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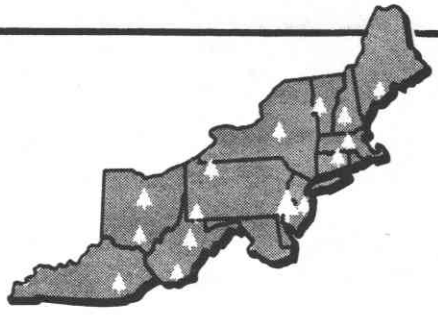

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FOLIAR NUTRIENT CONCENTRATIONS IN BALSAM FIR AS AFFECTED BY SOIL DRAINAGE AND METHODS OF SLASH DISPOSAL

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Abstract. Foliar nutrient concentrations in young balsam fir growing on strip clearcuts were assessed in relation to soil drainage and three methods of slash disposal. Concentrations of N, K, and Mn were higher for trees growing on well-drained soils than for trees growing on poorly drained soils. Mo concentrations were higher on poorly drained soils and all other measured nutrients were unaffected. Only foliar Fe was affected by the three methods of slash disposal.

Foliar analysis is a sensitive method of assessing tree nutrition and the ability of soils to supply nutrients for adequate tree growth. Although foliar nutrient levels have been reported for many species, little information is available for balsam fir (*Abies balsamea* (L.) Mill.) growing in Maine. In particular, little is known how soil drainage conditions and silvicultural practices might influence foliar nutrient levels. Hence, base-line levels of foliar nutrients are extremely limited for healthy balsam fir trees that are free of spruce budworm (*Choristoneura fumiferana* (Clem.)). In this study, foliar nutrient concentrations in young balsam fir were assessed in relation to two broad soil drainage groups and to three methods of slash disposal on clearcut strips 8 years after harvesting the mature stand.

THE STUDY

Area and plot layout

The study was made on the Penobscot Experimental Forest in Maine in conjunction with the earlier studies of the influence of strip-clearcutting and slash disposal methods on natural regeneration of spruce and fir and on site fertility. Detailed descriptions of the study area, the forest, soils, and plot layout are given by Czapowskyj et al. (1977).

Soils of the study area are complexes of well-drained to poorly drained soils on glacial till, and moderately well-drained to poorly drained soil of marine sediments. Soils on glacial till include Marlow, Peru, and Monarda; those on marine sediments include Elmwood, Buxton, and Scantic. Because of the

intricate pattern of these soils on the landscape and the differential restriction of root penetration by a dense layer that impedes water movement, the soils were subdivided into two broad groups: Group A, which included very poorly and poorly-drained sites, and Group B, which included moderately well and well-drained sites.

The mature stand was harvested by strip-clearcutting in 1965 and the slash was either left in place, or removed, or burned.

Foliage sampling and analysis

In early October 1973, foliage samples were collected from 180 young balsam fir trees that ranged from 30 to 80 cm in height. Three trees randomly selected represented each of the 60 plots, evenly divided among the two soil drainage groups and three slash disposal methods. Consequently, each soil drainage group and slash disposal treatment were represented by 10 plots.

Twigs with current-year needles were collected from upper crown portions. Foliage from each of the three trees on each of the 60 plots was composited, making a total of 60 samples. Samples were dried at 70°C, ground to pass through a 20-mash screen, and prepared in duplicate for chemical analysis. Nitrogen was determined by Kjeldall digestion. The other nutrients were determined with an emission spectrograph after dry ashing (Carpenter 1964).

Analysis of variance was used to test differences among soil drainage groups and slash disposal treatment.

RESULTS AND DISCUSSION

Average foliar nutrient concentrations of young balsam fir are summarized in Table 1. The data are consistent with results reported by Young and Quinn (1966) and Henry (1973). Inconsistencies were noted only for Mo and Cu concentrations, and these are probably a function of the soils upon which the trees were growing. Comparisons between the present data and those reported by Timmer and Stone (1978) suggest that our balsam fir contained less N than is needed for optimum shoot growth.

Analysis of variance test for differences (Table 2) showed that foliar nutrient concentrations of one or more elements was affected by soil drainage or slash disposal treatment, or by their interactions.

Table 1.—Nutrient concentrations in balsam fir needles as affected by soil drainage and slash disposal[a]

Nutrient	Slash disposal treatment							
	Left on site		Removed		Burned		Mean	
	A[b]	B[c]	A	B	A	B	A	B
Nitrogen (%)	1.38	1.41	1.23	1.41	1.32	1.64	1.31	1.50
Phosphorus (%)	0.18	0.18	0.15	0.17	0.15	0.18	0.16	0.18
Calcium (%)	0.55	0.54	0.56	0.56	0.52	0.41	0.54	0.50
Magnesium (%)	0.12	0.12	0.12	0.12	0.19	0.11	0.14	0.12
Potassium (%)	0.49	0.52	0.45	0.49	0.43	0.52	0.46	0.51
Manganese (%)	0.07	0.11	0.09	0.11	0.08	0.10	0.08	0.11
Iron (ppm)	64	67	49	64	71	77	61	69
Zinc (ppm)	50	36	39	40	40	41	43	39
Copper (ppm)	6	21	19	11	8	17	11	16
Molybdenum (ppm)	0.36	0.41	0.42	0.39	0.43	0.32	0.40	0.37

[a]Each value is the average of 10 replications.
[b]A = very poorly and poorly drained soils.
[c]B = moderately well and well-drained soils.

Table 2.—F-values for comparisons of nutrient concentrations in balsam fir needles by soil drainage and slash disposal method

Source of variation	Nutrient									
	N	P	Ca	Mg	K	Mn	Fe	Zn	Mo	Cu
Soil drainage	13.33**	3.33†	1.44 NS	1.31 NS	6.00*	5.29*	3.66†	2.25 NS	6.13*	1.75 NS
Slash disposal	3.05†	2.78†	2.89†	0.71 NS	1.07 NS	0.59 NS	5.89**	0.81 NS	2.09 NS	0.14 NS
Soil drainage × slash disposal	1.63 NS	0.56 NS	1.21 NS	0.96 NS	0.64 NS	0.29 NS	0.80 NS	4.14*	12.91**	3.03†

NS = Not significant.

†Significant at $P \leq 0.10$.
*$P \leq 0.05$.
**$P \leq 0.01$.

Effects of soil drainage

Concentration of N, K, and Mn in the foliage of trees growing on moderately well and well-drained soils were higher than concentrations in trees growing on very poorly and poorly drained soils. The differences were significant for N ($P \leq 0.01$) and for K and Mn ($P \leq 0.05$). There was also a tendency for P to be higher in trees growing on well-drained soils ($P \leq 0.1$). Higher concentrations of Mo ($P \leq 0.05$) occurred on very poorly and poorly drained soils than on the better drained soils.

CONCLUSION

Based on results of this study the following generalizations can be made:

1. Eight years after clearcutting and subsequent slash disposal, it was found that the three slash treatments did not affect the nutrition of young balsam fir.
2. Soil drainage affected the uptake of N, K, and Mn with lower concentrations occurring on poorly drained soils than on well-drained soils.
3. Regardless of the soil drainage or slash disposal method, all sites were less than sufficient in available N for optimum growth.

Effects of slash disposal

Differences in foliar nutrient concentrations attributable to methods of slash disposal were of much lesser magnitude than those for soil drainage. Of 10 nutrients studied, only Fe concentrations were different ($P \leq 0.01$). On plots where slash was removed, the concentrations of Fe were consistently lower; where slash was burned, concentrations were consistently higher. Weak, insignificant trends are suggested by means for N, P and Ca, but data are inconsistent.

Soil drainage X slash disposal interactions

Only two micronutrients showed significant soil drainage X slash disposal interactions; Mo ($P \leq 0.01$) and Zn ($P \leq 0.05$). Considerably more Zn was found in trees growing on poorly drained soils than on well-drained soils where slash was left in place. For the other slash dis-

posal X soil drainage combinations, Zn concentrations were about the same. The interaction for Mo had a different pattern. Where slash was left in place, less Mo was found in trees growing on the poorly drained soils than on better drained soils. The order of Mo concentrations is reversed for the other two slash disposal treatments.

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