DISTRIBUTION OF AGGREGATE RAYS IN RED ALDER[1]

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ABSTRACT

The distribution of aggregate rays in 23 trees of red alder was examined. Three patterns of distribution were determined for the relationship between the number of aggregate rays counted at the cambium on the cross section and height in the tree. Aggregate rays are virtually absent in a cone-shaped zone of juvenile wood in the lower half of the tree bole but present in varying numbers in the sheath of adult wood surrounding the juvenile core in the lower half of the bole and in both juvenile and adult wood in the upper half of the bole. That pattern explains their sporadic distribution in alder lumber. The number of aggregate rays observed at the cambium on cross sections from ground line to tree tip is not related to tree diameter, geographic location, or quadrant sectors within trees. Clusters of closely spaced aggregate rays are frequently associated with frost injuries, indentures, or undulating annual rings and branch traces.

Keywords: *Alnus rubra*, aggregate rays, wood figure, juvenile wood, adult wood, rays.

INTRODUCTION

One of the anatomical features in wood that can contribute to unusual and attractive figure patterns on longitudinal work surfaces is the ray. Figures are particularly conspicuous in some hardwoods, such as the oaks, which possess broad, multiseriate rays that produce pleasing and distinctive figure by the presence of ray flecks and ray cross sections on radial and tangential surfaces, respectively. Such figures are highly prized in wood furniture, cabinets, and wall paneling.

Red alder (*Alnus rubra* Bong.) possesses broad rays that contribute to figure in cabinets and furniture. Two types of rays characterize the wood of the species, namely, narrow (simple) and broad (aggregate). The narrow rays are uniseriate, or rarely in part biseriate, closely spaced (21 or more per millimeter of tangential distance as viewed on the cross section) but are not visible at low magnification. The aggregate ray, unlike the typical broad ray of oaks, is a composite structure consisting of a cluster of narrow rays between which there is tracheary tissue, including fibers and sometimes vessels. To the unaided eye or at low magnification, this structure appears as a single broad ray not sharply delineated on the cross section. Tangentially, it appears as a narrow dark brown streak in comparison to the flesh-colored tissue surrounding it and has a height of 20 mm or more along the grain. Aggregate rays on the wide surface of a quarter-sawn board of red alder do not exhibit conspicuous ray flecks because of the lack of contrast between the radially oriented tissue of the aggregate rays and the adjacent longitudinally oriented tissue. However, a conspicuous figure pattern of aggregate

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rays does appear on the wide surface (tangential) of flat-sawn boards where the ends (cross sections) of the rays are exposed.

Aggregate rays are present in the wood of a few other species of domestic hardwoods, viz., American hornbeam (*Carpinus caroliniana* Walt.), tanoak (*Lithocarpus densiflorus* [(Hook and Arn.) Rehd.], and live oak (*Quercus virginiana* Mill.). They are accompanied by typical broad rays in tanoak and live oak.

In red alder, the presence of aggregate rays is a useful feature in helping to identify the wood using gross features, particularly to separate it from woods of similar color and anatomical characteristics such as red gum (*Liquidambar styraciflua* L.). However, the distribution of aggregate rays in alder wood is rather sporadic. Some pieces have very few or no aggregate rays, while in others, a large number may be present. In cabinets and furniture, particularly in wide panels consisting of edge-glued narrow pieces, the sporadic and nonuniform distribution of aggregate rays (or their absence among several pieces) may create a figure pattern with an undesirable visual effect and detract from the overall appearance of the finished article.

The objectives of this study were:

1. To determine patterns of occurrence and distribution of aggregate rays within trees of red alder.

2. To determine the influence of geographic location upon patterns of occurrence and distribution of aggregate rays within trees of red alder.

No previous studies have been found related to this problem. A standard text concerned with wood properties and identification refers to the irregular and often wide spacing of rays in a wood cross section (Panshin and de Zeeuw 1970). A literature search revealed no published information concerning the distribution patterns of aggregate rays in trees of alder or other species.

METHODS AND PROCEDURES

Five plot locations were selected to be well distributed over the range of the species in western Washington, which is only a small part of the total species range. In all plots, overstory vegetation consisted of almost pure alder. Occasionally, trees of one or more species from the following group were mixed with the alder: Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco], western redcedar (*Thuja plicata* Donn), western hemlock [*Tsuga heterophylla* (Raf.) Sarg.], western paper birch [*Betula papyrifera* var. *commutata* (Reg.) Fern.], black cottonwood (*Populus trichocarpa* Torr. and Gray), bigleaf maple (*Acer macrophyllum* Pursh), vine maple (*Acer circinatum* Pursh), and cascara buckthorn (*Rhamnus purshiana* DC). All plots were on flat terrain with relatively well-drained soils.

Plot 1 was located near the town of Sumas (east of Bellingham) on private property. Plot 2 was located about 15 miles northeast of North Bend on land administered by the U.S. Forest Service (Snoqualmie National Forest). Plot 3 was located about one-half mile southeast of Sappho on the Olympic Peninsula on land administered by the Washington Department of Natural Resources. Plot 4 was located about 15 miles west of Centralia on land administered by the Washington Department of Natural Resources. Plot 5 was located about 5 miles northwest of Willard on the Gifford Pinchot National Forest. Plots 1 through 4 were on the west side of the Cascade crest and plot 5 about 5 miles east of that crest.

TABLE 1. *Plot description data.*

Plot no.	Elevation above sea level Feet	No. of trees in plot	DBH range Inches	Average DBH Inches	Total height range of felled trees Feet	Age range of felled trees Years
1	1,200	18	5.6–13.7	9.8	50.0–82.0	33–35
2	850	38	3.5–9.5	6.0	52.5–75.4	26–27
3	400	42	2.3–11.8	6.4	35.0–67.0	18–39
4	600	25	5.1–13.8	9.2	72.9–97.6	37–41
5	1,200	24	4.2–10.5	7.1	48.5–64.3	28–30

Five trees on each of four one-tenth-acre plots were felled and sampled. Only three trees on a fifth plot were felled because of field conditions so that 23 trees constituted the total sample.

In order to encompass the diameter range growing on a particular site, the five trees sampled in each plot were selected in the following manner: the DBH of all trees was measured and the average DBH ($\bar{X}$) and the standard deviation (σ) of diameters were computed. The five trees selected were determined in order of increasing size through the computations of $\bar{X} - 2\sigma$, $\bar{X} - \sigma$, $\bar{X}$, $\bar{X} + \sigma$, and $\bar{X} + 2\sigma$. Within each plot, trees were numbered from one through five in order of increasing diameter.

Trees with excessive lean or those that might hang up in the felling operation were not felled. Another tree with a diameter close to that of the rejected tree was felled as a substitute.

Prior to felling, the north side of each tree was marked by a black line on the bole drawn parallel to the axis of the tree and after felling, that line was extended the full length of the bole. The north-facing line was used for subsequent analysis of cross sections by quadrants.

After felling, the height of the main bole of each tree from the ground line to about a 1½-inch-diameter top was measured; the bole was then cut into 25 bolts of equal length. If a cut was calculated to be made at a nodal zone, its position was shifted up or down into an internodal zone and height of the new position recorded. Consequently, bolt lengths were not always equal over the length of each bole.

Pertinent data regarding plot elevations and tree sizes and ages within plots are presented in Table 1.

A 5-inch-long section was cut from the top of each bolt for use in laboratory analysis. In addition, the stump was cut at the ground line (the stump height having been included in the length of the first of the 25 bolts) and a 5-inch section cut from the lower end of the stump. A ring count made on the lower end of that section yielded the total age of the tree.

To aid in gathering data from the 5-inch sections, the upper cross-sectional surface of each bole section as well as the bottom of the section cut from the stump was sanded smooth on a power sander and then painted with a 1% water solution of methylene blue, followed by another light sanding of the painted surface. These procedures produced good contrast conditions so that annual rings and aggregate rays could be discerned more easily with the naked eye and a dissecting microscope.

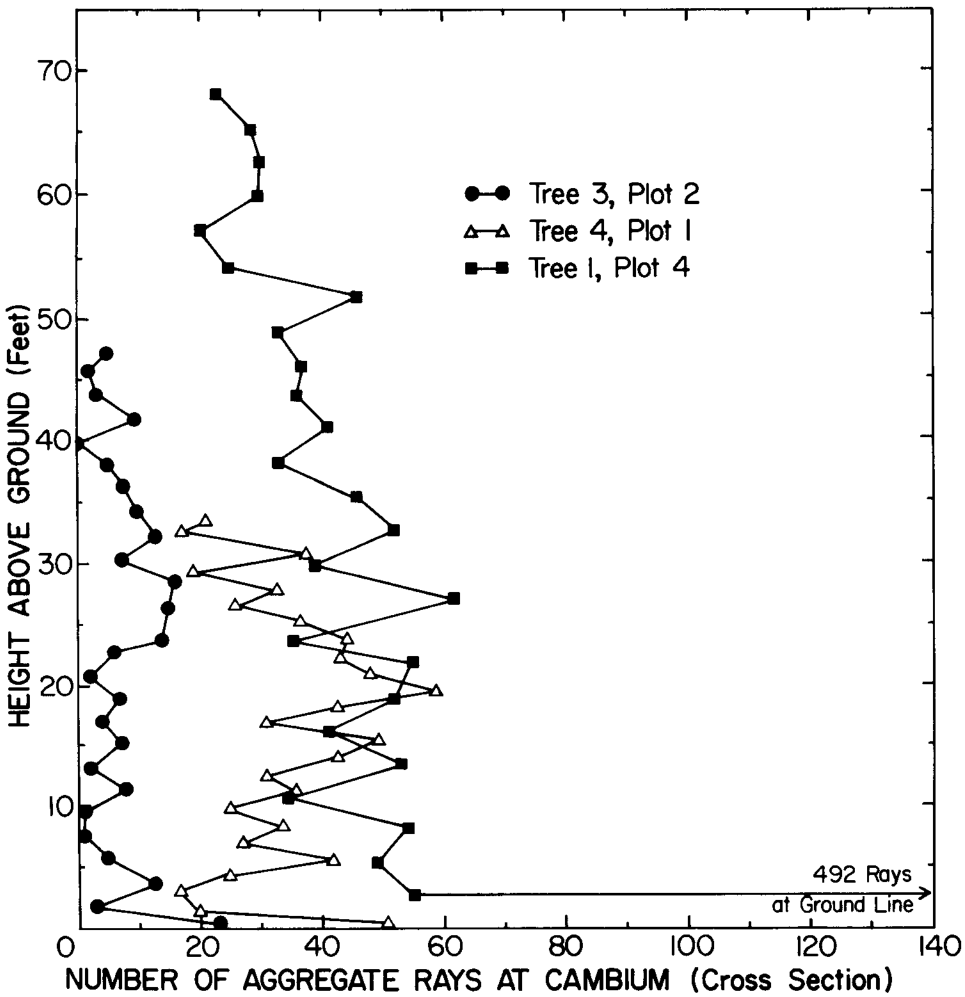

FIG. 1. Example of each of 3 patterns of the relationship between the number of aggregate rays at the cambium (cross-section view) and height in tree as observed in 23 trees of red alder. See text for descriptions of patterns.

Using the north-facing line as a reference, the top of each 5-inch bole section and the bottom of the stump section cut at the ground line were subdivided into quadrants. Measurements made on the top of cross sections were diameter outside bark, bark thickness, number of annual rings, and number of aggregate rays at the outer periphery within each quadrant. Diameter inside bark, circumference inside bark, and quadrant length at the outer periphery inside bark were calculated. Many of the cross sections were eccentric so it was necessary to average the lengths of the long and short axes of the ellipse in order to compute average diameter and quadrant lengths.

From data on aggregate ray counts and quadrant lengths, the average number of aggregate rays per inch in each quadrant and the average number per inch around the outer circumference inside bark were calculated. In addition, the

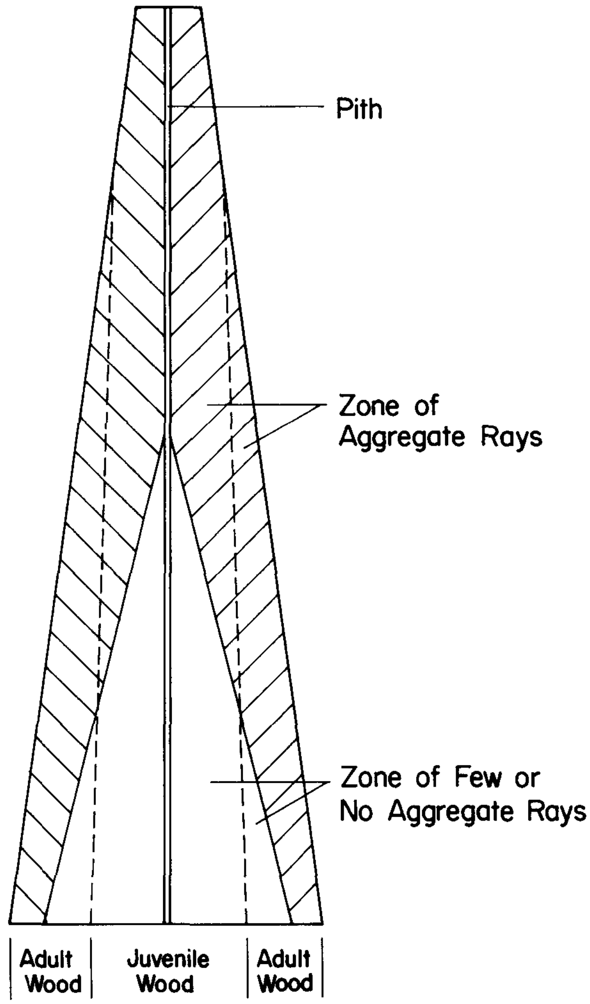

FIG. 2. Radial-longitudinal section of red alder bole illustrating typical distribution pattern of aggregate rays.

approximate age at which most aggregate rays were initiated was determined by counting the number of rings inward from the cambium to the point of initiation of a ray and then subtracting that number from the total age of the tree as determined by a ring count of the cross section at ground line.

Determination of the age of ray initiation was subject to error because of the following facts. When either a simple or aggregate ray is initiated at the pith or at some point in the xylem, it consists of only one or a few cells. As the ray increases in length radially, it also increases in height longitudinally until a maximum height is reached. Thus, a complete ray in a radial-longitudinal section through its center will appear wedge-shaped from the point of its initiation outward to its maximum height and then will continue at that constant height to the cambium and into the inner phloem. Therefore, when determining the age at which a ray is initiated as viewed on the cross section, the exact age of ray

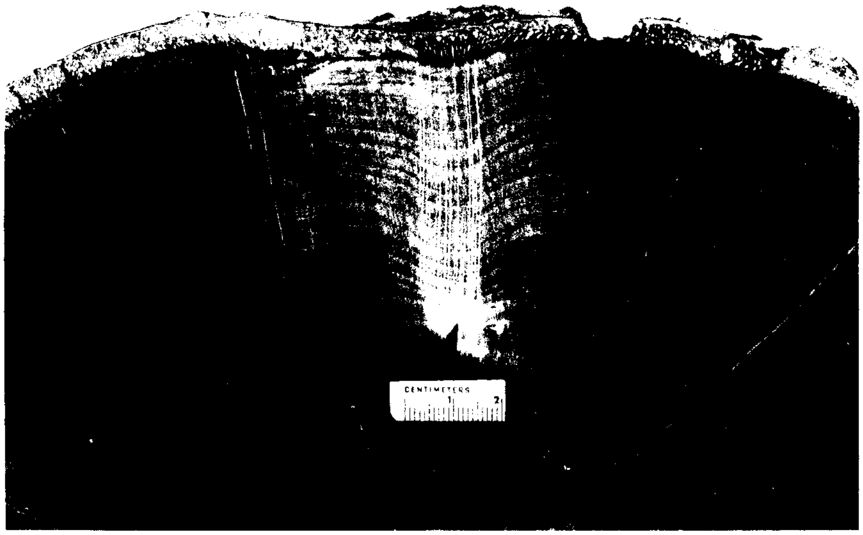

FIG. 3. Cluster of aggregate rays initiated at frost ring injury whose location is indicated by arrow. Dark radial lines are checks. Section was taken 22.3 ft above ground from a tree 82.0 ft tall.

initiation will be observed only if the plane of the section is at the midpoint of the ray's height. If the cross section plane is below or above the midpoint of ray height, then the age of initiation will be estimated at a later year than when determined at the midpoint plane. Furthermore, an error in the determination of the age of ray initiation is also introduced if the cross section plane is not perpendicular to the longitudinal tree axis.

RESULTS

Several aspects of aggregate ray distribution were examined as described in the following sections.

Number of rays at the cambium versus height

The relationship between number of rays counted at their intersection with the cambium around the entire circumference of the stem as a function of height was quite variable in the 23 trees although general patterns in tree groups could be discerned. Three patterns were observed as follows:

1. In 8 of the 23 trees, a large number of rays (ranging from 80 to 492) developed at or near the ground line, then dropped rapidly in number at about 5 to 10 feet in height above ground, then remained constant or decreased slightly in number to the top of the tree. Wide fluctuations in number occurred above the 5- to 10-foot level. An example of this pattern is tree 1 of plot 4, age—37 years, DBH—5.1 inches (Fig. 1).

2. In 9 of the 23 trees, the number of rays at or near the ground line varied from none up to about 25, then remained relatively constant in number or either increased or decreased slightly with height although wide fluctuations of 10 to 20

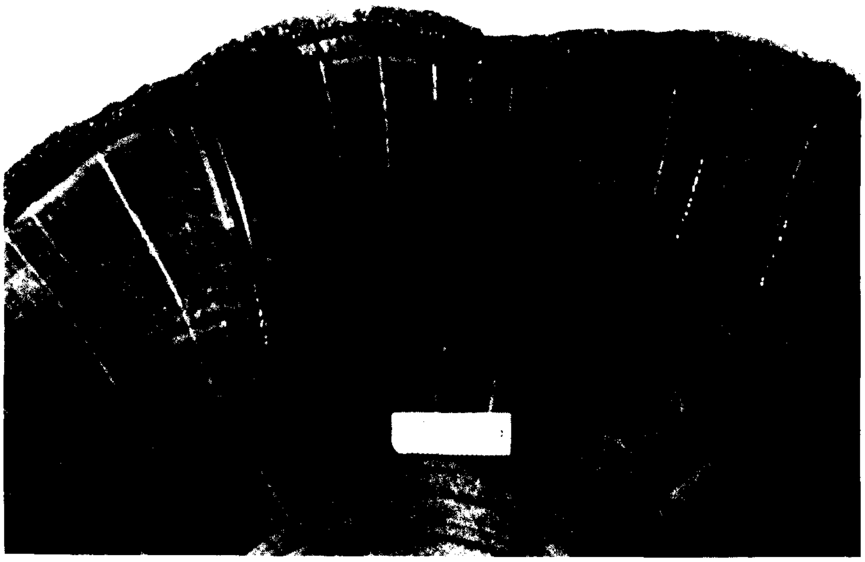

FIG. 4. Cluster of aggregate rays initiated at frost ring injury whose location is indicated by arrow. Section was taken 25.1 ft above ground from a tree 82.0 ft tall (same tree as in Fig. 3).

rays occurred. An example of this pattern is tree 3 of plot 2, age—26 years, DBH—6.2 inches (Fig. 1).

3. The remaining 6 trees exhibited a diversity of patterns of ray number as a function of height. After starting with a varying number of rays at ground line, wide fluctuations in ray number occurred with height and with a general trend of little or no change in number with height. An example of this pattern is tree 4 of plot 1, age—35 years, DBH—12.0 inches (Fig. 1).

Examination of all the plotted data revealed no apparent relationship between tree diameter and the pattern of number of aggregate rays at the cambium versus height. Also, there is no relationship between geographic location and the patterns of aggregate ray number versus height within trees.

Initiation of rays within trees

The method by which the determination of age at which rays are initiated within trees has been described.

In nearly every cross section, one or a few rays originated at the pith but in many trees there was a tendency for a large number of rays to be initiated at points removed from the pith area, particularly at heights ranging from ground line to about one-third to one-half the distance up the bole. Above that height, many rays started at the pith while others started at various radial distances from the pith. Once initiated, however, a ray increased in length outward to the cambium and there was a cone-shaped zone comprised mostly of juvenile wood in which aggregate rays were generally absent and whose tip was at about the mid-height of the tree. The aggregate rays were generally present in a sheath of mostly adult wood surrounding the inner core of juvenile wood in the lower half of the tree and continued into the upper half of the bole, which was comprised mostly

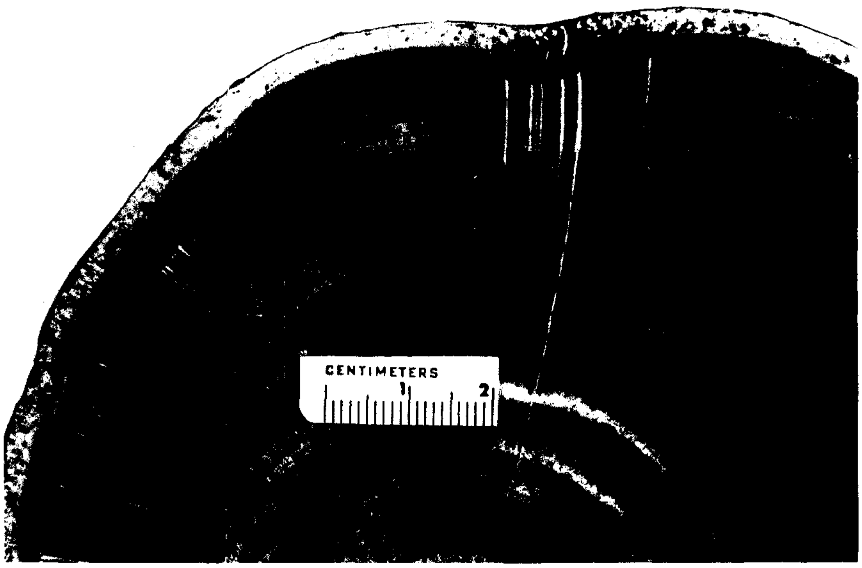

FIG. 5. Cluster of aggregate rays associated with ring indentures or inward curving of rings at two locations indicated by arrows. Section was taken 9.6 ft above ground from a tree 45.0 ft tall.

of juvenile wood and some adult wood. This pattern of distribution is portrayed in Fig. 2.

Two examples of such a pattern are described as follows:

Example No. 1: For tree 3 of plot 1, age was 33 years and tip height was 75 feet. From the ground line up to about 18 feet, rays were initiated between the 14th and 28th year rings (adult wood). Above 18 feet, and continuing to the top of the last section at 66 feet, several rays started at the pith (6th to 27th year, depending upon height), while other rays started at ages varying from the 24th to the 31st year (mostly in the adult wood).

Example No. 2: For tree 2 of plot 3, age was 20 years and tip height was 45 feet. From the ground line up to about 5.5 feet, rays were initiated at the 14th year and continued through 6 rings in adult wood to the cambium. Above 5.5 feet and continuing to the top of the last section at 35 feet, some rays were initiated at the pith while others were initiated anywhere from the 9th to the 16th year and continued mostly in adult wood to the cambium.

These patterns of distribution of aggregate rays largely explain their sporadic occurrence in red alder lumber. When a piece is sawn from the core of juvenile wood in the lower half of a tree, the chance of aggregate rays being present is low; and when a piece is sawn from the remainder of the bole, the chance is high.

Quadrant position effects within trees

To determine whether location within a tree had any effect on distribution of aggregate rays, an examination was made of the data on number of rays counted at their intersection with the cambium within quadrants within each tree as related to height. In none of the trees did there appear to be a tendency for any specific quadrant cross section, i.e., northwest, northeast, southeast, or southwest, to

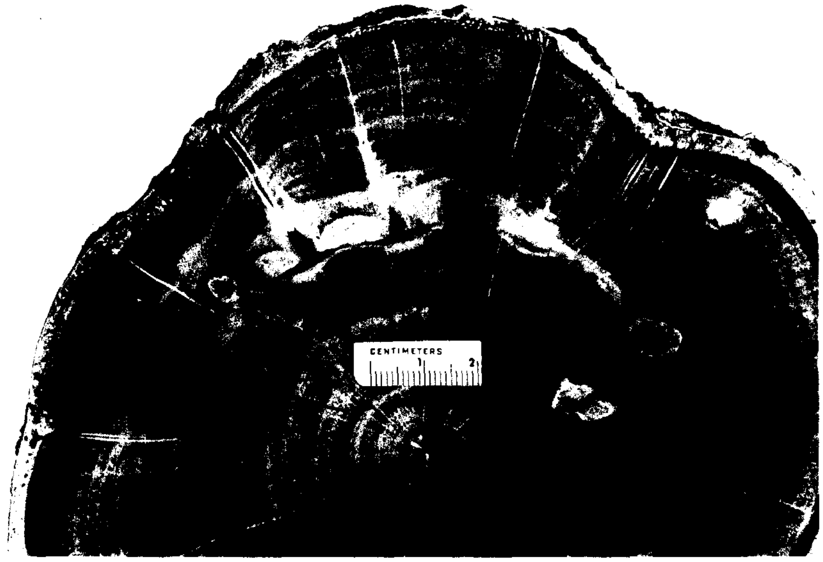

FIG. 6. Cluster of aggregate rays associated with ring indentures or inward curving of rings at two locations indicated by arrows. Several aggregate rays start at or near pith and others are associated with injuries. Section was taken 19.3 ft above ground from a tree 50.6 ft tall.

exhibit an increasing or decreasing trend of aggregate ray number with height. In general, there appears to be no influence of quadrant position within a tree on number of aggregate rays as related to height.

Development of ray clusters

Development of aggregate ray clusters was associated with unusual growth conditions as observed on the cross section in the following ways:

1. The present of a frost ring injury frequently triggered the initiation of aggregate rays, sometimes in large numbers and closely spaced. The injury may extend partly (Figs. 3 and 4) or wholly around the tree.
2. A cluster of rays was frequently located within an inward curving group of rings or indenture that usually occurred near the periphery of a cross section (Figs. 5 and 6).
3. When branch traces were present on a cross section, a cluster of several closely spaced aggregate rays was frequently associated with such traces (Figs. 7 and 8).

The reason why ray clusters were initiated or associated with the conditions described above is unknown. Perhaps hormonal mechanisms or growth stresses were involved. Nothing similar or identical to the above phenomena is known to occur in other species.

CONCLUSIONS

In the 23 trees that were examined, three patterns of distribution were determined for the relationship between the number of aggregate rays counted at the cambium on the cross section and tree height.

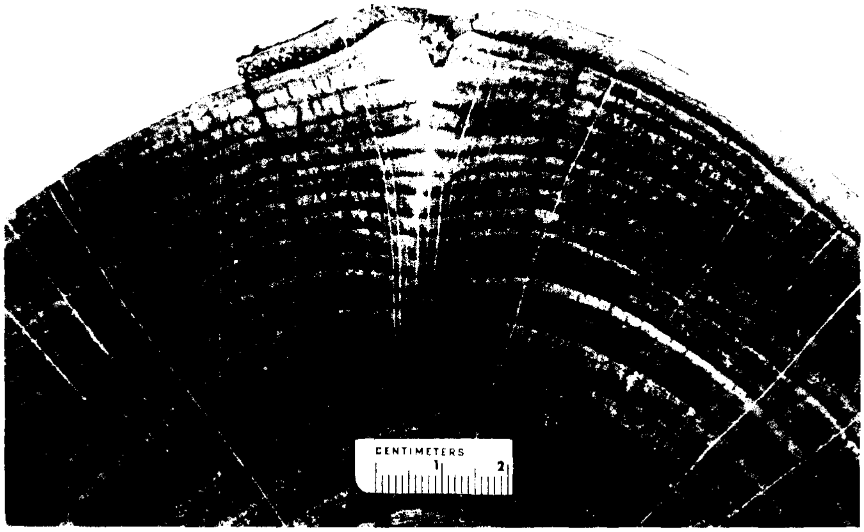

FIG. 7. Cluster of aggregate rays indicated by arrow associated with branch trace which emerges near cambium at top of section. Height of section is 9.7 ft above ground from a tree 64.3 ft tall.

In all trees, aggregate rays were virtually absent in a cone-shaped zone of juvenile wood in the lower half of the tree bole but were present in varying numbers in the sheath of adult wood surrounding the juvenile core in the lower half of the bole and in the juvenile and adult wood in the upper half of the bole.

FIG. 8. Cluster of aggregate rays indicated by arrow associated with branch trace which emerges near cambium at top of section. Height of section is 37.5 ft above ground from a tree 63.0 ft tall.

That pattern explains their sporadic distribution in alder lumber. Therefore, when reducing logs at a sawmill, pieces of red alder lumber with the greatest number of aggregate rays would be obtained from jacketboards cut from the outer portion of butt logs and from all boards cut from other logs located higher in the tree. Segregation of such material is feasible.

For the majority of trees in the sample, there is no tendency for rays to be confined to any particular quadrant within the length of a bole. Therefore the distribution in cross sections from ground line to tip of a tree is essentially random.

There is no relationship between tree diameter and number or distribution of aggregate rays as seen on the cross section.

Frost ring injuries, indentures or undulating rings, and branch traces are locations at which clusters of closely spaced aggregate rays frequently develop. The mechanisms responsible for their development are not known.

REFERENCE

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