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The Vertical Distribution of Needles and Branchwood in Thinned and Unthinned 80-Year-Old Lodgepole Pine

Abstract

About 30 years after thinning part of a 50-year-old stand, trees in adjacent thinned and unthinned lodgepole pine in southern Wyoming were studied to compare relative dry matter production of needles and branches and the distribution of their weights. The weight distribution within the canopy of the study trees was determined using a Weibull probability density function. In the thinned part of the stand, the observed and theoretical weight distribution of both needles and branchwood was symmetrical and much like a normally distributed population. In the unthinned part of the stand, weight distribution of needles and branchwood was strongly skewed upward in the top half of the canopy. The strong upward displacement of needles and branchwood was interpreted as further evidence of growth stagnation in the unthinned area.

Introduction

Lodgepole pine (*Pinus contorta* Dougl.) frequently regenerates too abundantly, and growth stagnates after a few years. The resulting single-storied, dense "dog-hair" stands (up to 100,000 or more trees per ha) can stay alive for as long as a 100 years, but make little height or diameter growth. Trees 50 to 60 years old have an average height often less than 2 m and a diameter less than 3 cm. Early heavy thinning is necessary to obtain satisfactory diameter and height growth in such stands (Alexander, 1956; Barrett, 1961).

Adjacent areas of thinned and unthinned lodgepole pine, located about 3.4 km southeast of Foxpark in southern Wyoming, afforded the opportunity to compare relative dry matter production of branches and needles and the distribution of their weights within the respective canopies. Information about the characteristics of lodgepole pine crowns is generally lacking. When more is known about the crowns, it should be possible to develop good models of canopy biomass distribution. In other timber types, such models have provided a useful tool to study the interaction among physical factors and physiological processes of growth, and also to interpret changes over time and thus provide possible management options (Schreuder and Swank, 1974).

Study Area

The study was conducted in an extensive 80-year-old lodgepole pine forest that resulted from natural reseeding on a burned-over area. The area was about 2470 m in elevation, and the terrain was relatively flat. When the trees were about 50 years old, a portion of the stand was thinned in 1939-40 by the Civilian Conservation Corps. Tree growth in the area is generally slow, and because of low economic value, the initial thinning was done with no plan for further thinning (Woodhead, 1934).

In 1970, few trees had died in the thinned area. Spacing averaged about 2.3 m or about 2000 trees per ha. Average height of trees was 10.7 m. Diameter at breast height (d.b.h.) for some 2500 trees in the thinned area ranged from 3.6 to 25.7 cm and averaged 12.8 cm. Basal area of the trees was about 28m^2/ha (125 ft^2/acre). The adjacent unthinned part of the forest, less than 60 m away, based on three 10 m^2 plots averaged between 25,000 and 50,000 trees/ha. Average height of the trees was about 7.6 m. Diameters ranged from 1 to 8 cm and average diameter was 3.1 cm. Basal area in the unthinned part of the stand was about 34 m^2/ha (149 ft^2/acre).

Measurements

Crown biomass relations and comparisons were determined in 1970 for five randomly selected trees taken from the thinned area. The trees were among a group of about 100 trees removed to make a 10 x 50 opening which was used to determine the clearing effect upon airflow and snow accumulation (Bergen, 1975; Gary, 1974). Five additional trees, subjectively selected to represent the unthinned part of the stand, were also studied.

Field measurements on the 10 trees included d.b.h., height to first dead and live branches, height of each succeeding annual whorl, and tree height. All branches from the annual whorls were removed from each tree, tagged for identification and oven dried to obtain weights of needles and branchwood.

Results

Bole and Crown Dimensions

All trees in the thinned part of the stand were generally released from early growth stagnation. The relative differences between the thinned and unthinned areas as indicated by the sample trees are given in Table 1. Thirty years after the initial thinning, the

TABLE 1. Average bole and crown dimensions 30 years after thinning.

Variable	Stand Condition	
	Thinned	Unthinned
Diameter breast height (cm)	11.2±0.5[1]	5.6±1.17
Height to 1st dead whorls (m)	1.49±0.18	1.47±0.45
Height to all-live crown (m)	5.60±0.48	4.84±1.30
Crown length (m)	4.36±0.22	2.64±0.58
Tree height (m)	9.95±0.60	7.47±0.97
Crown length/height	.44	.36

[1]Standard deviation

largest difference between the two samples of trees was bole diameter. Diameters of trees from the unthinned area averaged 5.6 cm and 11.2 cm for trees from the thinned area. Average basal area for trees from the unthinned part of the stand was 25.9 cm^2. In contrast, trees from the thinned part had an average basal area of 98.3 cm^2 and were approximately 3.8 times larger.

The next largest difference between the two groups of trees was live crown length. As a result of the wider tree spacing, crown length in the thinned part of the stand was about 65 percent longer, and thus had greater photosynthetic potential for future growth (Madgwick, 1970). The relative difference in tree height was less than the difference in diameter and crown length.

Comparisons of the annual height or leader growth, however, indicated a decline of 28 percent during the last 20 years in both the thinned and unthinned portion of the stand (Table 2). It was not known whether the tapering off of growth for trees taken from the thinned part of the stand indicated another period of growth stagnation or whether normal height growth was merely slowing. Average annual terminal growth during the last 20 years was 14.4 cm and 9.9 cm for trees on the thinned and unthinned areas, respectively. Based on cumulative annual terminal growth for 30 years since thinning, height growth was 25 percent greater on trees in the thinned area than those in the unthinned area.

TABLE 2. Average annual decline in leader growth (cm).

Leader	Stand Condition	
age (years)	Thinned	Unthinned
16-20	16.7±7.3[1]	11.8±3.6
11-15	15.6±7.5	10.4±2.9
6-10	13.2±7.1	8.9±3.2
0-5	12.0±4.9	8.5±2.7

[1]Standard deviation

Branch Development and Dry Matter Production

In lodgepole pine, as in many other conifers, the larger branches generally arise from auxiliary buds at the apex of the leader, while the smaller branches develop from latent buds along the leader. Both types of branches collectively formed the annual whorl of branches, and their ages could be counted fairly accurately up to 20 years. Number of live branches per whorl, over the most recent 20-year period, averaged 3.6 for trees in the thinned area and 3.5 in the unthinned area, ranging from one to eight in both groups of trees.

Mean diameter computed for the largest branch from 20-year-old whorls was 14.4 mm for trees in the thinned area and 9.1 mm for trees in the unthinned area. Mean diameter of the largest 1-year-old branches was 5.6 mm for trees in the thinned area and 7.5 mm, or slightly larger, for study trees in the unthinned area.

Mean lengths computed for the longest branch on 20-year-old annual whorls was 90.6 cm for trees in the thinned area and 46.5 cm, or about one-half as long, for trees in the unthinned area. Mean length for the longest 1-year-old annual whorl branches ranged from 15.0 cm to 10.5 cm for trees in the thinned and unthinned areas, respectively.

The initial development of all branch whorls was apparently similar, but branch size varied greatly over time due to yearly variation in the growing season, continual changes in the crown environment, and factors of competition. During the past 20 years (between 10 and 30 years after initial thinning) the cumulative weight of branchwood in the annual whorls of trees growing in the thinned area reached about 1.1 kg per tree or about 5.4 times more than their counterparts in the unthinned area (Fig. 1). For trees in the thinned area, there was a definite, although inconsistent, trend of increase in weight of the annual growth. Weight changes were negligible for branches older than about 8 or 9 years for trees in the unthinned part of the stand.

The cumulative production of needles was considerably greater than production of branchwood. If cast needles could have been accounted for, the ratios of needles to branchwood weights computed below would have been considerably greater:

	Needle/branchwood Weight
Thinned area	1.50
Unthinned area	2.36

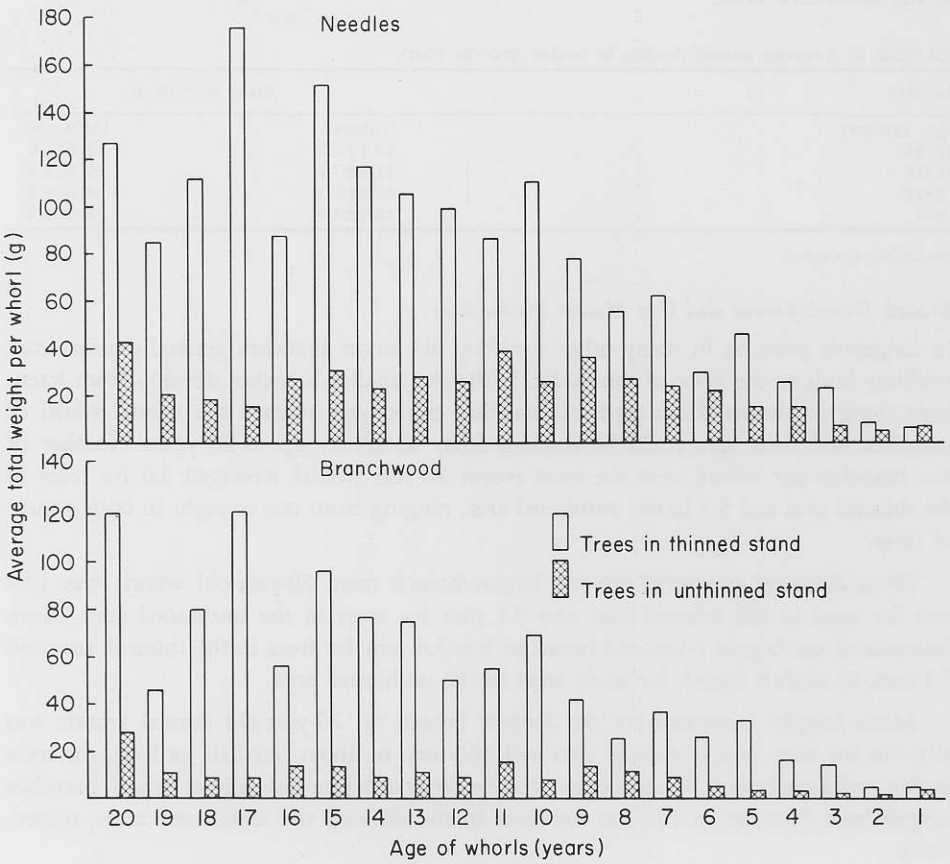

Figure 1. Average ovendry weights of needles and branchwood by age of whorls.

The correlation coefficient between weights of needles and branchwood was 0.96 for trees in the thinned area and 0.88 in the unthinned area.

Vertical Distribution of Needles and Branchwood

Individual tree crowns in both stand densities had wide gaps, both horizontally and vertically, between the needles and branches of successive whorls. Similar characteristics were observed by Stiell (1962) and apparently are common to all conifers. Because of the wide variability of tree heights, crown lengths, and amounts and location of needles and branchwood, analysis of individual tree crowns yielded little information about the relative distribution of needles and branches within the canopy itself.

Since the canopy is usually of greater interest from the standpoint of energy budgets, nutrients fluxes, etc., the distributions of needles and branches were computed in terms of canopy. For this purpose, the crowns of the five study trees in each area were assumed to represent collectively the stand canopy. The limits of the two canopies encompassed the space from the tip of the tallest tree down to the level of the lowest all-live whorl, usually on a different tree. The upper level of the canopy was about 1.5 m

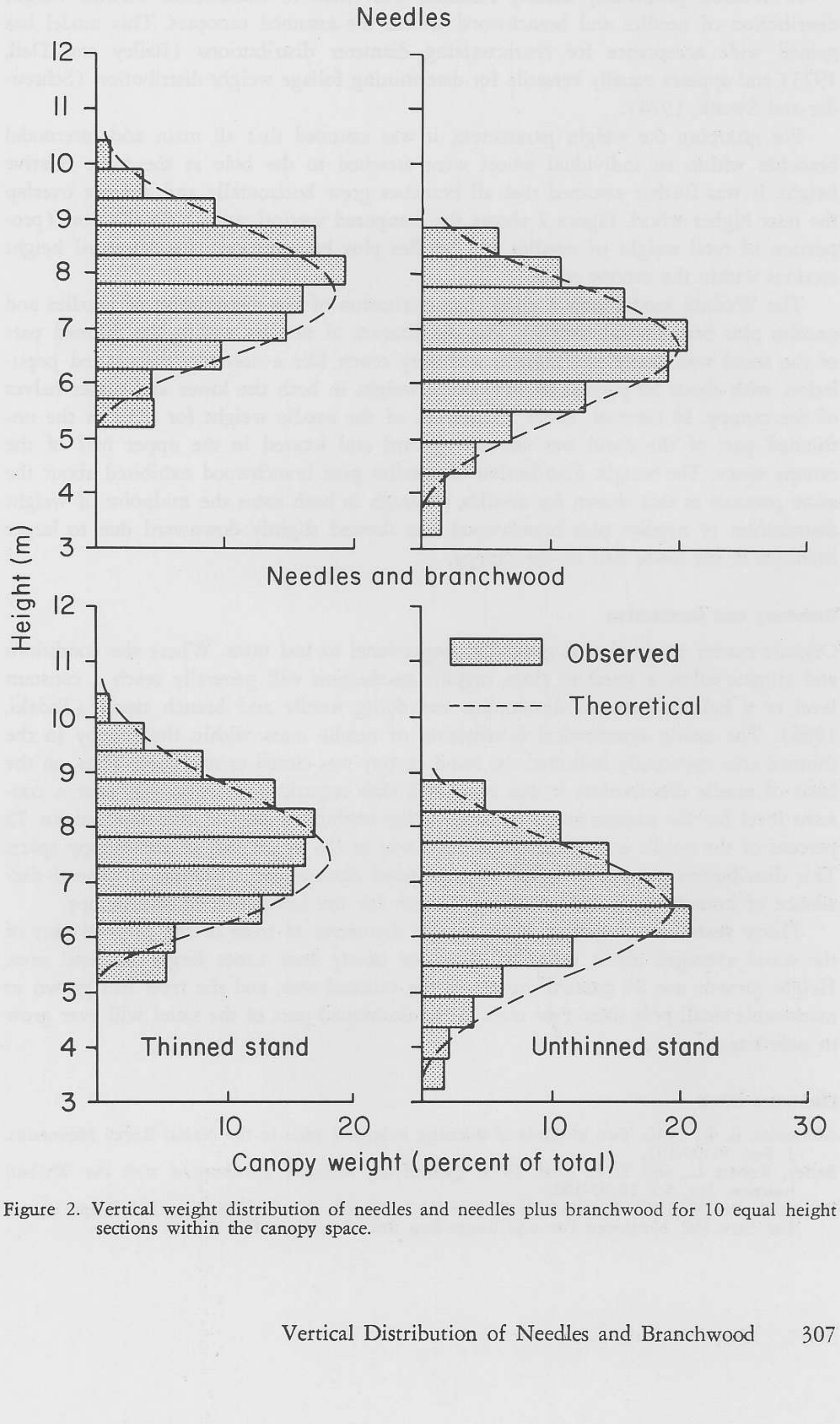

Figure 2. Vertical weight distribution of needles and needles plus branchwood for 10 equal height sections within the canopy space.

higher in the thinned area, while canopy depth was about 0.5 m less than in the unthinned area.

A Weibull probability density function was fitted to characterize vertical weight distribution of needles and branchwood within the assumed canopies. This model has gained wide acceptance for characterizing diameter distributions (Bailey and Dell, 1973) and appears equally versatile for determining foliage weight distribution (Schreuder and Swank, 1974).

For grouping the weight parameters, it was assumed that all main and internodal branches within an individual whorl were attached to the bole at the same relative height. It was further assumed that all branches grew horizontally and did not overlap the next higher whorl. Figure 2 shows the computed vertical weight distribution (proportion of total weight of needles and needles plus branchwood) for 10 equal height sections within the canopy space.

The Weibull model gave a good characterization of the distribution of needles and needles plus branchwood weights. The distribution of needles within the thinned part of the stand was nearly symmetrical and very much like a normally distributed population, with about 50 percent of the needle weight in both the lower and upper halves of the canopy. In contrast, about 75 percent of the needle weight for trees in the unthinned part of the stand was skewed upward and located in the upper half of the canopy space. The weight distribution of needles plus branchwood exhibited about the same patterns as that shown for needles, although in both areas the midpoint of weight distribution of needles plus branchwood was skewed slightly downward due to larger branches in the lower half of the canopy.

Summary and Conclusion

Organic matter production is generally proportional to leaf mass. Where site conditions and climate allow a stand to close, organic production will generally reach a constant level or a balance between developing and dying needle and branch tissue (Tadaki, 1966). The nearly symmetrical distribution of needle mass within the canopy in the thinned area apparently indicated the stand canopy was closed or nearly so. Thus, on the basis of needle distribution, it was concluded that organic production was near a constant level for the present stand density. In the unthinned part of the stand, about 75 percent of the needle and branchwood mass was in the upper half of the canopy space. This distribution pattern indicated obvious stand closure and a pattern of general decadence of branch tissue and needle production for the lower half of the canopy.

Thirty years after thinning, breast height diameters of trees in the thinned part of the stand averaged about twice as large—or nearly four times larger in basal area. Height growth was 25 percent greater in the thinned area, and the trees had grown to marketable small pole sizes. Few trees in the unthinned part of the stand will ever grow to pole size.

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