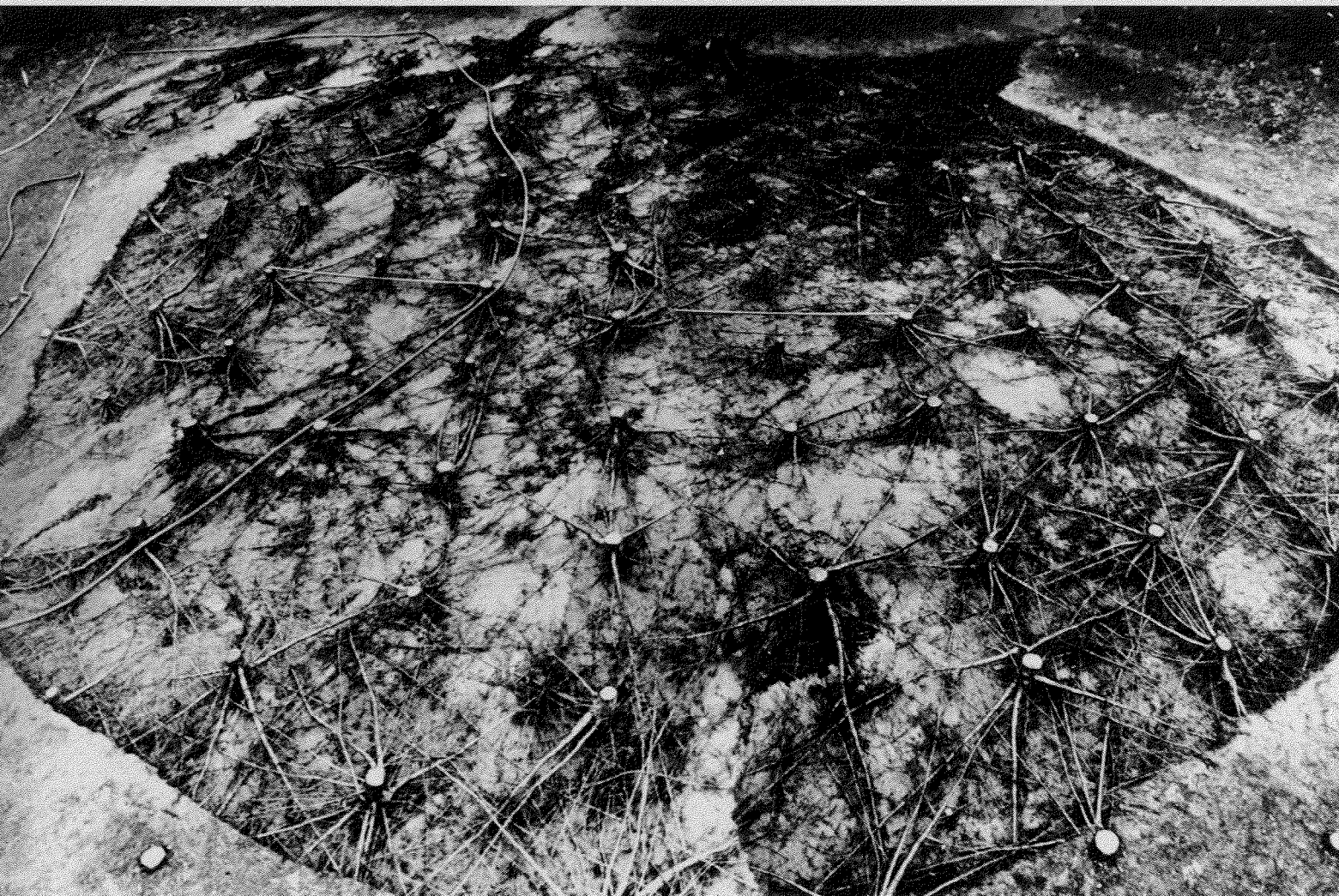


DAVID HODGSON

# SOME COMPETITIVE RELATIONS IN A RED PINE PLANTATION

by W.M. Stiell

*Résumé en français*



DEPARTMENT OF FISHERIES AND FORESTRY  
CANADIAN FORESTRY SERVICE  
PUBLICATION NO. 1275  
1970



Published under the authority of the  
Minister of Fisheries and Forestry  
Ottawa, 1970

©  
INFORMATION CANADA  
OTTAWA, 1970

Catalogue No. Fo. 47-1275



## ABSTRACT

Thirteen-year-old red pine (*Pinus resinosa* Ait.), planted at 5' x 5' and 7' x 7' spacings on sandy, old-field sites, were afforded various types of release from competition by bending over or felling their immediate neighbors, or by severing (but leaving upright) the tops of adjacent trees. Others were subjected to increased aerial competition by inserting severed tops in an upright position around them. The intention was to differentiate competitive effects of crowns from those of roots, and response to treatment was assessed by 2-year stem volume growth. The results could not be fully explained in terms of the treatments applied until hydraulic excavation revealed that root systems were overlapping and very widely dispersed, extending over many times the area occupied by the respective crowns. It is concluded that while above-ground competition is concentrated within the areas occupied by individual crowns, root competition is diffuse and its origin unpredictable for a given tree. Some of the implications for practical silviculture are presented.

## RÉSUMÉ

L'auteur diminua la concurrence entre de jeunes Pins rouges âgés de 13 ans, espacés de 5 pi x 5 pi ou de 7 pi x 7 pi, soit par l'abattage ou l'inclinaison des voisins adjacents ou par leur étêtage (suivi de la remise en place de la tête coupée). Puis il augmenta la concurrence aérienne entre certains autres en accolant verticalement, autour de ceux-ci, les têtes d'arbre précédemment coupées. Ces expériences avaient pour but de différencier les effets produits par la concurrence aérienne et la concurrence des racines, effets qui furent mesurés sous forme de l'accroissement subséquent du volume de la tige pendant 2 ans. Les résultats obtenus ne purent être interprétés de manière entièrement satisfaisante jusqu'à ce que les arbres fussent déchaussés par des moyens hydrauliques, opération qui révéla que les systèmes radiculaires se recouvrent beaucoup, s'étendent fort loin, et se développent sur une superficie plusieurs fois plus grande que le terrain occupé exclusivement par chaque cime. Il faut conclure que la concurrence des racines, au contraire de celle des cimes, s'étend plus loin que chez le voisin immédiat. En outre il semble impossible de prévoir dans quelle direction se fera leur développement. L'auteur termine par un exposé des pratiques sylvicoles recommandables par suite de ces conclusions.

# SOME COMPETITIVE RELATIONS IN A RED PINE PLANTATION

by

W.M. Stiell<sup>1</sup>

## INTRODUCTION

Trees in a forest stand must contend with one another for the basic elements necessary to support life and growth. While evidence of this can be found in the accelerated diameter growth rate of trees provided with additional growing space and, conversely, in suppression and mortality of the smaller individuals in a dense stand, the mechanics of intertree competition are not well understood. Crowns and roots are interdependent components of the same organism, yet each makes its own, quite different, demands on the ecosystem. Both, therefore, contribute to the tree's competitive status, but their relative effectiveness in this respect is difficult to assess. The matter may be further complicated by root grafting and, where partial cutting has been carried out, by the possibility that the roots of felled trees continue to function for a period.

In the experiment described here an attempt was made to differentiate the competitive effects of crowns from those of roots as indicated by stem growth following the application of special thinning techniques. The study was conducted in a regularly spaced, pure plantation where, it was thought, the complexities of intertree relationships would be at a minimum. In applying the treatments it was assumed that the four immediate neighbors (the two adjacent trees in the same row, and the two closest trees at right angles to the row) provide most of the competition an individual tree receives, and that the subsequent growth rate of that tree will reflect the removal or manipulation of these competitors.

## METHODS

### Material

The experiment was carried out near the Petawawa Forest Experiment Station in a 13-year-old plantation of red pine (*Pinus resinosa* Ait.) that had been established as a spacing trial. The soil is deep, fine to medium, windblown sand. It has about a 1 Moisture Regime and is "somewhat

---

<sup>1</sup>Research Scientist, Department of Fisheries and Forestry, Canadian Forestry Service, Petawawa Forest Experiment Station, Chalk River, Ontario.

dry" (Hills, 1950). The site was an old field, supporting a thin cover of grass at the time of planting. Part of the experiment was conducted where the trees were accurately spaced at 5 x 5 feet, and part where they were spaced at 7 x 7 feet. Both stands were fully closed, and crowns in the 5' x 5' plantation had already died for several feet above ground level. As would be expected, trees at the wider spacing had larger diameters and longer crowns, which were just beginning to recede at the base.

In the spring of 1966, 60 undamaged sample trees were selected, all within the 18-foot-height class (17.6 to 18.5 feet tall) and all with a full complement of competitors.

### Treatments

Ten sample trees each were subjected to the following treatments (Figure 1):

#### (a) In the 5' x 5' Spacing

(i) Full Thinning - The four immediate neighbors of each sample tree were cut. This effectively changed the average above-ground spacing of the sample trees from 5 x 5 to 7 x 7 feet, and was a conventional thinning operation.

(ii) Root Thinning - The four immediate neighbors of each sample tree were cut, as for full thinning. The felled trees were sprayed with a commercial green Christmas tree dye, replaced upright on their stumps, and fixed there by spiking to stakes driven into the ground. This treatment

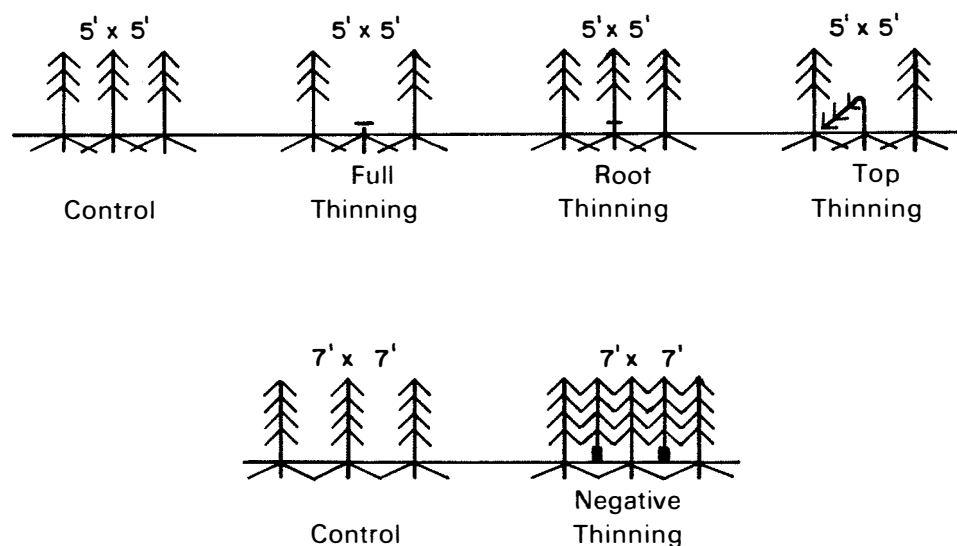


Figure 1. Schematic diagram of thinning treatments.

was intended to simulate removal of competing root systems only, while leaving crowns capable of intercepting light in the manner of living trees. The green dye was expected to offset fading and discoloration of foliage on the severed tops, and perhaps improve needle retention. The following year these tops were replaced by those (also dyed) of trees about 2 feet taller.

(iii) Top Thinning - The four immediate neighbors of each sample tree were bent down and away from it with a block and tackle, until the crowns no longer intercepted sunlight, which would otherwise fall on the sample tree crown. The tops were tied down with rope. The intention was to remove above-ground competition without preventing the root systems of the bent-over trees from functioning.

(iv) Control - These sample trees were not treated.

(b) In the 7' x 7' Spacing

(i) Negative Thinning - The tops of four trees that had been severed at ground level were dyed green and staked upright midway between the rows and equidistant from each sample tree. This altered the above-ground spacing from 7 x 7 to 5 x 5 feet without changing the density of the root systems. These tops were also replaced by those of taller trees the following year.

(ii) Control - These sample trees were not treated.

#### Root Excavation

In 1969 a corner of the 5' x 5' plantation was clear-cut, after mapping of the trees on it and measurement of their diameters. Part of this area was then hydraulically excavated, lateral root systems of 105 trees being thus layed bare.

#### Measurement and Analysis

The heights and diameters breast height (d.b.h.) of the sample trees were measured before treatment and after 1 and 2 years. Height to the first fully live whorl (branch whorl containing only live branches) was measured at the beginning of the experiment, and in the spring of 1968 when it ended. At that time all sample trees were felled and sectioned to permit measurement of form class. Total stem volume was computed for each year, and growth of various stem parameters was found by subtraction.

Analysis of variance for completely randomized design and a multiple range test (Duncan, 1955) were applied to the volume growth data for the 5' x 5' plantation. Mean values of volume growth for the two treatments in the 7' x 7' plantation were compared by t-test.



## RESULTS

Initial dimensions, as indicated in Table 1, were very similar for the sample trees within each spacing. In the 2-year period a large number of the bent-over trees in the top thinning treatment died; only data from the sample trees whose four treated competitors survived have been included.

As is usual in all but very severe thinnings, height growth was not evidently associated with treatment, but development of other measured dimensions did appear to be affected. Stem volume increment is taken as the full expression of measurable growth and was used to compare response to treatment. The significance of difference in mean volume growth is shown in Table 1.

### 5' x 5' Spacing

Growth of the control trees was used as the basis for comparison. Trees released by full thinning (i.e. where root and top competition were both judged to be reduced) showed the greatest growth - 125% of that of the controls. Growth associated with top thinning (only top competition reduced) was 115% of control growth. With root thinning (only roots cut), growth was almost exactly the same (98%) as that made by the controls.

### 7' x 7' Spacing

Negatively thinned sample trees (top competition increased) made only 87% of the growth of the controls.

## DISCUSSION

### Tops

The data are consistent in suggesting that the growth of sample trees was strongly influenced by the normally positioned tops of their neighbors, whether or not these were attached to root systems. Changes in sample-tree crowns (Table 1) suggest the mechanism whereby crown size and thence stem volume growth were primarily controlled. Where competing tops were retained (control and root thinning treatments), the length of sample-tree crowns was reduced almost twice as fast as in treatments where the tops were removed. At 7 x 7 feet, increased top competition (negative thinning) accelerated reduction of crown length in sample trees. Since tops, whether detached or not, seem to have had the same effect on sample-tree growth, their competitive role appears to be the purely mechanical one of intercepting light and thereby reducing the photosynthetic capacity of their neighbors.

In a regularly spaced plantation an area of regular size is assigned or prescribed for each tree, for example, 25 square feet where the spacing is 5 x 5 feet. A red pine crown is centered on its own area,



TABLE 1. PRETREATMENT MEASUREMENTS AND 2-YEAR GROWTH OF SAMPLE TREES

Spacing, ft	5 x 5				7 x 7	
Treatment	<u>Root thinning</u>	<u>Control</u>	<u>Top thinning</u>	<u>Full thinning</u>	<u>Control</u>	<u>Negative thinning</u>
Number sample trees	10	10	4	10	10	10
1966, before treatment:						
Height, ft	18.1	18.2	18.0	18.0	18.0	18.0
Height to crown, ft	4.2	4.7	3.8	4.2	1.3	0.8
D.b.h., inches	2.88	3.15	3.01	3.02	3.70	3.77
Change 1966-68:						
Height, ft	4.3	4.3	4.2	4.3	4.4	4.5
Height to crown, ft	3.7	4.3	2.1	2.0	4.3	7.7
Basal area, ft <sup>2</sup>	.0176	.0200	.0228	.0268	.0311	.0248
Volume, ft <sup>3</sup>	.301	.307	<u>.354</u>	<u>.385</u>	.428	.372

(Any two mean values for volume growth not underscored by the same line are significantly different.  
P = 0.01 for 5' x 5' spacing; P = 0.05 for 7' x 7' spacing.)

although there is some interlacing with the branches of its immediate neighbors. That is, invasion of the outer portions of adjacent prescribed areas is usual but for an individual tree is restricted to the areas adjoining its own (Figure 2). Light-interception effects are therefore quite local.

#### Roots

Sample-tree growth did not seem to be much affected by root systems of immediate neighbors. It is acknowledged that the top thinning was unsatisfactory in that the usable sample was small, and in that the tops of surviving bent-over competitors were probably not transpiring normally and hence not placing a normal drain on their roots. At any rate



*Figure 2. Side view of stems and crowns, 5' x 5' plantation.*

sample trees did not grow quite so well under this treatment as under full thinning, although the difference cannot be demonstrated statistically. No improvement in sample-tree growth followed root thinning.

This plantation site, while quite favorable to red pine as good height growth attests, is not oversupplied with soil moisture. It is therefore difficult to believe that root competition does not exist in this stand. Figure 3, however, and the following account of the disposition of the root systems suggest why the treatments applied did not afford release from such competition.

The structure of red pine root systems has been described in detail by Day (1941) and by Brown and Lacate (1961). On the other hand, little has been reported on the patterns of root distribution within a stand with regard to intertree relations, although Armson and van den Driessche (1959) and Horton (1969) have described the frequency of root grafting in red pine plantations and speculated on the competitive significance of this phenomenon. In the 5' x 5' plantation in question, the general lateral root systems occurred in the top 18 inches of soil. The laterals radiated from the stump, showing a fairly even distribution around it, although sometimes roots were absent from one or more 90-degree sectors. The lateral roots followed a slightly sinuous course but usually without much change in principal direction. Occasional sinkers descended from the laterals to depths in excess of 4.5 feet. The structure and appearance of the roots agreed well with the description given by Day (1941) for those of somewhat less well developed red pine growing on sandy soils in Michigan.

The root system of one tree (no. 150 on the clear-cut area) was selected as reasonably representative and examined in detail. The tree's d.b.h. in 1969 was 4.7 inches, and its height (from a height/diameter curve prepared for the plantation) was estimated at 27 feet. The individual lateral roots extended to a maximum (straight-line) distance of 32 feet from the stump, giving the root spread a diameter of 47 feet in one dimension and 34 feet at right angles to this. Of a total of about 222 linear feet of lateral roots emanating from Tree no. 150, only 33 feet were contained within the tree's own prescribed area, 189 feet extending farther. These laterals have invaded the prescribed areas of 23 other trees and, by contrast, the roots of 11 other trees were found to occur in the prescribed area of Tree no. 150.

The prescribed area concept may not be very meaningful below ground. A tree's roots are so widely dispersed from their origin and so widely separated from each other that they obviously ramify a zone of soil whose gross dimensions are many times greater, even though they occupy or even tap only a small part of it. Numerous other trees will share the same overall rooting zone, and whether or not any two roots are competing will depend on how close to each other they are growing, how many other roots occur in their vicinity, and what conditions of soil moisture prevail. In these circumstances, a tree may have many competitors in its rooting zone, but which trees provide this competition cannot be determined from above ground.



*Figure 3. Main lateral root system in 5' x 5' plantation.*



It follows, therefore, that removal of the four immediate neighbors around a tree will probably give little relief from competition to that tree's roots. This accounts for the lack of response to the root thinning treatment, and explains why growth associated with top thinning was almost the same as that with full thinning. These results are consistent with those of an experiment reported by Korstian and Bilan (1957), in which both crown and root competition to young loblolly pine (*P. taeda* L.) was reduced by poisoning adjacent woody plants, and crown competition only was reduced by tying back the tops of the plants.

In the red pine experiment at Petawawa the "full" thinning treatment evidently could not have given full release, since the competitive status of the sample-tree roots would have been little improved. Complete release, to tops and roots, would require a thinning applied uniformly over a large area. Some evidence for this can be found in an earlier experiment with red pine in which a considerable area in a 14-year-old plantation was systematically thinned from 5 x 5 to 7 x 7 feet.<sup>2</sup> Average basal area growth per tree at 7 x 7 feet was 221% of that in the unthinned (5' x 5') stand. The comparable figure in the full thinning treatment is only 134%.

## SUMMARY AND CONCLUSIONS

Above-ground competition in a closed red pine plantation is concentrated within the areas occupied by individual crowns and is mechanical in nature, acting as a barrier to light. As such it can be manipulated with a fair degree of control, but manipulation on a single-tree basis results in only partial release.

By contrast, roots are widely and irregularly dispersed. Root competition is therefore diffuse, and its origin is unpredictable with respect to a given tree. Manipulation cannot be applied selectively, but only by broadcast methods.

The foregoing have important implications for treatments aimed at individual trees. For example, thinning to release selected crop trees will not achieve maximum results unless the crop trees are well distributed throughout the stand and several adjacent trees are removed from around each of them. Local application to the soil of a fertilizer or silvicide will likely find multiple targets that will dilute its effectiveness with respect to the tree it is intended to treat. In experimental work, particularly thinnings or spacing trials, adequate allowance for root competition must be made by providing a much wider surround for each uniformly treated group of trees than above-ground appearances might suggest.

---

<sup>2</sup>Bickerstaff, A. 1941. The thinning of red pine plantations. Estab. Rep. Proj. 39. Petawawa Forest Exp. Sta. Binder 140. Unpublished manuscript.

## REFERENCES

- Armson, K.A. and R. van den Driessche. 1959. Natural root grafts in red pine (*Pinus resinosa* Ait.). Forest. Chron. 35:232-241.
- Brown, W.G.E. and D.S. Lacate. 1961. Rooting habits of white and red pine. Can. Dep. Forest., Forest Res. Br. Tech. Note 108.
- Day, M.W. 1941. The root system of red pine saplings. J. Forest. 39:468-472.
- Duncan, David B. 1955. Multiple range and multiple  $F$  tests. Biometrics 11:1-42.
- Hills, G.A. 1950. The use of aerial photography in mapping soil sites. Forest. Chron. 26:4-37.
- Horton, K.W. 1969. Root grafts influence development of a red pine plantation. Can. Dep. Fish. Forest., Forest Res. Lab., Sault Ste. Marie, Ont., Inform. Rep. O-X-105.
- Korstian, C.F. and M.V. Bilan. 1957. Some further evidence of competition between loblolly pine and associated hardwoods. J. Forest. 55:821-822.