.65	5.43
Calcium	0.62	1.04	0.73	1.45	1.74
P_2O_5	0.45	0.23	0.32	0.31	0.19
Magnesium	0.12	0.06	0.05	0.22	0.13
Potassium	0.73	0.36	0.50	0.63	0.37
SiO_2	1.42	0.69	2.44	0.36	0.39

*Expressed as percent of oven-dry weight.

Morosov (1949), in discussing the nutrient requirements of trees, stated that the uptake of mineral nutrients from the soil depends both on the season and on the age of the tree. He believed that the greatest utilization of mineral nutrients by trees occurred at the pole age, when annual increment is usually greatest. In this study, assuming that the percentage of ash is a measure of plant uptake and utilization, Morosov's conclusion was borne out only for the stems and twigs of 10 to 15-year-old eastern redcedar trees as compared with nursery-grown seedlings.

Furthermore:

a. The content of calcium and magnesium in foliage and twigs of mature trees was higher than that in nursery seedlings.

b. The content of potassium, phosphorus, and silica in foliage and twigs of mature trees was lower than that of nursery seedlings, although the ash content of foliage remained about the same.

c. Stems and twigs of seedlings and mature trees contained a consistently higher concentration of calcium than the foliage.

d. The phosphorus, potassium, and magnesium content of foliage from seedlings and mature trees was about twice that of stems and twigs.

e. There was no significant difference in the silica content of foliage and twigs from mature trees.

f. The ash content of seedling stems was consistently lower than that of either the foliage or roots.

g. There was a proportional and constant increase in the amount of phosphorus in foliage and twigs, particularly the foliage, as the silica content increased.

General Nutrient and Growth Relationship

Of the several mineral nutrients analyzed in this study, calcium and phosphorus seemed to be most critical in the growth and development of eastern redcedar seedlings. Soils rich in calcium and having adequate supplies of other nutrients produced plants with the most extensive root systems, other things being equal. Having better root development, these plants were capable, theoretically, of greater "uptake" of other nutrient elements. Available phosphorus provided the most definite soil-plant relationships. Thus, considering calcium and phosphorus together, it appears that for eastern redcedar seedlings (1) an increase of exchangeable soil calcium leads to increased root development which leads to greater nutrient uptake, especially phosphorus; (2) an increase of soluble soil phosphorus to 70 pounds per acre furrow-slice leads to increased length and oven-dry weight of stems and roots and oven-dry weight of foliage.

SUMMARY AND CONCLUSIONS

The objectives of this study were (1) to determine how much the mineral composition of eastern redcedar foliage and twigs varies with soil, season, age, and sex of the tree and (2) to determine the influence of the principal nutrient elements on seedling growth of this species.

The field investigation consisted mainly in the collection of foliage and twig samples from selected male and female trees of about the same age and size, growing in open fields on various Missouri soils, with repeated collections at two locations periodically throughout the 1951 growing season. The soils were analyzed for reaction, organic matter, soluble phosphorus, calcium, potassium, and magnesium. Soil-plant relationships were sought with regard to the amount of ash and the concentration of the several mineral elements.

The nursery investigation consisted of growing seedlings in separate wooden boxes containing various Missouri soils mixed with equal parts of sterile sand, mulching and watering them, and then harvesting the entire plants after one growing season. Plant growth in length and weight was related to the soils, which were analyzed for their content of readily available nutrients. Foliage, stems, and roots were likewise analyzed for their content of these mineral elements. In all, 110 vegetation samples and 55 soil samples were analyzed.

The major conclusions were:

1. Rich, calcareous soils produced maximum seedling growth (length and bulk) but least ash per unit of oven-dry matter.

2. The percentage of total seedling weight in root, stem, and foliage remained almost constant regardless of plant size or soil series in which the plant grew.

3. Soluble phosphorus and exchangeable calcium in the silt-loam soils were directly related to seedling growth.

4. The concentration of phosphorus in the foliage of seedlings and mature trees was related directly to its concentration in the silt-loam soils studied. There was no such definite soil-plant relationship for calcium, potassium, and magnesium.

5. The foliage, compared to the twigs, contained greater concentrations of potassium, magnesium, and phosphorus, about the same proportion of silica and total ash, and a lower concentration of calcium.

6. As the growing season advanced, the concentration of phosphorus in the foliage increased, but the concentration of calcium, potassium, and magnesium increased only slightly or remained relatively constant.

7. The calcium content of foliage from female trees increased as the growing season advanced, but that of male foliage remained relatively constant.

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