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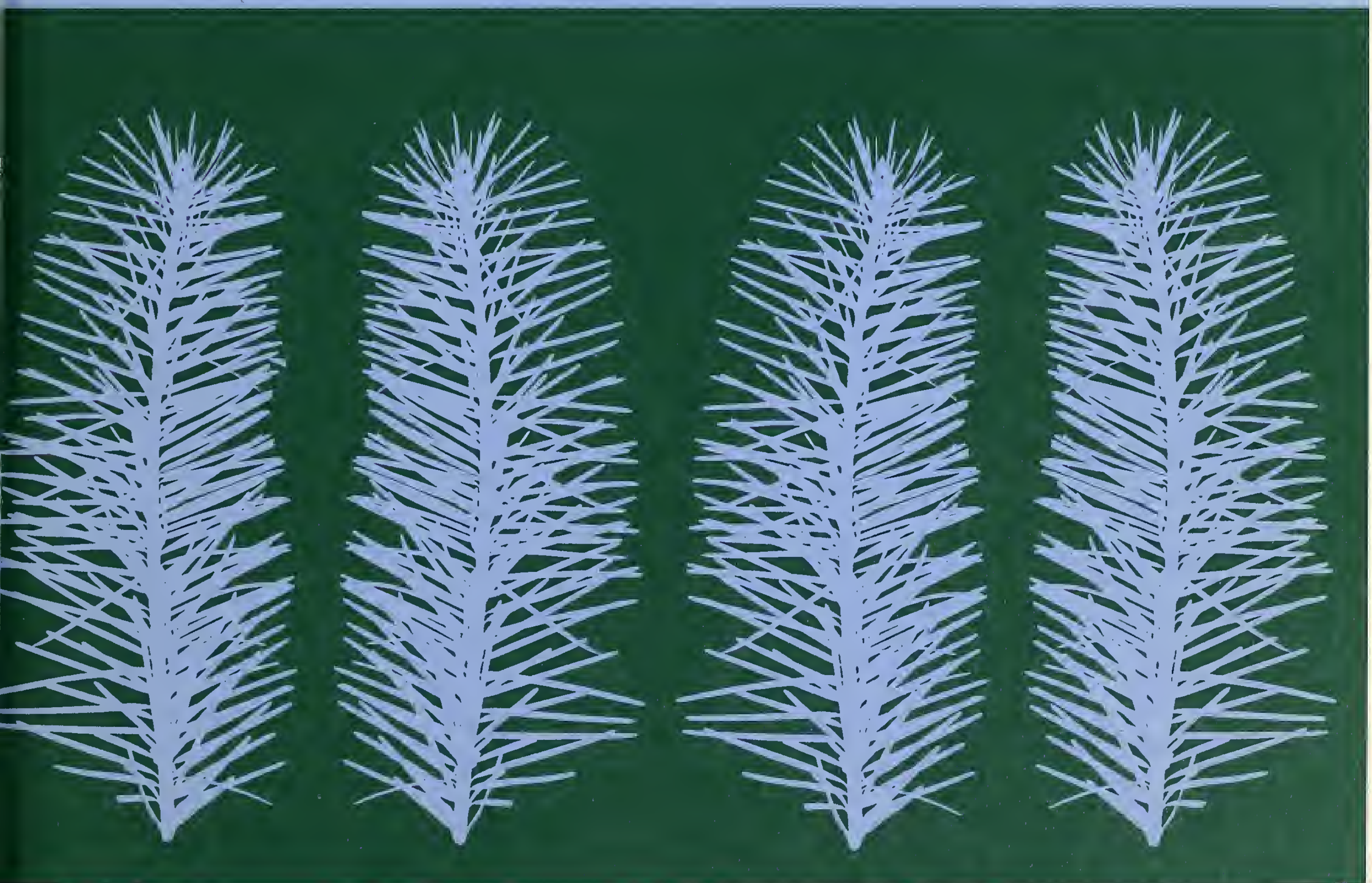
Foliar Mineral Content of Forest - and Nursery-Grown Douglas-Fir Seedlings

By Kenneth W. Krueger



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Introduction

High-vigor seedlings are required for consistently successful reforestation, and mineral nutrition undoubtedly plays a large role in determining seedling vigor. Though no serious mineral deficiencies were known to exist in Northwest forest nurseries, assurance of adequate seedling nutrition would eliminate this factor as a possible cause of plantation failures. Perspective was gained on Douglas-fir nutrition by determining essential element content in foliage of seedlings growing in 10 selected forest areas and 4 nurseries in Oregon and Washington. On the basis of comparative element levels, possible improvements in nursery fertilization are predicted.

Neither soil analysis nor tissue analysis will yield all-inclusive answers on mineral nutrition of seedlings. In many instances, tissue analysis may be more informative than soil analysis, since questions of nutrient availability are minimized. Tissue analysis has played an important role in agriculture in revealing mineral nutrition problems where none were suspected. Although there are both fundamental and practical unknowns in applying foliar analysis techniques to conifers, resulting data can provide some basis for assigning test priorities in fertilizer trials.

Methods

Collection

Fast-growing seedlings 2 to 5 years old were sampled in recently clearcut areas at 10 locations in western Oregon and Washington:

Sample name	Location
Brummet Creek	East of Coquille, Oreg.
Cherry Creek	East of Coquille, Oreg.
Marys Peak	West of Corvallis, Oreg.
Kautz Creek	Southeast of Hebo, Oreg.
Clatsop	Northeast of Seaside, Oreg.
Seaside	East of Seaside, Oreg.
Cathlamet	West of Skamokawa, Wash.
Ames Creek	South of Randle, Wash.
Quartz Creek	South of Randle, Wash.
Montesano	Southeast of Montesano, Wash.

Eight of the areas are in the Coast Ranges on soils of marine sedimentary origin and two, Ames Creek and Quartz Creek, are located on pumice soils in the Washington part of the Cascade Range (Forest Soils Committee 1957).[1] All areas were judged by local foresters to be of high site II or better quality (trees 170 or more feet tall at age 100 years).

Seedlings on seven of the areas originated from seed that fell from adjacent unlogged stands. Three areas — Clatsop, Seaside, and Montesano — had been artificially seeded with seed collected nearby; presumably, resulting seedlings were also well adapted to the particular site.

Samples of current-year foliage were collected in October and November 1964, prior to heavy winter rainfall. One lateral branch per seedling was clipped from

[1]*Names and dates in parentheses refer to Literature Cited, p. 11.*

the top whorl on 85 or more seedlings in each area, depending on seedling age and number available. Seedlings growing on severely burned spots or areas of major soil disturbance were not sampled.

Collections were also made in four Pacific Northwest forest nurseries:

Forest nursery	Location
Dwight L. Phipps	Elkton, Oreg.
Industrial Forestry Association	Canby, Oreg.
L. T. "Mike" Webster	Tumwater, Wash.
Wind River	Carson, Wash.

A seedling of average size and color was clipped at regular intervals from the center row in several hundred feet of beds considered by the nurseryman to be located in a representative part of the nursery. One composite sample of seedlings was taken at the Industrial Forestry, Phipps, and Webster nurseries and five at the Wind River nursery. Three of the latter were taken from beds in the oldest section of the nursery, which has been in continuous production for more than 50 years. The other two samples were taken from the Trout Creek division where production began only recently.

Foliage from a topmost lateral branch of the sample seedlings was used, except from 2-year-old seedlings collected in the Industrial Forestry, Webster, and Wind River nurseries. On these, needles from the terminal leader were used since seedling density in the beds had prevented formation of vigorous lateral branches.

Processing

Promptly after clipping, samples were placed in polyethylene bags in an insulated, iced cooler for transport to the laboratory. When samples could not be processed the same day as collected, they were kept at 7° C. In every case, processing and drying began within 24 hours of collection.

After being rinsed momentarily in distilled water to remove any surface dust, needles were stripped from the branches or leaders, placed in plastic-lined paper or glass containers, and ovendried at 60° C. Length and weight were determined on a subsample of dried needles to provide a comparison of seedling vigor. Dried needles were ground to powder with a glass mortar and pestle and stored in sealed glass containers at −16° C. until redried at 65° C. just before analysis.

Chemical Analysis

Separate subsamples for determining ash content and for copper, molybdenum, and phosphorus analysis were dry-ashed at 550° C. in a stainless-steel-lined muffle furnace. Subsamples for boron and chlorine analysis were also dry-ashed, but in mixture with calcium oxide (Chapman and Pratt 1961). Samples for other essential elements were wet-ashed with nitric and perchloric acids (Johnson and Ulrich 1959), except the nitrogen samples which were wet-ashed with sulfuric acid containing salicylic acid (Association of Official Agricultural Chemists 1960).

Nitrogen analysis to include nitrates was made by the micro-Kjeldahl method (Association of Official Agricultural Chemists 1960). Sulfur was determined by a turbidimetric method, modified from Butters and Chenery (1959), using a Klett colorimeter and green filter. Several elements were analyzed by methods summarized and described by Chapman and Pratt (1961): colorimetric measurement with a Beckman BD spectrophotometer was used for boron in a carmine procedure; for copper after reaction with "zincon"; for molybdenum by the thiocyanate method; and for phosphorus as molybdenum blue. Chlorine was determined by titration of chloride with silver nitrate to the silver chromate end point.

The Oregon State University Soils Department determined calcium, iron, magnesium, manganese, and zinc, using a Perkin-Elmer model 303 atomic absorption spectrometer, and potassium and sodium by flame photometry with a Beckman DU spectrophotometer.

All nitrogen, phosphorus, sulfur, plus selected boron and potassium analyses were made in duplicate. A single determination was made for the other elements.

Results

Needles of nursery-grown seedlings were in the same size range as those of forest-grown seedlings, except for those in the Trout Creek division at Wind River (table 1). Needles of seedlings in the Trout Creek division were considerably shorter, a condition which may have been associated with the slight chlorosis evident at the time of sampling. Ash content, average dry weight of 100 needles, and the weight-to-length ratio of needles for nursery seedlings also fell within the range of values for forest seedlings except for some Wind River samples.

Differences in physical characteristics of needles did not appear great enough to preclude comparing element quantities as concentration based on dry weight of needles. Weight data in table 1 are based on needles dried at 65° C.

Inspection of the data in table 2 and brief consideration of common ion interactions (after Smith 1962) reveals:

Nitrogen.—Foliar concentrations in seedlings from Webster and Wind River nurseries were quite low compared with those in seedlings from other sources. Neither Webster nor Wind River seedlings showed high potassium or chlorine concentrations which are sometimes associated with depressed nitrogen levels.

Phosphorus. — Concentrations found in seedlings from the Industrial Forestry Association nursery at Canby and from the Trout Creek division of the Wind River nursery were lower than those in seedlings from other sources. Nitrogen abundance sometimes depresses phosphorus content, but this explanation would not apply to seedlings from the Trout Creek division, and by comparison with other values in table 2, neither would it apply to the Industrial Forestry nursery. Seedlings from the Industrial Forestry nursery did have a higher-than-average concentration of iron, but in view of the iron-phosphorus ratio found in Phipps nursery seedlings, it seems doubtful that iron concentration in the foliage influenced the phosphorus level. However, it is possible that iron may be influencing phosphorus availability in the Sifton soil at Canby.

Table 1—Physical description of foliage samples[1]

Sample	Seedling age	Seedlings sampled	Average needle length	Ash content	Average dry weight of 100 needles	Average dry weight per 100 cm. needles
	Years	*Number*	*Centimeters ± 2 standard errors*	*Percent of dry weight*	*Grams*	*Grams*
Forest-grown seedlings:						
Brummet Creek	3,4	196	3.11±0.14	4.11	0.423	0.136
Cherry Creek	4,5	145	2.94± .14	3.73	.433	.147
Marys Peak	4	85	2.49± .10	4.48	.402	.162
Kautz Creek	3,4	131	3.21± .16	2.91	.459	.143
Clatsop	3	130	2.92± .16	4.24	.327	.112
Seaside	5	90	3.26± .18	3.50	.534	.164
Cathlamet	5	112	3.52± .18	3.20	.570	.162
Ames Creek	3,4	136	2.98± .23	4.72	.476	.160
Quartz Creek	2,3	127	2.89± .14	3.88	.473	.164
Montesano	3,4	184	3.24± .15	4.10	.362	.112
Average	—	134	3.06	3.89	.446	.146
Range	2-5	85-196	2.49-3.52	2.91-4.72	.327-.570	.112-.164
Nursery-grown seedlings:						
Industrial Forestry Association	2-0	205	3.20± .16	3.83	.447	.140
Phipps	2-0	465	2.69± .12	3.95	.414	.154
Webster	2-0	224	2.60± .05	3.19	.384	.148
Wind River:						
Old section 1	2-0	316	3.18± .15	3.73	.593	.186
Old section 2	2-0	180	3.03± .19	3.55	.536	.177
Old section 3	2-0	163	2.86± .18	3.76	.487	.170
Trout Creek 1	3-0	797	1.60± .08	2.58	.186	.116
Trout Creek 2	3-0	1,047	1.54± .06	2.71	.180	.117

[1] *Weight data based on needles dried at 65° C.; to convert values to 100° C. dry-weight basis, multiply by a factor of 1.031.*

Table 2.—Foliar concentration of 14 elements in Douglas-fir seedlings

Sample	N	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu	B	Mo	Na	Cl
	Percent						*Parts per million*							
Forest-grown seedlings:														
Brummet Creek	2.05	0.38	0.75	0.430	0.132	0.22	91	315	40	2	5	0.04	[1]	1,490
Cherry Creek	1.96	.34	.75	.400	.128	.14	84	358	36	5	4	—	2.5	150
Marys Peak	1.70	.31	.75	.325	.144	.20	69	483	22	5	8	.25	5.0	930
Kautz Creek	1.89	.18	.85	.270	.117	.23	61	540	34	1	6	—	[1]	680
Clatsop	2.32	.45	1.05	.289	.128	.19	95	870	55	7	12	.10	[1]	750
Seaside	1.94	.21	.95	.285	.123	.16	113	350	25	9	10	.01	[1]	1,340
Cathlamet	1.90	.20	.90	.214	.095	.19	85	500	27	5	6	.02	[1]	1,280
Quartz Creek	1.78	.26	.90	.337	.121	.19	73	233	36	3	5	—	[1]	700
Ames Creek	1.62	.30	.95	.348	.142	.15	77	298	26	6	5	.02	[1]	760
Montesano	1.94	.34	1.00	.412	.133	.25	68	333	37	11	14	—	[1]	1,160
Average	1.91	.30	.88	.331	.126	.19	82	428	34	5	8			924
Range	1.62-2.32	.18-.45	.75-1.05	.214-.430	.095-.144	.14-.26	61-113	233-870	22-55	1-11	4-14	up to .25	up to 5.0	150-1,490
Nursery-grown seedlings:														
Industrial Forestry Association	1.96	.16	1.00	.383	.110	.21	180	250	42	8	8	—	[1]	440
Phipps	2.00	.38	.90	.337	.110	.20	225	493	47	6	8	.10	[1]	650
Webster	1.46	.22	.50	.400	.104	.24	138	460	27	6	2	.04	[1]	680
Wind River:														
Old section 1	1.44	.25	.90	.360	.095	.23	127	500	33	6	3	.02	[1]	660
Old section 2	1.50	.22	.95	.343	.096	.24	88	490	36	11	3	.06	2.5	920
Old section 3	1.42	.22	1.00	.360	.088	.21	103	610	37	6	2	—	2.5	890
Trout Creek 1	1.33	.14	.50	.303	.086	.17	67	610	23	5	2	—	2.5	750
Trout Creek 2	1.28	.15	.55	.217	.065	.17	85	860	24	3	3	.02	[1]	430

[1] *Trace.*

Potassium.— Values for seedlings from Webster nursery and Trout Creek division of the Wind River nursery were substantially lower than those from other sources. High nitrogen, phosphorus, calcium, or magnesium concentration may sometimes depress potassium level, but none of these elements appear sufficiently abundant to have depressed potassium. Likewise, low values for sodium rule out its possible depressing influence on potassium level.

Calcium.—Foliage concentration in seedlings from all nurseries fell within the range found in forest-grown seedlings.

Magnesium.—Concentrations of this element in foliage samples from nurseries were near the low end of the range for those from forest-grown seedlings, and a few from Wind River were lower. In no sample does concentration of magnesium appear to have been caused by high concentration of phosphorus, potassium, zinc, manganese, or boron.

Sulfur.—Concentrations in foliage of nursery-grown seedlings fell within the range for forest-grown seedlings.

Iron, manganese, zinc, copper, chlorine. — Levels appear satisfactory, though the manganese concentration in seedlings from the Industrial Forestry nursery approaches the low end of the range found in forest-grown seedlings. Judged by iron and manganese levels in seedlings from the Phipps nursery, it appears unlikely that the higher-than-average iron concentration in seedling foliage at the Industrial Forestry nursery depressed manganese level.

Boron.—Seedlings from Webster and Wind River nurseries had lower concentrations than those in other locations. Low boron concentration is sometimes caused by high potassium concentration, but potassium levels were near average or less for seedlings from these two nurseries.

Molybdenum.—No conclusions can be reached, as concentration was too low in most cases for reliable determination.

Sodium.—Concentrations found in foliage of nursery-grown seedlings appear inconsequential.

Discussion

Foliar levels of macronutrient elements revealed by the analyses generally reinforce observations and experience at the various nurseries. At Wind River, soil analyses have shown the Trout Creek division to be lower in fertility than the old nursery. In nearby forest areas, higher soil nitrogen levels have resulted in increased growth of Douglas-fir trees (Tarrant 1961). Possibilities for increasing nitrogen in seedlings at Webster nursery are consistent with the experience that nitrogen fertilization of Douglas-fir growing on Puget Sound area soils characteristically produces additional growth (Gessel et al. 1965). The low concentration of potassium was unexpected, however. Phosphorus merits special attention at the Industrial Forestry Association nursery. Stunted seedlings have resulted there from temporary circumstances which led to reduced phosphorus uptake.[2] High levels of all elements found in seedlings from the Phipps nursery are reflected in their rapid growth.

For several micronutrient elements, the picture is less clear. For example, zinc concentration in seedlings at Webster nursery is one of the lowest among nurseries, but similar to that at several forest locations. Pot tests show zinc may produce a growth response on Webster nursery soils.[3] Therefore, pot tests of micronutrients seem desirable to confirm or modify interpretations based on these foliar analyses, especially since some micronutrient deficiencies are known to occur in the Northwest (Beeson 1959; Viets 1963).

Despite good agreement between information provided by this study and "educated" guesses on fertilizer needs in individual nurseries, the many unknowns existing in use of foliar analysis techniques call for examination of the assumptions involved in making comparisons between nursery- and forest-grown seedlings. For example, is current-year foliage from 2- and 5-year-old plants comparable? Experience has shown foliage age to be much more important than plant age (Smith 1962). Data of Hőhne and Nebe (1964), for example, show little or no difference in concentrations of several elements in 1-year-old foliage from spruce 15 to 90 years old. Element concentrations found in foliage of the seedlings studied (table 2) are also in reasonable agreement with concentrations found in or recommended for older Douglas-fir trees (Beaton et al. 1964; Beaton et al. 1965; Gessel et al. 1960). Thus, the age range among sample seedlings is not likely to have been a serious source of error.

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[2]*Study by James M. Trappe and Robert F. Strand. Data on file at Pacific Northwest Forest & Range Exp. Sta., U.S. Forest Serv., Portland, Oregon.*

[3]*Anderson, Harry W. The effect of soil zinc concentration on the growth of Douglas-fir seedlings. 1967. (Manuscript submitted to Tree Planters' Notes for publication.)*

What effect did the different environments from which seedlings originated have on the analytical results obtained? Environmental factors can affect mineral composition of foliage strongly under poor growing conditions (Bloomberg 1965). However, none of the seedlings sampled in this study, with the possible exception of those from the Trout Creek division at Wind River, could be classed as growing poorly. Temperature patterns undoubtedly differed among sample locations. Mergen and Worrall (1965) found no significant temperature effect on foliage concentration of nitrogen, phosphorus, or potassium in *Pinus banksiana* seedlings of several sources growing in three controlled environments. For the intended purpose of the present study, variation caused by environmental differences probably did not seriously confound comparisons of foliage concentration.

Genetic variation within a species may cause differences in mineral composition of conifer seedlings (Mergen and Worrall 1965). Uniform results (table 2) within divisions of the Wind River nursery, where seedlings from several beds of varying seed source were composited to make up each sample, indicate that if genetic-caused variations existed, they were averaged out. Reasonably good agreement between samples from the same division of the Wind River nursery may also indicate that the generous sample size used was adequate to characterize relatively homogeneous areas.

Nitrogen data provided by Leyton (1958) indicate that if needles from terminals rather than from lateral twigs are sampled, foliage concentrations tend to be greater. Since foliage of terminals was used from samples collected at Wind River and Webster nurseries, interpretations about low nitrogen levels there may be conservative.

Concentration in foliage provides little information on degree of response an increased supply of an element may produce, due to interactions with other elements and the environment. Only a general idea of nutrient balance can be attained. Tests of fertilizers on potted seedlings may also produce results not attainable in the field (Timm et al. 1966). Nonetheless, both foliar analyses and pot tests provide information to guide choice and scope of field tests.

In evaluating fertilizer tests, success in increasing growth in the nursery may be less important than increasing seedling capability to survive and grow rapidly after outplanting. What could be considered "luxury consumption" for growth in the nursery might serve later to enhance growth of outplanted seedlings (Anderson and Gessel 1966; Krueger 1967; Smith et al. 1966).

Based on results of this study, first priority in future tests should be given to improve: Industrial Forestry Association nursery — phosphorus and possibly manganese; Webster nursery — nitrogen, potassium, and possibly boron; Wind River nursery — nitrogen, magnesium, and possibly boron in the old nursery area, and nitrogen, phosphorus, potassium, magnesium, and possibly boron in the Trout Creek division.

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