Reprinted from ECOLOGY, Vol. 22, No. 2, April, 1941
Printed in U. S. A.

RING GROWTH IN THREE SPECIES OF CONIFERS IN CENTRAL WASHINGTON

RING GROWTH IN THREE SPECIES OF CONIFERS IN CENTRAL WASHINGTON *

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The measurement of tree rings and their correlation with precipitation have been studied to some extent in the Pacific Northwest. Marshall ('27) studied the relation of precipitation cycles to the growth of western white pine (*Pinus monticola*) in Idaho. He found that the climate of northern Idaho as reflected by the growth of white pine indicates wet and dry periods varying in length from 20 to 40 years. Keen ('37), in an intensive study of ring growth for 650 years in western yellow pine (*Pinus ponderosa*) in eastern Oregon, found a significant correlation between annual precipitation and tree growth, but no indications of a general trend toward drier or wetter years during this period. Average growth for the 20 year period 1900 to 1919 was identical with the average growth during the past 650 years. There were important fluctuations in growth throughout the entire period with alternate periods of good and poor growth. Growth in 1931, the poorest year, was 68 per cent below normal. Meyer ('34) found the same general tendencies in ring growth studies in the Blue Mountains of Oregon and northward throughout eastern Washington. Douglass ('28) analyzed ring growth for long periods in western yellow pine in eastern and southern Oregon, and in Douglas fir (*Pseudotsuga mucronata*) in western Oregon. He also secured increment cores from yellow pine and Douglas fir at the Wind River Experiment Station, Washington, but these showed erratic growth, and were not used in the study of cycles. Lyon ('36) correlated ring growth in hemlock (*Tsuga canadensis*) with precipitation in New England and reviewed the significance of ring growth studies in New England and parts of the Middle West. The work of Douglass ('19, '28, '36) carried on in Southwestern United States over a long period is the most intensive and valuable in this field.

This paper is concerned with the early ring growth in three species of conifers; western yellow pine, western larch (*Larix occidentalis*), and Douglas fir, and its correlation with precipitation since 1900. Douglass has shown that a high degree of correlation exists between radial growth and annual rainfall in Arizona. This is especially true where the annual precipitation is at a critical minimum and slight variations are reflected in the width of the annual ring. Diller ('35) in studying radial growth in beech (*Fagus grandifolia*) in northern Indiana, found that the radial growth usually varies inversely with the June temperature and directly with June precipitation. He also noted several instances of a one year lag in response to annual precipitation, which were caused by an accumulated moisture deficiency from droughts of the preceding year or years. Burns ('29) in correlating rainfall with the width of annual rings in Vermont stated that there can be no direct correlation between rainfall and radial growth because the width of the ring at any one point is not an index to the total increment, and soil moisture is not a measure of rainfall or food supply. Lyon ('36) says that ring growth data should be used with constant appreciation that they involve the response of living organisms to many factors internal and external even though one or more factors may dominate. The author (Hansen,

* Published with the approval of the Monographs Publication Committee, Oregon State College, as Research Paper, No. 40, School of Science, Department of Botany.

† The author thanks Dr. D. P. Rogers, Botany Department, Oregon State College, for reading the manuscript.

'38) in studying ring growth in Engelmann spruce (*Picea engelmanni*) near timberline in southeastern Wyoming found that constant prevailing winds, snow-shear, and a short period of favorable temperature were the chief limiting factors for maximum growth. It is obvious that the maximum radial increment in trees occurs when all of the factors that affect growth are at an optimum and at the same time in proper adjustment with one another. The optimum of each physical factor may vary, and the interplay of these factors further increases the possibilities of variations. Climate is probably the most unstable factor of the environment, and some correlation between climatic fluctuation and ring growth may be expected. Temperature and precipitation are perhaps the chief opposing factors, and their proper physiological compromise is essential for maximum growth. The advantage afforded by the optimum of one may be diminished by the excess or deficiency of the other. The temperature of the atmosphere and soil in part determines the relative income and outgo of water, and thus indirectly regulates the water relations of the plant. It is apparent that the total rainfall in an area is not necessarily an index to the amount available for tree growth, of which radial increment is a function. The time, amount, intensity, type, and frequency of precipitation, in conjunction with the depth, porosity, water holding capacity, and structure of the soil, and the topography, control the amount of water retained. Once the water is in the soil, the temperature, hydrogen-ion concentration, structure, and texture of the soil further control the amount of water available for absorption by the plant.

Climate and Phytogeography

The forest area from which the cores for study were obtained is located in section 8, of T. 21 N., R. 20 E. on the Wenatchee, Washington, Quadrangle, about 6 miles south of the city of Wenatchee. The elevation is about 2500 feet above sea level. In general, this area slopes sharply toward the east and is drained by Squilchuck Creek, which empties into the Columbia River a few miles to the northeast. The soil is sandy and shallow, and is derived from the Swauk Sandstone formation. Rock surfaces are exposed on the southern slopes, where the scanty vegetation has allowed erosion to occur.

Meteorological records kept since 1900, two miles to the north and 4 miles southwest of Wenatchee at an elevation of 2200 feet, show a mean annual precipitation of 12.77 inches. Less than 30 per cent occurs during the growing months, and the steepness of the terrain results in a high percentage of runoff during the winter when the ground is frozen, or during heavy rains. This is shown by the damage caused by a heavy rainfall in September, 1925, when Squilchuck Creek which drains a small watershed carried such a large volume of water as to remove houses from their foundations and carry automobiles for considerable distances near the mouth of the stream. The mean annual temperature is 48 degrees F., with the months of December, January, and February averaging below freezing. The summer temperatures are high, and with the low summmer precipitation these factors are neither at an optimum nor in adjustment with each other for tree growth (table I).

TABLE I. *Average monthly precipitation and temperature near Wenatchee, Washington, for 31 years*

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Precipitation; inches	1.81	1.50	.89	.54	.93	.78	.45	.31	.75	.90	1.86	2.07
Temperature; degrees F.	24.7	30.2	40.0	48.2	55.8	62.8	70.6	69.5	60.2	49.8	36.4	27.6

The area lies within the Arid Transition (timbered) Zone (Piper, '06), which in Washington is characterized chiefly by forests of western yellow pine. This grades into the Arid Transition (timberless) Zone at lower elevations to the east, and into the Canadian Zone at higher elevations to the west. The timbered Arid Transition Zone is confined to a narrow strip along the eastern slope of the Cascades in this region because of the rapid change in elevation and a corresponding variation in precipitation and temperature. Zon ('24) includes this area within the Douglas fir-yellow pine forest, while Clements' classification of the major North American vegetation climaxes places it within the larch-pine association of the Coast Forest (Weaver and Clements, '38). The latter classifies it as a transition forest between the Cedar-hemlock formation of the Coast Forest and the Montane forest farther to the east. Forest Type Maps ('36) designate this area as supporting a western yellow pine type of several size classes, with the smaller sizes predominant. Yellow pine is also climax in this area, and there is no disclimax or subclimax. When the pine is removed, it re-enters with no intermediate arboreal successional stage. Douglas fir and larch are not as abundant as pine at this elevation and proximity to the timberless zone. Other trees present include lodgepole pine (*Pinus contorta*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), and lowland white fir (*Abies grandis*). The last two are present chiefly on protected sites and near streams.

Precipitation is probably the chief limiting factor in the growth of trees in this area, and the nearness of the timberless zone indicates the presence of unfavorable conditions. Larsen ('29) in studying forest succession in northern Idaho found that yellow pine will exist with the least amount of moisture, followed by Douglas fir and then larch. With respect to tolerance pine is the least, while Douglas fir is the most tolerant of the three. Yellow pine is the least exacting as to soil requirements, while larch is the most so. Sudworth ('08) stated that the principal occurrence of yellow pine is in regions where the mean annual precipitation varies from 10 to 50 inches, but an annual precipitation of less than 20 inches probably limits its development in commercial quantities. Larch has the most restricted range, which suggests that it is more exacting in its requirements than the others. It thrives best in regions that have from 20 to 30 inches of rainfall per annum.

Methods and Results

Increment cores were taken in October 1938 with a Swedish increment borer in a north-south direction from normal appearing trees. Isolated trees apparently growing under similar conditions were selected so as to avoid abnormalities in development caused by nearness to others. Sufficient cores were obtained so as to have ten of each species showing no eccentricity of growth, fire scars, nor erratic development of any kind. The cores were mounted in grooves in small boards similarly to the method employed by Diller ('35). Half of the core was exposed and then smoothed down by fine sandpaper. The ring width was determined with a steel rule graduated in hundredths of an inch, and through a wide-field binocular microscope with a $10\times$ eyepiece and a $7.5\times$ objective. The average of the two radii was used and there was little or no deviation from the sequence of highs and lows for both radii. The ages of the trees varied somewhat; in pine from 56 to 100, larch from 26 to 86, and Douglas fir from 26 to 80 years. The average age for ten of each species was pine 73, larch 50, and Douglas fir 55. The rate of growth during the life of a tree is not constant, and the average of ten trees of different ages may tend to lessen the degree of correlation with the climate and with one another. Intraspecific cross identification was readily effected and perfect agreement with respect to increase and decrease in ring width occurred for many years,

TABLE II. *Number of years of positive response of ring growth with annual rainfall for 36 years*

	3 species	Yellow pine	Western larch	Douglas fir
Annual precipitation	8	14	19	22
Mar. to Aug. precipitation (incl.)	9	11	19	23
Modified annual precipitation	7	12	19	19

and in several cases almost perfect correlation existed for the life span of two individuals. Interspecific agreement was noted for many years between individuals, while the correlation of the average ring width between the three is also to be noted for several years. The curve of pine is represented by the average of ten trees for the last 50 years, that of larch and Douglas fir for the last 20 years only. The average ring width in pine is .052, larch .058, and Douglas fir .068 inches. Although in a yellow pine climax, this species is not living under optimum conditions, as is evidenced by the limited annual ring increment. The maximum average for a single year is pine .086, larch .109, and Douglas fir .115, while their minimum averages are .017, .017, and .025 inches respectively. The maximum differences between average ring widths for successive years are pine .033, larch .038, and Douglas fir .047 inches.

The absence of complacent ring sequences and the presence of sensitive rings throughout reflect the fluctuations of the adverse environment. Complacent rings are those uniform in width year after year, and indicate the presence of optimum and stable conditions (Glock, '37). Sensitive rings are those that show annual variation, indicating that the environment is neither stable nor constantly at an optimum.

CORRELATION OF RING GROWTH WITH PRECIPITATION

The average annual ring width for each species was correlated with the total rainfall for March to August inclusive, the annual precipitation, and a modified annual precipitation. Each species was also compared with the other two, and the number of times of agreement of all three with precipitation was noted (tables II and III). The method of correlation is that used by Lyon ('36) which consists of tallying changes from year to year. Each time the curve of a species increased or decreased with precipitation or with that of the other species it was considered as an instance of correlation. Agreement of ring width variation with the three

TABLE III. *Times of agreement of increase or decrease in ring growth of each species with the other two species (80 years)*

	Yellow pine	Western larch	Douglas fir
Yellow pine		40	37
Western larch	40		41
Douglas fir	37	41	

forms of precipitation curves did not differ sufficiently to warrant any general conclusion. Correlation of the three with six months precipitation occurred 9 of the 36 years of weather records. Douglas fir showed the greatest amount of concurrence with 23 times, while pine the least with only 11, and western larch 19 times (fig. 1*A*). Agreement with each other was greatest between Douglas fir and larch with 41 times out of 80, the number of years represented in the curves. Pine and Douglas fir coincided least with 37 times, while concurrence of all three occurred 24 times. This seems to be a fairly high degree of correlation, considering the diverse requirements of the species concerned and the different ages of the individuals of each species. These data tend to show that yellow pine was least sensitive to variations in rainfall for the six months, while Douglas fir responded positively most often.

In tallying with annual precipitation the three were in agreement 8 times, pine 14, larch 19, and Douglas fir 22 times (fig.

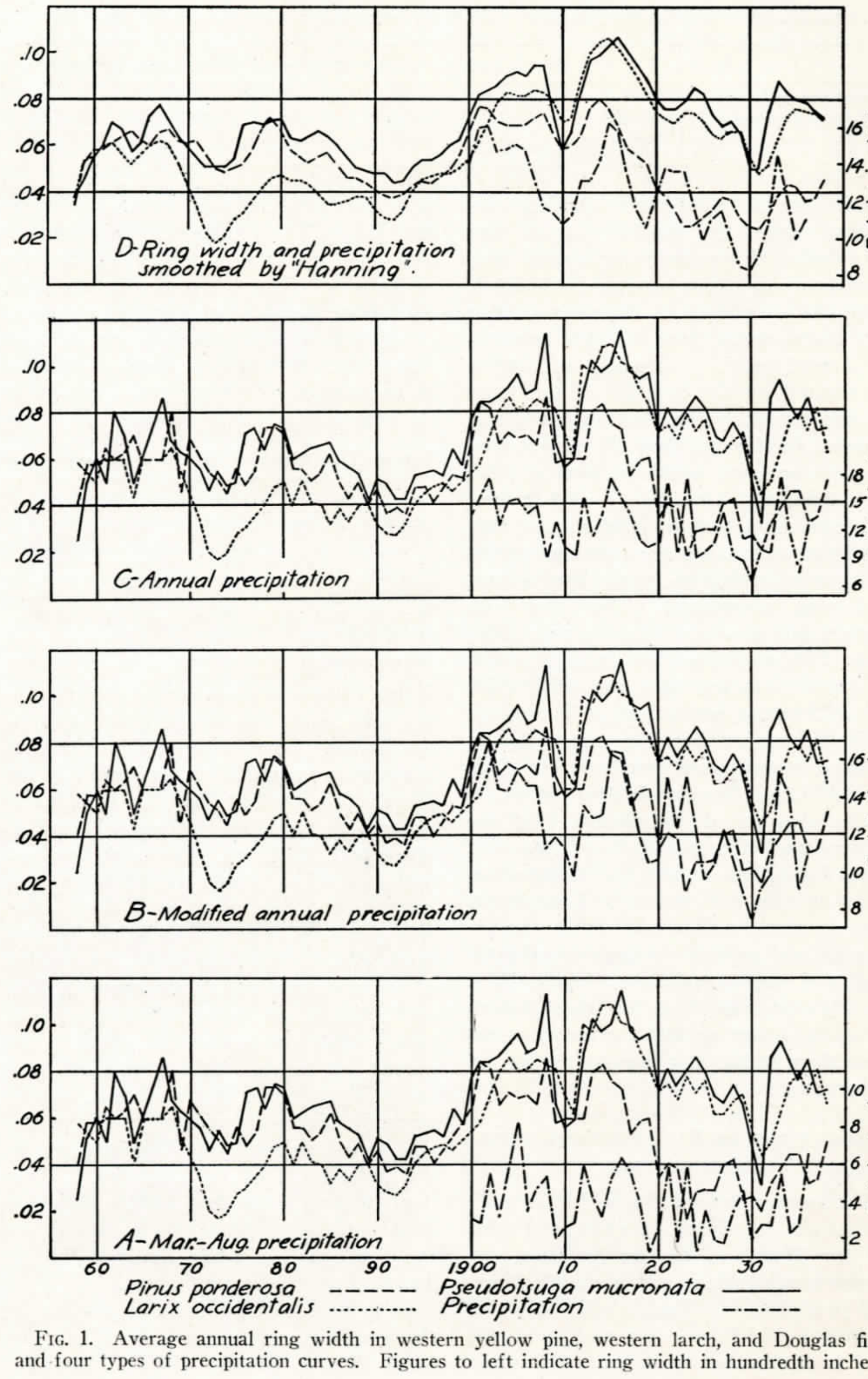

Fig. 1. Average annual ring width in western yellow pine, western larch, and Douglas fir, and four types of precipitation curves. Figures to left indicate ring width in hundredth inches.

1*C*). This makes a total of 63 as compared with 62 cases of agreement for the six months rainfall. Pine responded positively more often with the annual precipitation, larch the same, and Douglas fir less, although the differences are so slight as to be non-significant.

Another comparison of ring growth and precipitation was made by taking the average of the previous year's and twice the present year's precipitation. This was done with the belief that the precipitation of the previous year may be reflected in ring growth because of its carry-over, but not so much as that of the current year. By this method agreement occurred 12 times for pine, and 19 times for Douglas fir and larch. In several cases this eliminated the one year lag in response, but did not effect more correlation than with the six months' total (fig. 1*B*). Agreement of all three occurred 7 times.

A one year lag in response to precipitation is to be noted for all three in several cases. In 1930 precipitation for the six months was only 2.04 inches, but was not reflected by ring growth until 1931. The lowest annual average ring growth for all individuals of the three species occurred during this year, which was also the poorest year for yellow pine in eastern Oregon (Keen, '37). Likewise, a low rainfall of 1.29 inches in 1919 was not manifested by ring growth until 1920, when all three species decreased sharply. There are other minor instances of this latent response. The response to precipitation may be reflected during the current or following years in different degrees, depending upon the amount of the previous year or years. A sharp decrease in precipitation followed by a sharp increase may not be reflected to any great extent either year, because of the accumulated deficiency or carry-over of soil moisture from the previous years. This point is illustrated by the response of yellow pine to the annual precipitation from 1921 to 1926, and of all three from 1907 to 1915 (fig. 1*C*).

The curves of the three species were smoothed by computing the running mean of three with double weight on the middle term. This is Hann's formula and is known as "Hanning" (Douglass, '36). It is used to show the general trends of growth by eliminating small annual fluctuations (fig. 1*D*). The curve of the annual precipitation was smoothed by the same formula, and while it increases the amount of correlation it is probably of no significance. It does eliminate lags in response to rainfall, but it is obvious that the precipitation of one year does not influence ring growth of the preceding year. The smoothed ring growth curves show a close relationship in the general trend of growth for the three species and some correlation to the smoothed precipitation curve. This may suggest that there is a long cycle response to precipitation which is not reflected from year to year.

Pine shows the least annual fluctuation, suggesting that the prevailing conditions are more suitable for it than for the other species, or that it is less sensitive to periodic changes in the physical factors affecting growth. The deep root system of yellow pine may be responsible for its lesser agreement with rainfall fluctuations. The maximum development of Douglas fir in the cool, moist Puget Sound region is proof in itself that both the low precipitation and the high summer temperatures are the limiting factors in its growth in the area of this study. The limited growth of all the species indicates that the environment is far from an optimum, or if any one factor is at an optimum it is not in proper adjustment with the other dominant ones. The slightly greater positive response of

(*A*) Total rainfall from March to August inclusive; (*B*) Annual precipitation modified by the average of twice the current and once the preceding year's rainfall; (*C*) Total annual rainfall; (*D*) Annual precipitation and ring growth modified by average of a running mean of three years' rainfall with double weight on the middle term.

Douglas fir may be the reason for its greater ring growth, at least during its earlier life. Evidently the high summer temperatures tend to minimize any positive effects of the limited precipitation.

Summary

A study of radial growth in western yellow pine, western larch, and Douglas fir in central Washington near the lower edge of the Arid Transition (timbered) Zone revealed a limited annual ring growth. Of the three species studied yellow pine exhibited the least and Douglas fir the greatest growth.

In correlating ring growth with precipitation for 36 years, Douglas fir responded positively most often and yellow pine the least. There was little difference in the degree of correlation with the annual, March to August, and a modified annual precipitation curve. The limited ring growth indicates that the physical factors of the environment are neither at an optimum nor in adjustment with one another. The low summer rainfall and the high temperature seem to be the dominant opposing factors which prevent normal growth.

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