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# A Method for Estimating the Preharvest Potential for Seeding Height Growth on Cutover Forest Land in Southwestern Oregon



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## Abstract

Diameter growth of young trees as measured on Douglas-fir stumps of the previous stand was related to height of 5-year-old Douglas-fir seedlings on 16 cable-yarded, broadcast-burned progeny test plantations in southwestern Oregon. The resulting regression can be used to estimate the preharvest potential for seedling height growth on cutover land.

Keywords: Seedling growth, increment (height), site class (-increment, progeny tests.

## Introduction

The site quality of forest land can be readily determined when that land supports mature trees, but it is difficult to determine the original site quality after those mature trees have been harvested. Information about the preharvest potential of a cutover area for postharvest seedling growth is often needed, but seldom available.

The potential of a cutover area for seedling growth is important. Seedlings that eventually become crop trees usually overcome brush competition and escape browsing while they are young. Rate of young seedling growth determines the time required to attain the height necessary to escape brush and animals, and that rate varies with site quality. Young plantations and other cutover areas unfortunately lack trees that are suitable for the conventional determination of site quality. Suitable site trees can sometimes be found in adjacent uncut stands if those stands occupy the same slopes, aspects, and soils; but no local site index curves are available for stands in southwestern Oregon. The age-height relationships used elsewhere are difficult to apply because of the common occurrence of suppression periods in the growth of southwestern Oregon trees, and most site index curves provide little information about tree height during the first few years of plantation growth.

Postharvest seedling height growth may not reflect preharvest site quality of the land on which those seedlings grow because site quality can be changed: soil compaction, soil removal, erosion, and the effects of fire may significantly alter a site. If estimates of preharvest potential for growth are needed (for example, to assess the effects of site preparation on site quality), they should be obtained by using preharvest variables, not postharvest seedlings.

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Radial growth measured on stumps of the previous stand is a suitable preharvest variable, and Schmidt (1954) used it to estimate the site quality of cutover land on Vancouver Island, British Columbia. He selected five of the largest Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) stumps available on each of his 0.4-hectare (1 acre) cutover plots but excluded abnormally large stumps. Schmidt then measured growth along three radii and calculated the average diameter of each stump at age 100. These stump diameters were averaged for each plot, and the plot averages were used to construct freehand curves that related stump diameters to the site indexes determined by measuring heights and ages of trees in adjacent uncut stands. His results varied with the site index involved, but Schmidt's stump estimates and the age-height measurements were similar on 73 percent of his plots. He measured 100 years of stump growth to minimize the effects of variations in stand density that are characteristic of young stands.

It is important to minimize the effects of stand density when using tree diameter as an indicator of site quality. This can be done by using the largest trees available. A second strategem may be effective—measurement of diameter when the trees are young and not yet competing with adjacent trees.

Duvall (1983) found that the diameter growth of young seedlings was unrelated to spacing in the plantations that he studied. Site quality, not spacing, influenced their diameter growth. This initial free growth was followed by a transition period in which spacing began to affect growth. Duration of the initial period of free growth was variable and difficult to determine, but Duvall suggested that the influence of site quality would continue to be discernible until competition became severe.

Drew and Flewelling (1979) assumed that individual tree growth is not related to stand density before crown closure occurs. If that assumption is valid, the influence of site quality on diameter growth will be discernible until crown closure wherever competition from other vegetation is not severe. Unfortunately, other vegetation is often abundant in young stands, and seedling growth is often reduced by shrub and grass competition.

The method described here was designed to minimize the effect of vegetative competition and stand density variation while maximizing the effect of preharvest site quality on the radial growth measured on Douglas-fir stumps. My objective was to relate stump measurements to seedling heights in a regression that could be used on cutover land to estimate its preharvest potential for seedling height growth.

## Methods

Field data were collected on 16 progeny test plantations administered by the Forest Service, U.S. Department of Agriculture, and the Bureau of Land Management, U.S. Department of the Interior, in southwestern Oregon. Eight of the plantations were in Curry County, and eight were in Douglas County. Alf had been cable yarded and broadcast burned, and all were fenced to keep out browsing mammals. Brush competition, if present, had been controlled. The site quality of these minimally disturbed, carefully maintained progeny test plantations was assumed to be unaffected by logging and to be representative of the preharvest site conditions. The plantations were 4 to 5 hectares (10 to 12 acres) in size. Each contained several thousand carefully planted, individually tagged Douglas-fir seedlings of known parentage. When the seedlings were 5 years old from seed, their heights were measured by Forest Serv--ice or Bureau of Land Management personnel. I obtained the average 5-year seedling, height, for each plantation from records stored at the Forest Service, Forestry Sciences Laboratory, in Corvallis, Oregon.

Twenty Douglas-fir stumps were measured on each of the 16 plantations in 1984. In selecting the stumps to be measured, I assumed that growth potential would be best expressed by the best growing stumps. There were three other assumptions: (1) when the trees were very young (the stump centers), brush competition or browsing may have reduced both height and diameter growth; (2) when the trees were pole size or larger (peripheral portions of the stumps), intertree competition probably reduced growth; and (3) a sapling 10 centimeters (3.9 in) in diameter would be large enough to escape browsing and serious brush competition but small enough to be relatively unaffected by the intertree competition that occurs after crown closure. Annual ring width at 5 to 15 centimeters (2 to 6 in) from the pith was the criterion used in selecting 20 well-growing stumps. Stump sizes and heights varied, but neither size nor height was considered in choosing the stumps to be measured.

Beginning at a distance of 5 centimeters (2 in) from the pith, the distance occupied by 10 annual rings was measured along four radii on each of the 20 stumps selected on each plantation. The radii were oriented at right angles, in north, south, east, and west directions (fig. 1). The 10-ring distances were measured to the nearest millimeter (0.0394 in). A paint scraper was useful in removing pitch, and I used dissecting needles to mark the inner and outer boundaries of the 10-ring distance to be measured (fig. 2).

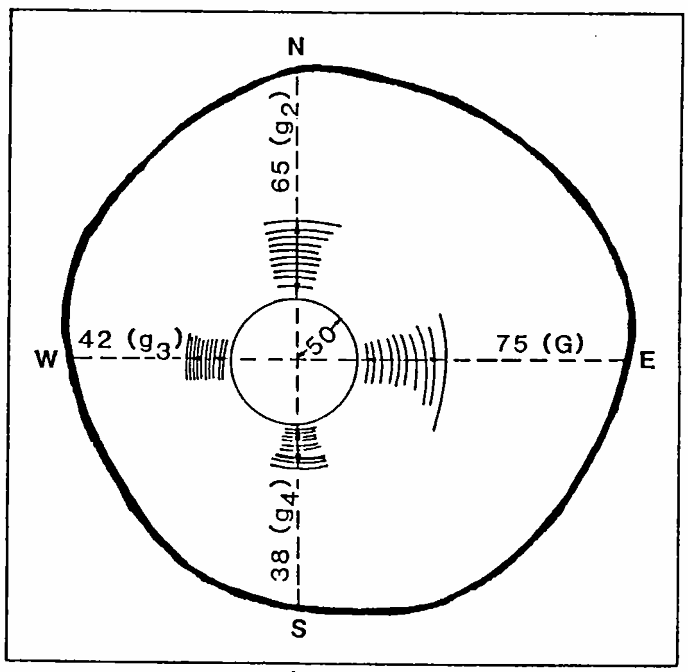


Figure 1–The four radial growth measurements obtained for each stump in the sample. Ten annual rings are included in each measurement. Distances shown are in millimeters.

Figure 2.—Radial growth measurement in the field. Dissecting needles mark the 10 annual rings to be measured along a single radius.

Stump measurements and seedling heights were compared in several ways to obtain the best possible relation of preharvest stump growth to postharvest seedling height on the 16 plantations. I began with the following assumptions:

1. Postharvest seedling height growth can be related to radial growth measured on stumps of the previous stand where minimal disturbance occurred during harvest and site preparation. That relationship is often obscured, however, by extreme sam--ple variation; high preharvest stand densities; and laterally unequal influences on growth, such as slope, unequal vegetative competition, and early injury.

2. Extreme sample variation can be reduced by discarding the two extremes in each 20-stump sample—the stump with the best growth and the stump with the poorest growth. This trimmed-mean technique is appropriate when the sampled distribution has long tails.

3. Radial growth reductions caused by high preharvest stand densities can be minimized by ranking the stumps on each plantation in order of growth and using a subsample of the same number of similarly ranked, well-growing stumps from each plantation.

4. Laterally unequal influences on growth produce asymmetric stumps and may be associated with reduced seedling height. Stump symmetry therefore should be considered-'When relating stump measurements, to seedling height

Regression analyses were used to relate 5-year seedling height and several, expressions of stump growth.

## Results and Discussion

Growth varied among radii on the same stump, among stumps in the same plantation, and among stumps in different plantations. The variation among radii and among stumps in the same plantation tended to obscure variation among plantations (appendix, table 2). Nevertheless, average 10-year radial growth of the stumps was significantly ($P<0.01$) related to average 5-year seedling height on the plantations when the four growth measurements from each stump were averaged and all the stumps were used. Less than half of the among-plantation variation in seedling height was associated with radial growth when this was done, however; and the regression was not strong enough to be useful in predicting seedling height.

Growth variation among radii on the same stump could be eliminated by using only the largest growth measurement obtained for that stump—the maximum radial growth (R). Unfortunately, this did not improve the stump growth-seedling height correlation, and it did not reduce the variation among stumps in the same plantation (appendix, table 3). The maximum radial growth value was convenient for comparing stumps, however; and I found it to be useful in ranking stump growth.

Growth variation among stumps in the same plantation was most evident when the best growing stump was compared with other stumps in that plantation (appendix, table 3). The high-growth ends of the sample distributions were long tailed, and the trimmed-mean technique was used to reduce sample variation. The two stumps with extreme R-values (stumps 1 and 20) were deleted, which left data for 18 stumps in each plantation. Of these 18 stumps, the five with largest maximum radial growth were judged to be least influenced by stand density. These five stumps were used in all subsequent calculations (appendix, table 3).

Radial growth and symmetry were both important in relating stump measurements to seedling heights on the 16 plantations, and I weighted the maximum radial growth of each stump by that stump's symmetry. The simplest and most effective weighting factor reduced the maximum growth measurement (R) by an amount equal to the sum of the differences between R and the three other growth measurements:

$$R - \sum (R - n) ;$$

where: R = the largest radial growth measured on the stump, and
$r_i$ = the three other radial growth measurements.

For example, if R is 16 and the $r_i$'s are 15, 13, and 12 then

$$[R - \sum (R - r_i)] = 8.$$

This growth-symmetry factor (GSF) was calculated for each of the five stumps with, the largest R-values in each plantation. The plantation averages (table 1) were then related to 5-year seedling height averages in a regression (fig. 3):

$$SH = 44.32 + 1.79(\text{average GSF}) ;$$

where: SH = average 5-year seedling height in centimeters, and
GSF = average growth-symmetry factor.
$R^2$ = 0.692
$s_{y \cdot x}$ = 20.55
n = 16

This regression can be used to predict the height of unbrowsed 5-year-old seedlings on cable-yarded, broadcast-burned clearcuts in southwestern Oregon. It should be most helpful, however, when it is used to estimate preharvest growth potential on cutover land where site quality has been affected by logging or by site preparation treatments. Only measurements of stumps are required, and those measurements reflect the undisturbed conditions present when the stumps were saplings with diameters of 10 centimeters (3.9 in).

Estimates obtained from the stump measurement-seedling height regression express growth potential in terms of average unbrowsed 5-year seedling height rather than mature tree height, and they do not indicate relative volume production at the end of a rotation. Nevertheless, the potential for seedling growth is important information whenever the effects of harvesting methods or site preparation treatments are compared, and it is a value that should be considered in managing cutover land.

## Summary of Method

The following steps should be followed to estimate the preharvest growth potential of a cutover area:

1. Locate on the area at least 10 stumps that show no evidence of suppression
between 5 and 15 centimeters (2 and 6 in) from the pith. Choose stumps with the widest annual rings that can be found between 5 and 15 centimeters (2 and 6 in).

2. On each stump, beginning 5 centimeters (2 in) from the pith, measure the distance (mm) occupied by 10 annual rings on north, south, east, and west radii.

3. After all the stumps have been measured, use the maximum radial growth measurement (R) on each stump to rank the stumps from best growing (stump 1) to poorest growing.

4: Calculate growth-symmetery factors for stumps, 2, 3, 4, 5, and 6:

$$R – [(R – r_2) + (R - r_3) + (R -r_4)] \text{ or } R - \sum(R -..r_i)$$

where: R = the maximum growth measurement and
$r_2$, $r_3$ and $r_4$ (or $r_i$) = the other three growth measurements.

5. Average the five growth-symmetry, factors and use that average in the regression equation.

Average 5-year seedling height = 44.32 + 1.79(average growth-symmetry factor).

**Table 1–Average maximum 10-year radial growth (R), growth-symmetry factor [R-∑(R- $r_i$)], and 5-year seedling height, by plantation.**

| Plantation | Average R, 20 stumps | Average R, 18 stumps 1/ | Average R, 5 stumps 2/ | Average R- (R-r ), 5 stumps 3/ | Average 5-year seedling height 4/ |
|---|---|---|---|---|---|
| | mm 5/ | mm 5/ | mm 5/ | mm 5/ | cm 6/ |
| A | 18.8 | 18.1 | 21.8 | 11.2 | 69.0 |
| B | 39.0 | 36.3 | 52.6 | 28.2 | 98.6 |
| C | 30.4 | 29.3 | 39.6 | 16.0 | 98.9 |
| D | 31.0 | 29.7 | 40.8 | 16.0 | 91.6 |
| E | 35.4 | 35.2 | 45.6 | 25.4 | 76.0 |
| F | 29.4 | 29.2 | 38.2 | 8.2 | 56.4 |
| G | 39.6 | 39.8 | 48.8 | 12.2 | 57.3 |
| H | 74.3 | 74.7 | 90.2 | 66.8 | 144.9 |
| I | 55.4 | 54.8 | 64.6 | 38.0 | 111.7 |
| J | 51.9 | 50.3 | 64.0 | 47.0 | 180.0 |
| K | 72.0 | 71.8 | 86.6 | 51.4 | 136.2 |
| L | 56.1 | 56.4 | 69.2 | 42.2 | 99.1 |
| M | 41.6 | 41.4 | 53.4 | 16.2 | 50.4 |
| N | 57.4 | 56.8 | 70.6 | 30.4 | 106.1 |
| O | 44.7 | 43.4 | 56.2 | 20.8 | 58.1 |
| P | 42.4 | 40.3 | 57.0 | 27.6 | 95.0 |

1/ The stumps with largest and smallest R-values were deleted to reduce within-plantation variation,

2/ The 5 stumps with largest R-values remaining after deleting the 2 extreme values.

3/ The 5 largest R-values are here reduced in proportion to the asymmetry of the stump on which they were measured.

4/ Average height of all seedling in the plantation.

5/ To convert to inches, multiply by 0.3937.

6/ To convert to inches, multiply by 0.3937.

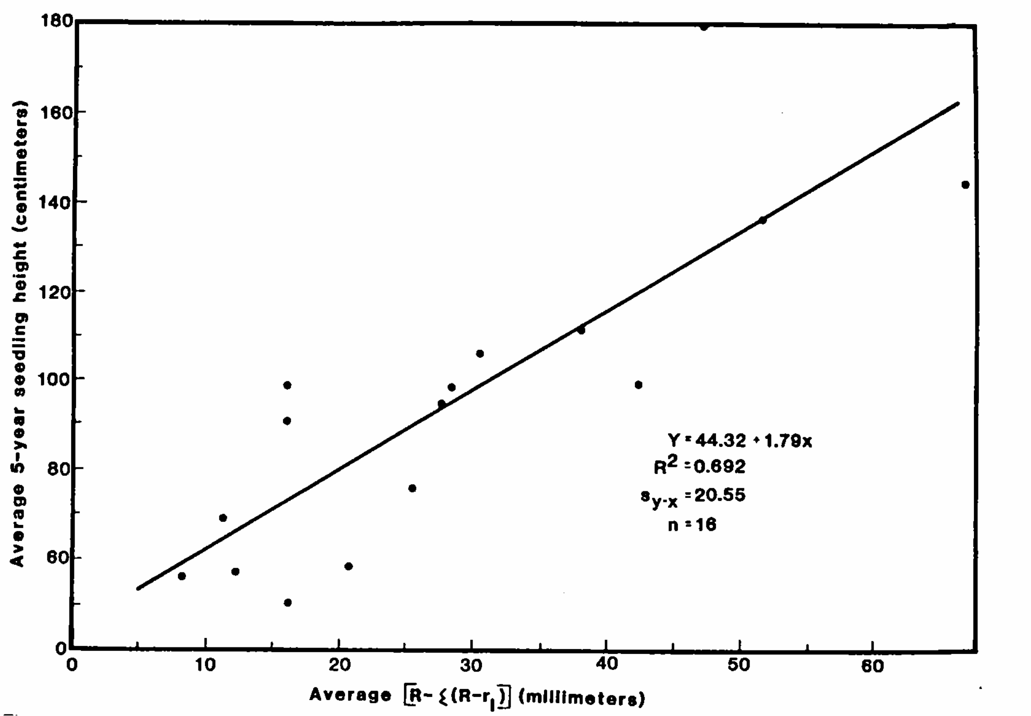


Figure 3.–Relation of the growth-symmetry factor [R-∑(R-$r_i$)] to 5-year seeding height.

## Acknowledgments

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## Appendix

### Table 2–Average 10-year radial growth 1/ for each of the 20 stumps on each plantation, ranked from best growth (stump 1) to poorest growth (stump 20), and average 5-year seedling height on each plantation

| Plantation | Stump 1 | Stump 2 | Stump 3 | Stump 4 | Stump 5 | Stump 6 | Stump 7 | Stump 8 | Stump 9 | Stump 10 | Stump 11 | Stump 12 | Stump 13 | Stump 14 | Stump 15 | Stump 16 | Stump 17 | Stump 18 | Stump 19 | Stump 20 | Average, all stumps | Average 5-year seedling height 2/ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10-year radial growth in millimeters 3/ | | | | | | | | | | | | | | | | | | | | | cm 4/ |
| A | 32.5 | 19.5 | 19.5 | 19.2 | 18.8 | 18.8 | 17.8 | 17.8 | 17.5 | 16.8 | 16.5 | 14.8 | 14.0 | 14.0 | 13.8 | 13.5 | 11.2 | 10.5 | 8.8 | 8.5 | 16.2 | 69.0 |
| B | 104.5 | 57.5 | 56.0 | 47.0 | 39.0 | 37.8 | 35.5 | 34.8 | 34.0 | 33.0 | 30.5 | 26.2 | 24.5 | 22.8 | 22.2 | 20.0 | 17.5 | 16.8 | 15.2 | 15.2 | 34.5 | 98.6 |
| C | 40.5 | 39.0 | 38.5 | 34.5 | 29.0 | 27.0 | 26.0 | 25.5 | 24.8 | 24.2 | 23.2 | 21.8 | 21.0 | 21.0 | 19.8 | 19.5 | 19.5 | 19.5 | 18.2 | 17.2 | 25.5 | 98.9 |
| D | 55.8 | 40.8 | 38.8 | 34.5 | 33.5 | 30.5 | 29.5 | 27.2 | 25.5 | 23.5 | 23.5 | 21.5 | 21.5 | 21.2 | 20.0 | 19.8 | 18.8 | 18.0 | 17.8 | 15.2 | 26.8 | 91.6 |
| E | 47.0 | 46.5 | 42.2 | 40.0 | 38.8 | 35.2 | 34.5 | 34.0 | 30.2 | 29.8 | 28.8 | 28.5 | 28.0 | 26.5 | 26.0 | 25.2 | 22.8 | 22.2 | 20.8 | 19.0 | 31.3 | 76.0 |
| F | 42.5 | 36.2 | 32.5 | 32.2 | 29.8 | 28.5 | 27.2 | 25.5 | 25.0 | 25.0 | 24.5 | 24.0 | 22.2 | 20.5 | 18.8 | 18.0 | 14.8 | 14.5 | 14.2 | 11.2 | 24.4 | 56.4 |
| G | 45.0 | 42.0 | 42.0 | 40.8 | 39.2 | 38.0 | 36.2 | 35.5 | 35.2 | 35.0 | 34.8 | 34.0 | 33.8 | 33.5 | 32.0 | 31.0 | 30.5 | 24.5 | 21.5 | 21.2 | 34.3 | 57.3 |
| H | 89.8 | 88.2 | 87.8 | 85.2 | 81.0 | 79.5 | 79.2 | 79.0 | 78.8 | 77.2 | 72.5 | 64.0 | 63.2 | 60.5 | 58.8 | 53.5 | 52.5 | 49.0 | 45.8 | 43.0 | 69.4 | 144.9 |
| I | 71.0 | 62.8 | 61.8 | 59.5 | 56.0 | 54.0 | 53.8 | 52.5 | 51.8 | 50.5 | 48.8 | 48.8 | 46.0 | 44.0 | 43.0 | 41.5 | 39.5 | 39.0 | 38.5 | 36.2 | 50.0 | 111.7 |
| J | 81.0 | 67.2 | 65.2 | 59.8 | 55.8 | 51.2 | 50.8 | 48.8 | 48.2 | 45.2 | 45.0 | 42.2 | 39.5 | 38.5 | 37.5 | 36.8 | 35.8 | 33.8 | 33.0 | 27.5 | 47.1 | 180.0 |
| K | 90.5 | 89.2 | 77.0 | 76.2 | 75.8 | 72.8 | 70.8 | 69.5 | 66.5 | 66.5 | 64.5 | 63.0 | 59.0 | 58.0 | 57.8 | 55.2 | 53.5 | 51.0 | 48.0 | 47.8 | 65.6 | 136.2 |
| L | 68.5 | 65.5 | 65.0 | 61.8 | 59.0 | 58.8 | 57.8 | 54.8 | 53.0 | 51.8 | 48.2 | 46.0 | 44.2 | 41.8 | 40.2 | 38.8 | 36.8 | 34.8 | 29.8 | 29.0 | 49.3 | 99.1 |
| M | 56.5 | 49.8 | 49.8 | 43.0 | 41.5 | 39.8 | 39.5 | 36.5 | 35.8 | 35.5 | 33.8 | 34.8 | 33.2 | 33.2 | 30.8 | 30.2 | 27.5 | 27.5 | 27.0 | 18.8 | 36.2 | 50.4 |
| N | 81.5 | 69.8 | 61.5 | 59.8 | 59.0 | 57.5 | 56.2 | 55.5 | 51.8 | 51.2 | 50.8 | 49.8 | 41.5 | 41.5 | 40.5 | 38.8 | 38.0 | 37.5 | 36.2 | 34.2 | 50.6 | 106.1 |
| O | 77.5 | 56.5 | 48.5 | 47.2 | 42.5 | 42.0 | 40.8 | 38.0 | 38.0 | 36.5 | 36.2 | 35.2 | 34.0 | 33.5 | 33.0 | 32.2 | 30.2 | 30.2 | 25.8 | 24.0 | 39.1 | 58.1 |
| P | 80.0 | 79.2 | 54.8 | 45.2 | 37.8 | 36.8 | 36.5 | 35.0 | 34.8 | 31.5 | 29.5 | 27.8 | 27.5 | 27.2 | 24.8 | 24.2 | 24.0 | 21.2 | 18.8 | 15.5 | 35.6 | 95.0 |

1/ Growth was measured along north, south, east, and west radii, then averaged for each stump.
2/ Average height of all seedlings in the plantation.
3/ To convert to inches, multiply by 0.03937.
4/ To convert to inches, multiply by 0.3937.

**Table 3–Maximum 10-year radial growth (R) and growth-symmetry factor [R-∑(R- $r_i$) for each of the 20 stumps measured on each plantation, ranked from best to poorest maximum growth [1/]**

10-year radial growth in millimeters 5/

| Plantation | Stump 1 R 2/ | Stump 1 $R-\Sigma(R-r_i)$ | Stump 2 3/ R | Stump 2 3/ $R-\Sigma(R-r_i)$ | Stump 3 3/ R | Stump 3 3/ $R-\Sigma(R-r_i)$ | Stump 4 3/ R | Stump 4 3/ $R-\Sigma(R-r_i)$ | Stump 5 3/ R | Stump 5 3/ $R-\Sigma(R-r_i)$ | Stump 6 3/ R | Stump 6 3/ $R-\Sigma(R-r_i)$ | Stump 7 R | Stump 7 $R-\Sigma(R-r_i)$ | Stump 8 R | Stump 8 $R-\Sigma(R-r_i)$ | Stump 9 R | Stump 9 $R-\Sigma(R-r_i)$ | Stump 10 R | Stump 10 $R-\Sigma(R-r_i)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 40 | 10 | 25 | 3 | 22 | 12 | 21 | 14 | 21 | 12 | 20 | 15 | 20 | 11 | 20 | 10 | 20 | 7 | 20 | 6 |
| B | 110 | 88 | 61 | 47 | 61 | 41 | 51 | 35 | 45 | 21 | 45 | -3 | 42 | 25 | 42 | 10 | 40 | 22 | 39 | 22 |
| C | 59 | -23 | 46 | 24 | 43 | 27 | 37 | 27 | 37 | -9 | 35 | 11 | 30 | 18 | 30 | 14 | 30 | 7 | 29 | 12 |
| D | 66 | 25 | 47 | 22 | 45 | 20 | 39 | 21 | 37 | -9 | 36 | 26 | 34 | 20 | 31 | 25 | 30 | 19 | 29 | 7 |
| E | 52 | 87 | 51 | 16 | 49 | 39 | 43 | 31 | 43 | 12 | 42 | 29 | 39 | 21 | 36 | 28 | 35 | 10 | 33 | 22 |
| F | 48 | 26 | 41 | 22 | 39 | -21 | 38 | 16 | 37 | 3 | 36 | 21 | 35 | 14 | 32 | 4 | 32 | 4 | 30 | 12 |
| G | 53 | 9 | 51 | 27 | 51 | -13 | 49 | 21 | 47 | 22 | 46 | 4 | 42 | 31 | 40 | 19 | 44 | 20 | 40 | 25 |
| H | 95 | 74 | 93 | 74 | 92 | 75 | 92 | 65 | 89 | 51 | 85 | 69 | 85 | 60 | 85 | 54 | 82 | 71 | 82 | 70 |
| I | 80 | 44 | 70 | 37 | 68 | 47 | 63 | 27 | 62 | 52 | 60 | 27 | 59 | 33 | 57 | 53 | 55 | 50 | 53 | 43 |
| J | 102 | 18 | 70 | 51 | 69 | 62 | 66 | 41 | 59 | 46 | 56 | 35 | 55 | 40 | 50 | 45 | 50 | 31 | 50 | 30 |
| K | 96 | 74 | 96 | 20 | 92 | 81 | 84 | 51 | 81 | 62 | 80 | 43 | 79 | 54 | 78 | 32 | 77 | 47 | 70 | 56 |
| L | 75 | 35 | 74 | 40 | 73 | 55 | 68 | 31 | 66 | 49 | 65 | 36 | 62 | 50 | 60 | 32 | 59 | 30 | 57 | 48 |
| M | 62 | 40 | 62 | 13 | 60 | -14 | 54 | 37 | 46 | 34 | 45 | 11 | 44 | 27 | 43 | 10 | 41 | 35 | 41 | 10 |
| N | 85 | 71 | 81 | 36 | 70 | 36 | 70 | 12 | 69 | 32 | 63 | 36 | 62 | 50 | 61 | 47 | 61 | 22 | 60 | 23 |
| O | 84 | 58 | 64 | 34 | 60 | 9 | 55 | 29 | 55 | 5 | 47 | 27 | 45 | 17 | 44 | 31 | 42 | 26 | 42 | 20 |
| P | 105 | 2 | 88 | 56 | 61 | 36 | 49 | 34 | 44 | -6 | 43 | 18 | 43 | 11 | 41 | 28 | 40 | 26 | 38 | 25 |

10-year radial growth in millimeters 5/

| Plantation | Stump 11 R | Stump 11 $R-\Sigma(R-r_i)$ | Stump 12 R | Stump 12 $R-\Sigma(R-r_i)$ | Stump 13 R | Stump 13 $R-\Sigma(R-r_i)$ | Stump 14 R | Stump 14 $R-\Sigma(R-r_i)$ | Stump 15 R | Stump 15 $R-\Sigma(R-r_i)$ | Stump 16 R | Stump 16 $R-\Sigma(R-r_i)$ | Stump 17 R | Stump 17 $R-\Sigma(R-r_i)$ | Stump 18 R | Stump 18 $R-\Sigma(R-r_i)$ | Stump 19 R | Stump 19 $R-\Sigma(R-r_i)$ | Stump 20 R 4/ | Stump 20 $R-\Sigma(R-r_i)$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 18 | 17 | 18 | 2 | 16 | 8 | 16 | -6 | 15 | 14 | 15 | 10 | 15 | 9 | 12 | 9 | 12 | -2 | 11 | 2 |
| B | 33 | 23 | 33 | 6 | 30 | 1 | 27 | 17 | 26 | 11 | 24 | 8 | 20 | 10 | 19 | 10 | 16 | 13 | 16 | 13 |
| C | 26 | 15 | 25 | 9 | 25 | 4 | 23 | 18 | 23 | 15 | 23 | 0 | 22 | 12 | 22 | 12 | 22 | 12 | 22 | 7 |
| D | 28 | 10 | 26 | 7 | 23 | 17 | 23 | 17 | 23 | 10 | 22 | 6 | 21 | 17 | 20 | 11 | 20 | 1 | 19 | 18 |
| E | 33 | 13 | 32 | 23 | 30 | 24 | 30 | 16 | 30 | 11 | 28 | 7 | 27 | 23 | 26 | 11 | 26 | 5 | 22 | 10 |
| F | 29 | 22 | 27 | 17 | 26 | 11 | 25 | -3 | 23 | 13 | 23 | 6 | 18 | 5 | 18 | 3 | 17 | -6 | 15 | 13 |
| G | 39 | 24 | 39 | 17 | 37 | 25 | 36 | 16 | 35 | 30 | 35 | 23 | 34 | 20 | 27 | 17 | 24 | 14 | 24 | 13 |
| H | 79 | 68 | 69 | 46 | 68 | 52 | 67 | 41 | 61 | 52 | 60 | 34 | 56 | 42 | 50 | 46 | 49 | 36 | 47 | 31 |
| I | 53 | 17 | 53 | -5 | 51 | 42 | 50 | 45 | 50 | 34 | 50 | 22 | 46 | 28 | 44 | 24 | 43 | 29 | 40 | 25 |
| J | 49 | 46 | 45 | 34 | 43 | 25 | 43 | 18 | 43 | 14 | 42 | 32 | 41 | 27 | 40 | 15 | 34 | 30 | 31 | 17 |
| K | 70 | 48 | 67 | 51 | 65 | 37 | 65 | 26 | 62 | 50 | 62 | 45 | 56 | 36 | 55 | 49 | 54 | 29 | 51 | 39 |
| L | 55 | 19 | 55 | 2 | 53 | 34 | 50 | 5 | 50 | -3 | 49 | 14 | 46 | 39 | 40 | 19 | 33 | 20 | 32 | 20 |
| M | 39 | 25 | 38 | 29 | 38 | 19 | 37 | 24 | 34 | 8 | 32 | 25 | 31 | 30 | 30 | 20 | 30 | 18 | 24 | 3 |
| N | 57 | 36 | 52 | 43 | 48 | 22 | 46 | 28 | 45 | 27 | 45 | 20 | 44 | 20 | 44 | 13 | 44 | 5 | 41 | 27 |
| O | 41 | 13 | 39 | 28 | 39 | 15 | 37 | 30 | 36 | 26 | 36 | 21 | 36 | 13 | 35 | 16 | 29 | 16 | 28 | 12 |
| P | 37 | -26 | 34 | 9 | 34 | 8 | 34 | 7 | 32 | 22 | 30 | 9 | 30 | 6 | 28 | 13 | 20 | 15 | 18 | 8 |

1/ Growth was measured along north, south, east, and west radii on each stump. R = largest measurement. $r_i$ = the other 3 measurements.
2/ The largest R measured on each plantation.
3/ Stumps used in the stump growth-seedling height correlation.
4/ The smallest R measured on each plantation.
5/ To convert to inches, multiply by 0.03937.

The **Forest Service** of the U.S. Department of Agriculture is .dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

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