Growth and foliar nutrients in direct seeded red pine in relation to micro-site

Effort to retain or remix humus and topsoil in seedspots will contribute to better and more uniform growth of seedlings in these spots. Nutrient concentration in young seedlings cannot be used as a simple index of nutritional status.

Croissance et contenu en éléments nutritifs du feuillage du pin rouge ensémençé artificiellement en relation avec la microstation. L'étude porte sur l'influence de la microstation sur la croissance et le contenu en éléments nutritifs des feuilles de pin rouge de 3 ans provenant d'ensemencement artificiel dans des placeaux dans un champs abandonné. On a noté aucune différence entre les semis exposés et ceux protégés. Il y avait corrélation étroite entre le contenu en éléments nutritifs des feuilles et la quantité du feuillage alors que pour l'azote et le calcium, il y avait corrélation négative entre leur concentration et la taille du feuillage. Par ailleurs, il y avait corrélation significative entre la matière organique du sol et le poids du feuillage et également entre la matière organique du sol et le contenu du feuillage en azote et en phosphore, ce qui laisse supposer un effet nutritionnel. La retention de l'humus et de l'horizon minéral supérieur dans les placeaux semble être un moyen pratique d'améliorer la croissance et la nutrition des semis.

The studies reported in this paper were initiated in an attempt to evaluate the influence of micro-site differences upon growth and nutrient uptake of red pine (*Pinus resinosa* Ait.) seedlings which had been direct seeded in seedspots in an old field.

The growth rates of tree seedlings often determine their ability to survive environmental stress, a matter of importance particularly when costly methods of artificial establishment are used for reforestation or conversion from one forest type to another. The influence of shade on the development of tree seedlings has been widely discussed in the literature. In some species partial shade has been reported favorable for germination and early survival, attributed to lower temperatures and more favorable relative humidity and more favorable soil moisture (Baker 1950, Marquis 1969). Later growth and development of seedlings have generally been reported to be greater where competition and shade from either overstory or ground cover have been absent (Baker 1950, Le Barron 1944, Logan 1969, Marquis 1969).

Seedbed conditions in regard to germination, survival, and growth of tree seedlings have also been widely investigated. Germination and early survival for many species are favored by mineral soil seedbeds which are cited for better water supplying characteristics (Baker 1950). However, growth rates of young seedlings are often better on mixed humus-mineral materials, usually credited to great-

DONALD L. MADER

Department of Forestry and Wildlife Management
University of Massachusetts
Amherst, Mass.

er nutrient supply (Prochnau 1963, Stoeckler 1945). The studies of Hoyle (1964), Hoyle and Bjorkbom (1969) and Marquis (1969) illustrate well both the ability of seedlings to germinate on subsoil materials and the poor growth which may occur from lack of nutrients.

The relative importance of seedbed protection by adjacent vegetation, the nutrients available to and absorbed by seedlings, and soil physical conditions influencing available moisture were evaluated in this study in an attempt to determine their effect on red pine seedling growth.

Methods

Site description and field methods. The seedlings examined in this study were taken from a direct seeding study (Davidson 1963, Abbott and Davidson 1965) established in May, 1960, in an old field on the Cadwell Memorial Forest of the University of Massachusetts in Pelham, Massachusetts. The field, abandoned for more than 15 years, was approximately 2 acres in size, and was covered with a mixture of grass, shrubs (*Aronia*, *Vaccinium*, *Amelanchier*, etc.), and small trees (*Crataegus*, *Acer rubrum*, *Quercus* spp.). The soil is a Gloucester fine sandy loam, a glacial till soil. The site was scarified with a bulldozer equipped with a rock-rake blade. The larger shrubs and trees were pushed to the edge of the area, other vegetation was turned under or pushed in irregular windrows so that surface conditions were extremely variable. Red pine was direct seeded at that time at 6-ft intervals in small (ca. 6 inches x 6 inches) seedspots made with a garden hoe. In 1962, 160 seedspots at 30-ft intervals on transects 15 ft apart were marked for further study, of which 30 were selected for this study—15 in exposed micro-sites and 15 in positions protected by surrounding grass, shrubs, or microtopography. Seedlings in these spots were sampled on October 2 and 3, 1962 by clipping at ground level seedlings visually judged to be representative of the size distribution on the spot. The number of seedlings removed was variable (from 3 to 16), depending on the number and size of the seedlings in the spot, but averaged about 30% of

TABLE 1. Means, standard deviations, and t-tests for differences between means for seedling and nutrient data from protected and exposed seedspots

Variable		Protected spots		Exposed spots		Difference between means	T-test $t_{05} = 2.05$
		Mean	S.D.	Mean	S.D.		
Nitrogen	%	1.45	0.23	1.48	0.10	- 0.03	- 0.46
	mg	6.13	1.22	7.11	1.15	- 0.98	- 0.72
Phosphorus	%	0.12	0.04	0.15	0.03	- 0.03	- 0.71
	mg	0.57	0.15	0.70	0.11	- 0.13	- 0.87
Potassium	%	0.55	0.09	0.49	0.09	+ 0.06	+ 1.82
	mg	2.43	0.50	2.34	0.39	- 0.09	+ 0.17
Calcium	%	0.22	0.06	0.20	0.03	+ 0.02	+ 0.91
	mg	0.91	0.19	0.96	0.16	- 0.05	- 0.29
Magnesium	%	0.054	0.020	0.049	0.015	+ 0.005	+ 0.78
	mg	0.29	0.08	0.24	0.05	+ 0.05	+ 0.66
Avg. foliage wt. per seedling	g	0.46	0.33	0.49	0.26	- 0.03	- 0.23
Avg. seedling ht	(in.)	5.2	1.9	4.2	1.6	+ 1.0	+ 1.53
No. seedlings/spot		20.1	10.0	22.2	11.2	- 2.1	- 0.53

the seedlings (Table 1). The information recorded at time of sampling to describe the seedspots was as follows:

- 1/ Exposed or protected, based on subjective judgment of development of adjacent grass or shrubs, or closeness to windrows or protective microtopography.
- 2/ Average height of seedlings in the spot.
- 3/ Total number of seedlings in the spot.
- 4/ Average depth of A1 horizon was determined on eight cores taken around the seedlings with an open-face tube sampler.

A composite soil sample, consisting of the eight cores taken with the tube sampler to a 6-inch depth, was retained for analysis.

Laboratory methods

The seedlings sampled were taken immediately to the laboratory and dried in a forced-draft oven at 180°F (82°C) for a 24-hour period. Needles were stripped from the woody portions of the seedlings and weighed. Average dry weight of foliage per seedling for each sample spot is included in Table 2.

The needles were ground in a Wiley mill to pass through a 40-mesh screen and the ground samples analyzed for content of nitrogen, calcium, potassium, magnesium, and phosphorus. Nitrogen content was determined by the Kjeldahl technique (Jackson 1958). Subsamples of tissue were wet-digested in nitric-perchloric acid (Mader and Hoyle 1964), the phosphorus content in the digestate determined by the molybdovanadate method (Jackson 1958) and content of calcium, magnesium and potassium determined by flame photometry using a Beckman model DU spectrophotometer.

The composite soil samples were air-dried, passed through a 2 mm sieve and analyzed for organic matter, silt and clay, exchangeable potassium, and exchangeable calcium plus magnesium. Organic matter was determined by ignition at 600°C, silt and clay by the Bouyoucos method (Wilde et al. 1964), exchangeable K by extraction with 1N ammonium acetate and determination by flame pho-

tometry; exchangeable Ca plus Mg was determined on the same extract by versene titration using Eriochrome Black T indicator (Jackson 1958).

Results and discussion

Seedling height and foliage weight data, seedling numbers, and concentration and total content of nutrients in the foliage are presented in Table 1. Average soil data are presented in Table 2.

The differences in seedlings among seedspots were striking, the seedlings from the most vigorous seedspots averaging more than ten times the weight of foliage per tree as compared to the smallest (1.12 g/tree versus 0.08 g/tree). The average height in the most vigorous seedspots was 9.5 inches, while the lowest seedspots averaged only 1.5 inches. Average height and foliage weight were quite strongly correlated ($r = 0.77$) as is evident in Figure 1. These differences in size, which are almost certainly a result of environmental differences, are of a magnitude important to subsequent survival, growth, and competitive ability.

TABLE 2. Average soil data for seedspots

	Humus Depth Inches	Organiz. matter %	Silt & Clay %	K meq/100g	Ca & Mg meq/100g
Protected	2.53	6.09	17.33	0.72	2.14
Exposed	2.64	7.45	17.13	0.80	2.20

The relative exposure of the seedspots as influenced by the low vegetation or microtopography situated close by and affording shade to the seedspots apparently had little influence on germination, growth or nutrient uptake of the seedlings. No significant difference occurred in any measured character between the spots judged exposed versus protected (Table 1), although variation in size and other characteristics was somewhat greater in the protected spots. As suggested by Baker (1950) and Logan (1969), the ratio of height to foliage weight for seedlings from the shaded spots was generally higher than for the exposed spots (Figure 1), competition tending to reduce height-growth less than total plant size. Number of seedlings per

seedspot showed no difference between protected and exposed seedspots. Number of seedlings per spot was not related to size of seedling, indicating that seedling density was not important in governing growth rate of seedlings.

Interpretation of the relationships between nutrient content of foliage and seedling growth presents some difficulties. Total amounts of nitrogen in the foliage of the seedlings were very highly correlated with the amount of foliage (Figure 2), and the correlation coefficients for other nutrients were nearly as high at about 0.95. Whether the increased size and foliage mass is a result of the greater nutrient uptake is not certain.

Nutrient concentrations in the foliage provide line of evidence concerning the nutrient absorption and growth. Increased concentration of a particular nutrient associated with greater growth is often interpreted as evidence of response to that nutrient (Thomas 1937). However, negative correlations between growth and nutrient concentration also occur. These may be evidence that some other factor is limiting (Tamm 1964) or represent a case of the "dilution effect" where an increased supply of a nutrient increases growth to such an extent that its concentration in the tissues decreases.

In this study negative correlations between amount of foliage and percent nutrient concentration are significant for nitrogen ($r = -0.67$, Figure 2) and calcium ($r = -0.41$). Magnesium concentration has a positive but non-significant ($r = 0.35$) relationship with foliage amount. The negative relationships between nitrogen and calcium concentrations in the foliage and foliage amount may be interpreted as evidence that other factors are limiting, or conversely as a "dilution" effect caused by growth responses to these nutrients. The relationships demonstrate the difficulty of using nutrient concentration levels as a simple index of adequacy of nutrient sup-

Fig. 1. Relationship between average foliar weight (X) and average height (Y) of 3-year-old red pine in direct-seeded seedspots. $R = 0.77^{**}$, $Y = 2.41 + 4.83 X$.

ply. Lowering of nutrient concentration with increased growth and size appears to be the normal tendency in this study.

A further line of evidence concerning nutrient uptake-growth relationships lies in the relations between soil nutrients and nutrient contents in the foliage. If seedling size and total nutrient content increased in proportion to the nutrient supplies in the soil while other factors, particularly soil moisture, remained unchanged, this would tend to indicate a nutritional response. However, under natural conditions, those factors which provide better nutrition, such as more organic matter, also influence moisture supply so that positive conclusions about nutritional effects are difficult. In this study seedling foliage weight is significantly, although not strongly, correlated to soil organic matter (Fig. 3). Higher levels of organic matter seem to have a definite favorable effect on amount of foliage. Total nitrogen content of the foliage is significantly but weakly correlated to soil organic matter (Fig. 4, $r = 0.42^{*}$). Total phosphorus content of the foliage is also significantly, but more weakly correlated to soil organic matter ($r = 0.39^{*}$), while calcium and potassium are not significantly correlated. Levels of calcium, magnesium, and potassium in foliage were not related significantly to amounts in the soil and the amount in foliage appears to be primarily a response to growth rather than to the supply available in the soil. These relationships suggest that the

Fig. 2. Relationships between foliage weight (Y) and nitrogen content (X) of 3-year-old direct-seeded red pine seedlings.

Fig. 3. Relationship between average foliage weight (Y) and organic matter content (X) of surface 6 inches of soil on seedspots of 3-year-old direct-seeded red pine. Equation: $Y = .1685 + .04521 X$, correlation coefficient = 0.39*.

greater amounts of foliage are promoted by more favorable nutrient supplies, of which nitrogen is the most important. The lack of significant relationship between seedling weight and silt and clay content of the soil ($r = -0.21$), the other prime determinant of moisture-supplying capacity, seems to indicate more likelihood of a nutritional effect than a soil moisture effect.

In conclusion, this study suggests that the large differences in development of direct-seeded red pine seedlings in an old field were not attributable to genetic variation or the effects of shading or competition from adjacent low vegetation to any extent, but were associated with amount of organic matter in the soil of the seedspot. The close correlation between foliage weight and nutrient content, and the significant, although weak, correlations between soil organic matter and nitrogen and phosphorus contents of foliage suggest that growth was influenced primarily by relative nutrient supply, particularly nitrogen, rather than soil moisture; but this cannot be shown conclusively. On the practical side it appears that effort to retain or remix humus and topsoil in seedspots will contribute to better and more uniform growth of seedlings in these spots, thus giving a better probability of survival against environmental stress and resulting in more even stand development. The results suggest the desirability of nutritional tests to determine more exactly the role of nutrients in the growth of direct-seeded coniferous regeneration, and they demonstrate that nutrient concentration in young seedlings cannot be used as a simple index of nutritional status.

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Fig. 4. Relationship between total nitrogen content of foliage per average seedling of 3-year-old direct-seeded red pine (Y) and soil organic matter (X). Equation: $Y = 2.39 + 0.626 X$, $R = 0.42^*$.

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