EFFECTS OF COMPETITION ON POST-PLANTING GROWTH OF POTTED WHITE SPRUCE[1]

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Plantations of white spruce (*Picea glauca* (Moench)) Voss have often been considered unsatisfactory because of poor top growth or check in early years *(16, 20, 21).* Check occurring because of heavy weed competition has been noted (21, 22). This report is based on greenhouse pot studies of white spruce, grown in competiton with grass sod, hard maple *(Acer saccharum* Marsh.), and black spruce *(P. mariana* (Mill.) BSP.). The inhibitory influence of grass sod on growth was examined further in a pot study comparing the presence of living grass roots to irrigation by a leachate from grass sod, and an extract of crushed grass roots.

Review of Literature

Competition for water has probably been studied most, although it has usually occurred with other elements *(1, 6, 17).* In tree-planting literature, references to site treatment, usually resulting in better survival and growth, have often attributed this improvement to reducting competition *(5, 14, 15)* . Many authors have noted that reducing competition made more moisture available to planted trees *(2, 8, 9, 10).* Generally a much greater rate of water is lost from soil covered with a growing crop than from bare soil, perhaps two to eight times greater (3, 7).

Apart from physical competition for water and nutrients, there may be toxic or inhibitory exudates or residues, or conversely, stimulation, by which one plant may influence the growth of another (4, *18, 19).*

This study deals with the characteristics of spruce as they relate to soil moisture and competition. Spruce grows more slowly than pine in juvenile growth phases, because of specific physiological differences (12). Spruce also controls transpiration poorly resulting in considerable growth reduction under conditions of moisture stress (11). Another study has shown that white spruce achieved maximum rate of photosynthesis at soil moisture just below field capacity, and that photosynthesis was reduced at soil moistures above and below this level (13).

Procedure

In 1964 and 1965 white spruce was grown in a plastic greenhouse shelter at Midhurst Nursery, about 60 miles north of Toronto. The trees were planted, one per pot, in 5-inch plastic pots, using regular nursery shipping stock, 2-2 in 1964 and 3-0 in 1965.

The four treatments of competition were as follows: 1. a control, with white spruce only; 2. with grass sod; 3. with hard maple; and 4. with black spruce. These four treatments were randomized in

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a split-plot design with four moisture regimes, classified as: a, very dry; b, dry; c, moist; and d, very wet. There were 10 replications. The potting soil was a fertile sandy loam from the surface of an adjacent nursery compartment.

Using the 1964 experiment as an example, the four soil moisture regimes were established as follows. On the day of potting in early spring, small amounts of water were added to eight pots of the d regime (very wet) at half-hour intervals until drip-through was obtained. The average amount, which was 225 ml. (depth approximately 1.8 cm.), was added to all d pots, 150 ml. (1. 2cm. depth) to c pots, 75 ml. (0.6 cm. depth) to b pots, and none to a pots. All 16 pots in one replication were then weighed. At V_2-week intervals during the growing season, the pots were reweighed. The difference between the first (or base) weight and the new weight was averaged for the four pots in each regime, and this amount of water was added to all replications. This included the a regime, which was thus returned to moisture condition as at the time of planting.

Two automatic temperature recorders were installed, one with a 10 cm. long sensor placed vertically in the pot center to obtain soil temperature within a c pot, and the other to obtain air temperature at plant level. Average daily maximum and minimum temperatures in the pot were within 2° C. of air temperature, a difference similar to that occurring under natural conditions (7).

The potting was done in early May and the experiments maintained until late September or early October. The trees were then washed from the pots by submersion in water. The following measurements were obtained from the three species: Terminal length (current season's growth), top length (soil level to bud tip), root length (soil level to tip of longest root straightened along a measure) , stem diameter (approximately 2 cm. above soil level), ovendry weight (24 hours at 105° C.), and top-root ratio (ovendry basis) .

In 1966, a similar procedure was followed in which the competition treatments were as follows: 1, white spruce alone; 2, with grass; 3, watered with a solution obtained by leaching through grass sod on a shallow pan; and 4, watered with a solution obtained by crushing and grinding grass roots in a soil mixer and dispersion cup. In treatments I and 2, rainwater was used for irrigation. In treatment 8, the leachate from rain was supplemented with spring water run through a shallow pan (approximately lm. by 2m. by 15 cm.). In treatment 4, fresh grass roots were dug at each time of watering and an equal amount by weight placed in the dispersion cup. After grinding, the solution was filtered through cloth and diluted in sufficient water for the experiment.

Results and Discussion

Moisture Effects on Growth.-Among the data obtained, ovendry weight was the least variable and most statistically significant, and for this reason, these values are used in the discussion. The growth of the white spruce in two experiments-ovendry weights of entire seedlings after one season-is summarized (table 1), in relation to moisture regimes. The depth of water added over the approximate 22 weeks of the experiments, to permit comparison with natural precipitation, was a, 8.7 cm., b, 23 cm., c, 38.4 cm., and d, 48.0 cm. Estimation of the moisture content, just after watering, by means of ovendry weights of samples, expressed as moisture percent by weight, was: a, 12; b, 20; c, 29; and d, 38 percent.

Of special interest was the fact that growth of the white spruce was best at the highest soil moisture level examined. In this treatment, the pots had been raised to drip-point twice a week. This is similar to the high water demand of the species, reported by others (13).

TABLE 1.—*Effects of moisture regimes on growth of white spruce*

[AVERAGE OVENDRY WEIGHTS PER TREE (GRAMS)]

Experiment	Moisture treatments— a Very dry	b Dry	c Moist	d Very wet	Significance
1964	5.93a	10.05b	12.44c	13.92d	[1] ***
1965	[2] 0.98a	1.96b	2.28c	2.46c	***

[1] Significant differences between treatments, by the analysis of variance, at 0.1 percent level.

[2] Figures in horizontal rows not followed by the same letter differ significantly from each other.

Competition Effects on Growth.-Growth of the white spruce as related to the treatments of 1, with white spruce alone; 2, with grass; 3, with hard maple; and 4, with black spruce is summarized in table 2, for the same two experiments. In each group, the presence of other plants reduced the growth of white spruce, with high significance and with no qualifying interactions statistically.

Among the elements for which competition may occur, water was the only one controlled in these experiments. Effects of the moisture regime and competition on growth of white spruce were highly significant, but their interactions were not. This implies that competition was effective in reducing growth at all levels of moisture tested. With the approach of moisture to and above the highest level used, excess water and less restriction could be expected on growth due to competition.

TABLE 2.—*Effects of competition treatments on growth of white spruce*

[AVERAGE OVENDRY WEIGHTS PER TREE (GRAMS)]

	Competition treatments—				
Experiment	1 White spruce	2 With grass	3 With hard maple	4 With black spruce	Significance
1964	12.75a	9.43b	10.58c	9.59b	[1] ***
1965	[2] 2.24a	1.81b	1.68c	1.95d	***

[1] Significant differences between treatments, by the analysis of variance at 0.1 percent level.

[2] Figures in horizontal rows not followed by the same letter, differ significantly from each other.

Other factors also may reduce growth, in addition to competing for moisture. One could postulate that for grass, it might be competition for nutrients, as the soil mass in the pots was apparently well filled by roots. For the trees, this might be competition for light as the presence of the two plants per pot offered greater shade to the white spruce.

Competitive Effects of Grass.-Results of the leachate and crushed-root extract experiment are summarized (table 3), which includes terminal lengths (1966 leaders), stem diameters, and oven dry weights of the entire seedling at the end of the experiment. The effects of the treatments were highly significant in all criteria, and there were no qualifying statistical interactions in the analysis of variance. Further analysis of the ovendry weight data showed that the average tree weight, for the grass treatment 2, was significantly below that of the control; that for treatment 4 was not statistically different from the control; and that for treatment 3, the leachate, was significantly higher.

TABLE 3.—*Effects of grass, grass leachate, and crushed grass root extract on growth of white spruce*

[AVERAGES PER TREE]

Item	1 White spruce	2 With grass	3 Watered with grass leachate	4 Watered with extract	Significance
Terminal lengths cm.____	5.30a	4.60b	5.14a	5.23a	[1]***
Stem diameter cm.______	0.440a	0.436a	0.462b	0.443a	[2] **
Ovendry weight g.______	[3]5.96a	5.20b	6.31c	5.85a	***

[1] Significant at 0.1 percent level.

[2] Significant differences between treatments, by the analysis of variance at 1.0 percent level.

[3] Figures in horizontal rows not followed by the same letter differ significantly from each other.

Possibly growth was inhibited by the presence of living grass and not to substances exuded from the roots. The beneficial effects of treatment 3, the leachate, are assumed to be caused by nutrients accumulating in the solution as it passed through the sod.

Summary

The experiments showed that the best growth of the white spruce was achieved at the highest moisture level, in which pots were cyclically raised to a drip-point twice weekly and permitted to dry by evapotranspiration between water additions.

In all experiments the presence of other plants in a shared environment reduced growth of the white spruce, showing inhibitory effects of competition.

Factors other than competition for water were involved but not identified. In the grass roots studies, only the presence of grass reduced growth of the white spruce, and inhibitory root exudates were not found.

Literature Cited

1. Australia.
1963. Annual Report, Forestry and Timber Bureau, 1963. Forest Soils 2, Field Exp., pp. 17-18.
2. Barring, U.
1965. Studia Forestalia Suecica 24 (On importance of scalping and other problems connected with planting of *Pinus silvestris* L. and *Picea abies* Karst.) . (Engl. Sum., pp. 67-71).
3. Black, C. A.
1957. Soil-plant relationships. John Wiley and Sons, New York. 332 pp.
4. Bonner, J. and Galston, W. A.
1955. Principles of plant physiology. W. H. Freeman and Co., San Francisco. 499 pp.
5. Cayford, J. H. and Haig, R. A.
1964. Survival and growth of 1949-62 red pine plan tations in southeastern Manitoba. Canada Dep. Forest., Forest Res. Br., Publ. 1093, 15 pp.
6. Donald, C. M.
1963. Competition among crop and pasture plants. Advance in Agron. 15: 1-118.
7. Geiger, R.
1957. The climate near the ground. (translation.) Harvard Univ. Press, Cambridge, Mass. 494 pp.
8. Hermann, **R. K.**
1964. Paper mulch for reforestation in southwestern Oregon. J. Forest. 62 (2) : 98-101.
9. Hunt, L. O.
1963. Evaluation of various mulching materials used to improve plantation survival. U.S. Dep. Agr., Forest Serv., Tree Planters' Notes 57: 19-22.
10. Illingworth, K. and Clark, M. B.
1966. Planting trials with Ponderosa pine in British Columbia, B.C. Dept. Lands, Forests, Water Res., Res. Div., Res. Note 41, 34 pp.
11. Jarvis, P. G. and Jarvis, M. S.
1963. The water relations of tree seedlings IV. Some aspects of the tissue water relations and drought resistance. Physiol. Plant. 16: 501-516.
12. Keller, T. and Wehrmann, J.
1963. (Photosynthesis, root respiration and yield of pine and spruce seedlings grown in different nutrient solutions) . Mitteilungen Schweizerisch Anstalt fur das Forstliche Versuchswesen 39 (4) . (Engl. Sum.)
13. Kozlowski, T. T.
1964. Water metabolism in plants. Harper and Row, Publ., New York. 227 pp.
14. MacArthur, J. D.
1964. Planting methods to overcome strong competition from dense, herbaceous vegetation. Tree Planters' Notes 66: 25-29.
15. McNamara, E. F. and Reignor, I. C.
1960. Effect of competition on height growth and survival of planted Japanese larch. U.S. Dep. Agr., Forest Service, Northeast. Forest Exp. Sta., Forest Res. Note 103, 4 pp.
16. Mullin, R. E.
1963. Planting check in spruce. Forest. Chron. 39(3): 252-259.
17. Newton, M.
1964. Seedling survival and vegetative competition. Western Reforestation, Western Forest. and Conserv. Assoc., pp. 39-42.
18. Peterson, E. B.
1965. Inhibition of black spruce primary roots by a water-soluble substance in *Kalmia augustifolia.* Forest Sci. 11 (4) : 473-479.
19. Slankis, V.
1958. The role of auxin and other exudates in mycorrhizal symbiosis of forest *trees. IN* The physiology of forest trees. Ed. K. V. Thimann. Ronald Press, New York: 427-443.
20. Stiell, W. M.
1960. A co-operative experimental planting project in Ontario. Pulp and Paper Magazine of Canada. Woodlands Rev., 60(2): 3-6.
21. White, D. P.
1960. Effect of fertilization and weed control on the establishment, survival, and early growth of spruce plantations. Trans. vol. 111, 7th Intl. Congr. of Soil Sci., Madison, Wis., pp. 355-362.
22. White, D. P.
1962. Don't choke your trees! Control those weeds. Amer. Forest, June 1962.