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NORTH CENTRAL FOREST EXPERIMENT STATION, FOREST SERVICE—U.S. DEPARTMENT OF AGRICULTURE
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EFFECT OF FERTILIZATION ON SURVIVAL AND EARLY GROWTH OF DIRECT-SEEDED RED PINE

ABSTRACT. — Fertilization resulted in increased height and top weight of red pine seedlings by the end of the second growing season, but also resulted in considerable seedling mortality. A high level of watering also increased seedling growth but to a much lesser extent than fertilization. Fertilization of 1-year-old seedlings resulted in dramatic changes in their chemical composition after one growing season.

OXFORD: 237.41:237.6:232.332:174.7 *Pinus resinosa* **(776). KEY WORDS: chemical composition, irrigation, nutrients.**

Direct seeding can be potentially much less costly than planting of tree seedlings. However, survival of direct-seeded red pine (*Pinus resinosa* Ait.) has frequently been less than satisfactory (Roe 1963). Even with satisfactory germination and early survival, seedlings are frequently overtopped by competing vegetation. This results in growth retardation and sometimes in seedling death (Strothmann 1967). Faster seedling growth would decrease the time during which they compete with herbaceous vegetation, and would lessen the need to control this competing vegetation. Thus, a study was undertaken to determine the effect of fertilization on the survival and growth of direct-seeded red pine under two moisture regimes.

METHODS

The study area is in north-central Minnesota and contains soils tentatively classified by the Soil Conservation Service as the Cutfoot Soil Series. These are deep, well-drained, glacial outwash soils formed from medium and coarse sands. The area had a mixed red and jack pine stand (site index of red pine ca. 60), which was clearcut in the winter of 1967-68; the slash was broadcast burned the following summer.

In the spring of 1969 twelve 1/5-acre plots were disked in preparation for direct seeding. Within each of the plots four 1/4-milacre subplots were seeded with 100 red pine seeds. At the time of seeding two of the subplots on each plot were fertilized with a commercial 12/12/12 fertilizer at rates of N, P, and K of 180, 90, and 150 pounds per acre. The following spring (1970) the same rate and kind of fertilizer was applied on each plot to one of the subplots fertilized in 1969 and to another subplot not fertilized in 1969.

The extremely variable growing season precipitation was supplemented during dry periods with sprinkler irrigations of about 0.5 inch of water per application. Irrigation was performed after a specified number of days (1, 3, 6, 9, 12, or 15) with less than 0.2 inch of rainfall. Irrigation at 1- or 3-day intervals was categorized as the high-water treatment, and less frequent irrigation was categorized as the low-water treatment. During the two growing seasons the high-water treatment resulted in an average of 15 irrigations per season, and the low-water treatment in three irrigations per season.

Seedling counts were made weekly throughout the 1969 growing season. All seedling counts are expressed on a tree-percent basis; that is, the number of live seedlings per 100 seeds sown.

In October of 1970 total seedling height was measured for each seedling, and five seedlings were collected from each subplot (except from those having less than 10 seedlings, in which case one-half of the seedlings were collected).

The seedlings were oven-dried at 70° C. and the tops and roots were weighed. Portions of the ground tops were analyzed for nitrogen (N) by the Kjeldahl method. Another portion was ashed at 550° C. for 2 hours, taken up in dilute HCl, and analyzed for calcium (Ca) and potassium (K) by atomic absorption, and phosphorus (P) colorimetrically.

RESULTS AND DISCUSSION

Seedling Survival

Tree percent at the end of the first growing season was 30 percent for the unfertilized plots and 15 percent for the fertilized plots (table 1). The difference between these values is significant at the 1-percent level. Survival was not significantly different under the two watering treatments, probably because of heavy rainfall in 1969 (table 2). Few dead seedlings were observed in 1969, indicating that the fertilizer reduced the tree percent either by preventing germination or by killing the seedling before emergence. Laboratory germination of the seed lot used in this study showed a viability of 95 percent. Seedling losses over the first winter amounted to about 13 percent of trees present the previous fall, whether or not fertilization had occurred at the time of seeding.

The May 1970 fertilization of 1-year-old seedlings (half of which had been fertilized in 1969) resulted in a seedling mortality of 40 percent within 2 weeks. At the end of the second growing season the tree percent was lower on plots fertilized in both 1969 and 1970 than on plots fertilized only once, and only about one-third as high as on the unfertilized plots (table 1). No differences in second-year survival could be attributed to the different watering treatments.

The rapid seedling mortality after fertilization indicates direct salt injury to the plants, which was also found after fertilizing transplanted red pine nursery stock (White 1965). Clearly the effects of this high rate of fertilization are severe, and 1-year-old seedlings are affected as well as germinating seeds.

Table 1. — *Tree percent at the end of the first and second growing seasons*

Treatment	Tree percent at end of: First growing season	Second growing season
No fertilizer	30	20.5
Fertilized 1969	15**	12.9*
Fertilized 1970	--	10.9**
Fertilized 1969 and 1970	--	7.7**

* Significantly different from the no-fertilizer treatment at the 5-percent level.

** Significantly different from the no-fertilizer treatment at the 1-percent level.

Table 2. — *Rainfall and irrigation during the growing season*

Rainfall and Irrigation	Water Regime (Inches) High	Low
1969		
Irrigation	8.6	1.5
Rainfall	11.3	11.3
Total	19.9	12.8
1970		
Irrigation	6.7	2.0
Rainfall	5.0	5.0
Total	11.7	7.0

Seedling Growth

At the end of the first growing season no obvious size differences were apparent between the seedlings on the control plots and those on the fertilized plots; however, by the end of the second growing season, differences were apparent. Fertilization significantly increased both the height and weight of the seedlings (table 3). Differences among the three fertilizer treatments (fertilized in 1969, 1970, and 1969 + 1970) were not significant, therefore the results were combined. The fact that these three fertilizer treatments resulted in similar seedling sizes at the end of two growing seasons suggests that the added nutrients were most effectively utilized during the second growing season.

Table 3. — *Height and top weight of seedlings after two growing seasons*

Treatment	No fertilizer	Fertilized	Difference	Increase due to fertilization
SEEDLING HEIGHT				
	Centimeters	Centimeters	Centimeters	Percent
Low-water	4.70	5.79	1.09**	23
High-water	5.15	6.00	.85*	16
Difference	.45	.21	--	--
SEEDLING TOP WEIGHT				
	Grams	Grams	Grams	Percent
Low-water	.605	.920	.315**	52
High-water	.724	1.295	.571**	79
Difference	.119	.375**	--	--

* Significant at 5-percent level.
** Significant at 1-percent level.

Fertilization increased the top weight by 52 percent under the low-water treatment and by 79 percent under the high-water treatment (table 3). The top weight of the seedlings was not significantly affected by water level on the unfertilized plots, but was strongly affected by water level on the fertilized plots. The importance of adequate moisture for fertilizer response is well known and has been examined for red pine by Jurgensen and Leaf (1965). However, even under the low-water treatment, and even though 1970 was a dry summer, fertilization increased top weight by 52 percent.

The top root ratio for the 2-year-old seedlings was 7.4 and was not significantly affected by either the fertilizer or water treatments. The height-growth response to fertilization was much less striking than the top-weight response (table 3), but was still significant. Height growth was not significantly affected by the two watering treatments.

Seedling Composition

Fertilization at the time of seeding in 1969 resulted in a large growth increase after two growing seasons, but the concentrations of N, P, Ca, and K in the plant tops were no different from those in plant tops from the unfertilized plots (table 4).

After fertilization, large amounts of N, K and Ca[1] in soluble form leached into the soil and were available for plant uptake. On the other hand, P is strongly absorbed by acid soils (Weld 1950), resulting in little downward leaching. Consequently, top-growth was increased following the 1970 fertilization as the seedlings took up large amounts of N, Ca and K, but P was not taken up proportionately (table 4).

No information is available on optimum nutrient concentration for red pine seedlings, but data for Scots pine (*Pinus sylvestris* L.) (Ingestad 1960) and loblolly pine (*Pinus taeda* L.) (Fowells and Krauss 1959) suggest that the levels of P, Ca, and K on the unfertilized plots were adequate for good growth, whereas N was lower than desirable. Therefore, it is probable that the increased growth following fertilization was primarily due to N.

[1] *The commercial fertilizer used contained about 3 percent Ca.*

Table 4. — *Weight and nutrient composition of plant tops after second growing season*

Treatment	Top weight (grams)	Nutrient (percent)			
		N	P	Ca	K
No fertilizer	0.66	1.56	0.20	0.30	0.63
Fertilized 1969	1.16**	1.46	.22	.26	.65
Fertilized 1970	.96**	2.04**	.14**	.55**	.78*
Fertilized 1969 and 1970	1.18**	1.94*	.13**	.48*	.84*

* Significantly different from the no-fertilizer treatment at the 5-percent level.

** Significantly different from the no-fertilizer treatment at the 1-percent level.

CONCLUSIONS

Fertilization of red pine seedlings increased mortality, but also increased the size of the surviving seedlings. Fertilization had no effect on the top root ratio. The effects of the two watering regimes employed were generally minor and were much less important than the fertilizer effects. Fertilization of 1-year-old seedlings had a marked influence on their chemical composition for at least one growing season.

The results show that the growth of red pine seedlings can be increased by fertilization even on a relatively good site, and one might expect the stimulated growth to continue because of the greater photosynthetic mass of the seedlings on the fertilized plots. The decreased survival after fertilization is a problem that has also been observed with red pine planting stock, but one that can be overcome by the use of slow-release fertilizers or careful fertilizer placement (White 1965). Further work is obviously needed to evaluate kinds, rates, and methods of fertilizer application and their relations to seedling growth, mortality, and weed competition on a wide range of sites. Fertilization may, however, by increasing seedling growth, enable the seedlings to more favorably compete with other vegetation and thereby lessen the need for future release.

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