

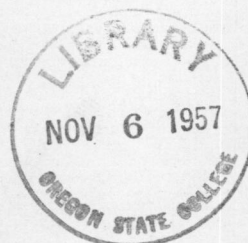
7.17

G R O W I N G   Q U A L I T Y   T I M B E R

SUBMITTED MARCH 17, 1933

by

Conrad P. Wessela



FOND  
1933

1933-1934

## INTRODUCTION

### Importance of Growing Quality Timber.

In growing timber crops, as in other business enterprises, the main incentive for expansion lies in greater profits resulting from decreased costs or larger gross returns or both. (1) (Numerals refer to literature cited) Increased revenue in forestry lies in three main fields, namely; enlarged merchantable yields per acre per year, improved quality of raw products, and closer and better utilization including the development of new uses of wood. (2) (3) (4) This paper will deal principally with the second of these fields, the improvement of the quality of raw products.

The numerous and changing environmental factors which each forest tree species grows are known to modify its structure, and to some extent its chemical composition (1) (5). Since it is the structure and chemical composition of any material that determines its properties there consequently is considerable variation in the proportions of wood produced under different growth conditions. (1) This principal is already well known, in general, but just what the detailed relationships are between environment of the tree and the intrinsic properties of the wood is almost unknown (1).

Even the intrinsic properties of wood do not necessarily determine its final value. There is considerable opportunity for improving the value of a species of wood as a whole by modification of properties, by proper grading, by improved and specialized manufacturing processes, and by better design; all



of which aid in developing new uses so that markets may be made where none now exist. (1) Viewed from this angle the field of improving the quality of wood is intimately connected with improved utilization.

### Historical

Little attention, so far, has been paid to improving the quality of growing timber through scientific application of biological principles in which sciences such as physiology, morphology, ecology, anatomy, genetics, soils, biophysics, and biochemistry play important roles. In this respect forestry is fully 60 years behind that of agriculture. In a letter to Professor J. J. Starker of Oregon State College, Arthur Koehler makes the following statement: "I wouldn't say that foresters have made a mistake in the past in not recognizing differences in the quality of wood of trees growing under different conditions, since they have had their hands full and were not in a position to accurately appraise the quality of wood, but I think it is high time that more attention is paid to quality and less to volume production in our reforestation programs."

Certain European investigators have attacked the problem from certain angles, however their results are hardly applicable. Benson H. Paul and Arthur Koehler, both under the auspices of the Forest Products Laboratory at Madison Wisconsin, are pioneers in the field in America. A large percentage of this paper is taken from the results of their investigations.

### Quality of Wood Desired.

Just what improvement in the quality of wood should be striven for needs careful consideration of requirements and

possibilities. That clean, straight, tall boles with little taper are more desirable than crooked stunted ones goes without saying, but wood of low density should not necessarily be considered inferior or part growth superior. The only criterion of quality is the requirements of the industries which are influenced by substitutes on the one hand and by the development of new uses on the other hand. A study of use requirements therefore is imperative in any program of silvicultural management (1).

#### Scope of This Paper.

This paper is not original in any way, but is merely a brief review of some of the more important American literature on the subject of growing quality timber. Since utilization is so intimately connected with the production of quality wood, each tree species (in so far as practical) will be considered first from the standpoint of its uses and the qualities desired for those uses and then the silvicultural practices which will tend to produce the desired qualities. This method of procedure may not at all times be considered in the above order due to lack of information, in which case a general discussion of the factors effecting the growth of the particular species in question will be discussed.



## GROWTH IN TREES

A tree may be considered as a tall cone of wood<sup>d</sup> terminating in leafy expanses. The base of the cone is subdivided into myriads of rootlets, through the surfaces of which the soil-solutions enter, and the water passing upward is transpired from the leaves. The trunk of the tree is composed largely of dead cells, but enclosing it is a thin sheet of spindle-form cambium cells in 2 to 10 or more layers which in the growing season enlarge in thickness and divide lengthwise, those on the outside becoming transformed into cork and phloem and those on the inner into wood cells and vessels. Extending from the center of the trunk are thin sheets or rays of the medulla or pith of the young stem. The most recently formed cells of these elements are still living and in some trees the medullary cells remain alive for several years, so that the woody cylinder of the trees may comprise wood cells or tracheids, vessels, and thin-walled ray cells, some of which are alive (24).

The greatest amount of increase or change in volume is that which results from multiplication by fission of the cambium cells, and their enlargement accompanied by the differentiations mentioned all based upon hydration of cell-colloids (24).

Growth in organisms is essentially a hydration of colloids of protoplasm accompanied by metabolic changes which result in the conversion of materials in the cell sap to the emulsoid condition characteristic of living matter. Both processes, one of adsorption and the other a result of shifting equilibria in chemical systems, cause an increase of the volume of the pro-



toplasm and the enlargement of the cell mass of which it forms a part. (24)

Trees often show a surprising variation in the amount of height and diameter growth of the same tree in different years (6). This suggests a similiar variation in the factors which promote or effect tree growth. The factors recognized by ecologists and silviculturists as effecting tree growth are temperature of the air and soil, solar radiation, humidity, precipitation, wind, impurities in the air, quality of the soil, biotic agencies, fire, and mechanical imjuries. All of these factors are known to effect either directly or indirectly the quality of wood produced in forest trees. The problem then lies in controlling these factors so as to produce the quality of wood required by the industries. However, before controlling any of the factors which effect growth it will first be necessary to know what part each factor plays in the growth of wood.

As has been indicated above in this paper, very little investigative work has been performed regarding the factors which effect growth. For instance, every forester knows that trees lay on a ring of wood each year, but how many know what causes a variation in the density of the wood in each ring, that is spring and summer wood. Sachs and De Vries attempted to explain the formation of summerwood by rind or bark pressure. (25) However, this theory has been refuted, and the most common excepted theory of today is that the formation of dense wood in the late summer is caused by water relations (25).

From the above discussion it obviously is somewhat of a

problem to control any of the factors effecting growth. However, some of the factors can be controlled to some extent. Prominent among such factors are light, fertility of the soil, and to some extent, soil moisture.

## RING POROUS HARDWOODS

White Ash(*Fraxinus Americana*).

### Uses and desired qualities.

White ash is used principally in the handle and vehicle industries, which calls for a high quality material particularly strength in bending. Consequently wood of high strength properties is desirable and will bring in the highest prices. (The Forest Products Laboratory has found that specific gravity is in direct proportion to strength. Therefore, wood of high specific gravity is of high strength qualities.)

### Geographic distribution in relation to specific gravity.

Benson H. Paul (7) in investigating the strength and properties of white ash as related to growth conditions found that there was little or no striking difference in the specific gravity values for white ash from different parts of its range. He goes on to state that the only feature that could be attributed directly to the influence of locality was found in the wood from the lower portions of the trees which were cut from the over flow bottoms along the Mississippi River. This wood was lower in specific gravity than wood from cross sections in the trees 16 or more feet higher up, in contrast to the wood from all the other places where the wood at the base of the white ash trees was heavier than higher up in the trees.

The above results are striking in view of the fact that white ash has such a wide range. The temperature, soil, and moisture conditions certainly vary a great deal over such a wide range, yet these primary factors which supposedly effect



the quality of wood produced in timber seemingly fail to modify the specific gravity of white ash.

Relation of width of annual rings and rate of growth to specific gravity.

Most foresters and manufacturers have always considered hardwoods (ring porous) of slow growth as inferior to that of fast growth with the consequent wide annual rings. Laboratory experiments (8) have proven that hickory of slow growth was sufficiently heavy and possessed satisfactory strength properties. However, when individual specimens exhibiting low specific gravity were considered with respect to the whole life of the tree, a retardation of diameter growth was revealed (7). An analysis has been made (9) of samples from a great many trees from a number of stands some of which had been subjected to widely diversified conditions at various times. Some stands exhibited very rapid growth; in others, trees of very slow growth were found. In some stands part of the trees had grown rapidly and others slowly, and all intermediate rates of growth were represented. Gradual variations and abrupt changes in rate of growth were found within individual trees. But in spite of the general confusion and apparent lack of uniformity in growth it was found that the specific gravity of the wood in any tree remained quite uniform from its initial starting period until some change, abrupt or gradual, took place which interfered with the normal growth for that tree. Thus a tree which makes a slow beginning nevertheless produces good heavy wood so long as a normally uniform growth

rate obtains; but with the first noticeable decrease in growth rate the specific gravity of the wood decreases as well. When a tree grows rapidly at the beginning it produces heavy wood and continues to do so until some unfavorable development reduces the growth rate. An important fact is that trees in which a falling off had occurred were able again to resume rapid growth and produce wood of superior quality upon the restoration of favorable conditions, even though the unfavorable period had lasted for as long as 100 years (9).

Effect of thinning on quality of wood produced.

Benson H. Paul states (9) that the most common cause of the production of inferior wood is undoubtedly the crowding in virgin forests where trees have carried on a consistent struggle for growing space and plant food elements in the soil. Thus in old stands of ash where the growth of trees has been stagnant for a very long time the percentage of inferior quality is likely to be high. The effect of crowding upon the specific gravity and consequently upon the mechanical properties of ash is illustrated by the following typical examples from the records of the investigation. Wood of white ash from two unthinned woodlots in Ohio showed average decreases in specific gravity of 8 and 11 percent respectively between the wood formed in the early lives of the trees and that produced after the stands had become crowded. In the same locality white ash from a similar woodlot which had been thinned produced wood of uniformly good quality. Similar results of crowding and thinning were observed in two hickory stands, one in Kentucky, and one



in Ohio (9). The thinned stand had made greatly accelerated growth and was producing wood of the highest specific gravity, while a marked decrease had occurred in the unthinned stand even though the trees were 90 years old (9).

### The Hickories

*Hicoria ovata*----*Hicoria glabra*

#### Uses and desired qualities

Hickory is used for the same purposes that ash is used in most cases. The desired quality<sup>y</sup>s in order to obtain maximum profits ~~is then~~ strength.

#### General discussion of factors effecting quality of hickory.

The Forest Products Laboratory, to check the results obtained from white ash carried on a similiar survey with shagbark and pignut hickory since the two woods are essentially similiar in structure . (7) The specific gravity results conformed very closely to those obtained in the white ash. A sustained or an accelerated rate of diameter growth produced wood of non-uniform and lower specific gravity. In this same study the effect of unfavorable soil upon the specific gravity of the wood of hickory was very well shown. (7) Some samples were taken from the south slopes of Mount Logan and some from the north slope. The trees on the south slope were not crowded and were of the slow growing type, relatively stunted in height and diameter growth. The low site quality of this slope is attributed to repeated forest fires, no doubt lessening the moisture holding capacity of the soil and to some extent depleting the soil fertility. The forest conditions on the



north side of the mountain judging from the relative vigor and size of the hickory trees were favorable ~~for trees were favorable~~ for tree growth. The results of specific gravity tests are given in Table. 1. (Taken from U.S.D.A. Tech. Bul. #168).

Table 1.

Situation	No. Trees	Avg. Age	Total ht.	Initial growth		Final growth	
				annual rings per. inch	Specific gravity	Annual rings Per inch	Specific gravity.
North slope	6	90	80	12.5	.833	19.4	.792
South slope	5	70	45	15.8	.803	25.4	.726

The above results certainly collaborate those obtained from tests of white ash and show very clearly the effect of soil fertility and moisture content of the soil upon the specific gravity of two important ring porous woods.

Benson H. Paul in a study of Appalachian hickory (10) found that in old virgin growth trees that the stronger material is found toward the center and the weaker wood toward the circumference of the bole. The material of lower strength in such trees usually included all the sapwood and often a portion of the heartwood as well. This type of wood, concludes Paul, was of very slow growth representing a period of great retardation of the growth rate in the trees brought about by many years of competition in the Virgin forest. Brashness in Appalachian hickory is also largely the result of retarded growth caused by competition for light, moisture, and nourishment in the virgin forest (10). Generally such wood is more prevalent in the sapwood than in the heartwood in virgin timber, however it may be present in both. Brash hickory is re-

latively soft and of light weight, possessing characteristics similiar to the mountain oak and yellow poplar (10). Paul in this article (10) points out that brash hickory can be used for many purposes where hardness and strength are not prime requisites.

### Conclusions

1. Geographic distribution has very little effect upon the quality of ring porous wood produced.
2. The width of the annual rings is not necessarily an indication of the strength of the ring porous wood.
3. Anything which destroys the uniformity of the annual growth, however, effects the strength of hickory and ash. The wood of slow but uniform growth from the center of the tree may be of high quality, while wood of slow growth from the outside of the same tree is sure to be poorer if an interval of faster growth has intervened, or if the outer growth is slower than that about the center. On the other hand the more rapidly growth at any period in the life of a tree is likely to be excellent.

### Diffuse Porous Hardwoods

#### Rock Elm(Ulmus racemosa)

Rock elm is not, strictly speaking, a diffuse porous hardwood nor is it, strictly speaking, a ring porous wood. For this reason it was ~~selected~~ by the Forest products laboratory as representing a wood intermediate in structure between ring porous and diffuse porous hardwoods. (7) The results obtained



conformed very closely to those for the white ash and hickory in regard to the relation between growing space and specific gravity. (7)

#### Sugar Maple (*Acer saccharum*)

In studying sugar maple the Forest Products Laboratory (7) selected specimens of wood from Southern Michigan, Northern Ohio, and the Adirondack region of New York. Specimens from forty four trees were selected from eight localities. The trees were divided into two groups, those showing a decreasing rate of diameter growth and those maintaining the initial rate of this growth. In averaging the results obtained in specific gravity tests for the two groups the author finds that those trees grown at a uniform rate have a specific gravity of .057 more than those grown at a decreasing rate of diameter increase for the final growth period. (7) In the initial growth period the results show a difference of .015 in the specific gravity between the two groups of trees referred to above. The number of annual rings per inch in both groups, in general, appear to be related to the specific gravity; the less the number per inch the greater the specific gravity, however, a few discrepancies occur indicating that other factors other than the rate of growth affect the strength of wood. (7)

#### Yellow Poplar (*Liriodendron tulipifera*)

In the same investigation mentioned above, the wood of yellow poplar was investigated as a typical diffuse porous wood. (7) The yellow poplar trees studied gave wider variations in specific gravity than the sugar maple trees, but like the latter



they showed less abrupt changes in specific gravity with the retardation of the growth rate than the typical ring-porous species investigated. (7) But whenever prolonged suppression of growth occurred, the severity of the suppression was reflected in a lowering of the specific gravity of the wood. Similarly, old virgin growth trees responded readily to improved conditions of growth, effected by a thinning of the original forest stand. (7)

The wood of second growth yellow popular trees was heavier than that of the old virgin-growth trees, which had struggled for many years under the crowded conditions of the original forest. In the second growth the wood of 14 trees under 150 years of age had an average specific gravity of 0.460 while that of 11 older virgin growth trees averaged only 0.426. (7)

Relation of Specific Gravity to the  
Structure of the Annual Ring  
in Hardwoods.

In ring-porous wood a retardation of the rate of growth brings the rows of large open pores in successive annual rings closer together by reduction in the amount of thicker-walled summer wood cells. (7) This leads to the conclusion that some unfavorable growth condition occurred during the summer months thereby decreasing the amount of heavy thick-walled cells grown during that time. The result of such a condition is lighter wood with the consequent decrease in strength. (7)

In diffuse porous wood less contrast exists in the portion of the annual rings formed during the early and during the later

parts of the growing season, so that the first gradual retardation of radial growth may not be reflected in the specific gravity of the wood. (7) However, a continuation of adverse growing conditions produces not only narrower rings but also forms rings more porous so that the wood is correspondingly lighter. Thus it is evident that <sup>in</sup> the ~~in~~ ring porous species and in diffuse porous species the results are essentially the same and undoubtedly depend upon the same factors of growth.

### Conclusions

From the foregoing discussion it is apparent that the wood of highest quality in the broad leaves is obtained when the trees are relatively free from knots and have maintained a rapid uniform rate of growth. Growth during the summer months is of utmost importance if wood of high strength is to be obtained. The silvicultural operations in stands of hardwood should then be of such a nature as to maintain a fairly dense stand during the youth of the stand in order to cause lateral branches to die and fall off. However, the stands should be thinned before a retardation in growth is caused by too close spacing. Subsequent thinning~~s~~ should follow in such a manner as to maintain a uniform rate of growth until the rotation is completed. However, in thinning stands, care must be exercised in order to maintain soil fertility and the water holding capacity of the soil since these factors are essential to rapid growth especially in the summer.

Forest management may not anticipate wood of the greatest strength in some species of broad leaved trees. Volume production may be the prime requisite. Obviously, different qualities of wood are needed for different uses. It, therefore,



becomes the duty of the forester to so manage the forests as to produce wood which will call for greater gross revenue. The tools of the forester in regard to growing the quality of timber desired are maintaining a high fertility of the soil as well as improving the water holding capacity of the soil, and controlling the growing space of individual trees.

## THE CONIFERS

The structure of coniferous wood differs considerably from that of the hardwoods in that the xylem is composed entirely of (tracheae.<sup>3</sup>) In cross section the gymnosperm wood resembles that of the ring porous hardwoods somewhat; in that ~~it~~ is composed of alternate bands or layers of lighter and heavier wood. However, the spring-wood and summer-wood in coniferous species are more variable in width. The springwood consists of thin-walled cells while the summer-wood cells consist of thick-walled cells. ~~th~~As in ring porous hardwoods the weight of the wood depends upon the relative proportion of each kind of wood present. However, in the conifers both very wide and very narrow annual rings usually contain a larger proportion of springwood than summerwood, therefore, either may be of light weight with the consequent relative weakness in strength. The relation between the rate of growth in conifers, therefore, differs from that of hardwoods. Whereas second growth rapidly grown hickory and ash are considered superior to virgin-growth in strength properties, the second-growth conifers are considered to be decidedly inferior in the quality of strength, especially in the Southern pines.

### The Southern Pines

Longleaf pine (*Pinus palustris*)

#### Uses

Longleaf pine is unsurpassed as a structural timber, and finds a wide use in bridge, trestle, warehouse, and factory con-



struction in the form of dimension timbers, posts, piles, and joists. (11) It is also used extensively for spars and masts. (11) Therefore, considering the uses to which longleaf pine is put strength and hardness would seem to be a prime requisites. The Forests Products Laboratory in investigating longleaf pine used specific gravity as a criterion of strength. Obviously, the heavier wood contains the larger proportion of summerwood with the consequent greater strength qualities.

#### Controlling summerwood in longleaf pine.

In studying and investigating the factors controlling the amount of summerwood in longleaf pine two methods of approach to the problem present themselves: (1) A study of growth and structure under such conditons that any one environmental factor may be regulated at will; and (2) a statistical analysis of existing stands to determine through correlation the effect of a given factor on growth.

To date two men have attacked the problem, Lodewick (13) from the statistical method of analysis; and Paul and Marts (12) from a combination of the two methods. Paul and Marts in their study attempted to control the amount of moisture available for the plant by irrigation, otherwise the statistical method of analysis was employed.

Paul and Marts (12) for their study selected an area in the Choctahatchee National Forest, Florida, where the following conditions existed:

1. The soil at the site was of a deep and nearly sterile Norfolk sand, showing upon test only traces of available nitrogen and phosphorous and calcium.

2. On account of the porous nature of the soil very little water was retained either in the surface layers or in the sub-soil.

3. Near the site was a plentiful supply of fresh water.

4. At the beginning of the experiment, in the spring of 1927, it was estimated that this area had not been burned for at least 4 years.

5. Longleaf pine and oak sprouts with a small amount of herbaceous vegetation in areas not otherwise occupied were the only vegetative cover.

6. The root systems of the longleaf pine occupied the first 18-inch layer of soil which indicated keen competition for food and moisture between the longleaf pine, oak sprouts, and other herbaceous vegetation.

7. Since 1913 the region has had an average annual rainfall of 60 inches or more, but in spite of this fact seasons of extremely low rainfall do occur, and further the precipitation at times consists largely of heavy rains or extreme downpours at such infrequent intervals that the soil does not retain sufficient moisture for normal tree growth. In fact conditions for growth are not much more than those of a semiarid region.

#### Establishment of Experimental plots.

The trees on the area upon which this study of controlling the summerwood in longleaf pine <sup>was conducted</sup> were divided into eight plots lettered A to H (see Fig. 1 to 8.) with five to nine trees to each plot. Each group received separate treatment as is indicated under each graph Fig. 1 to 8.



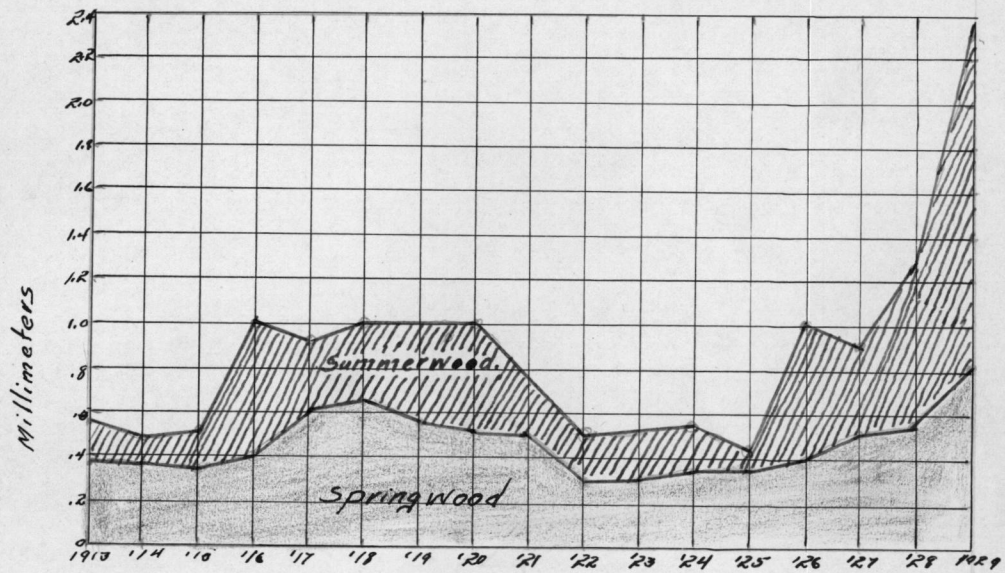


Fig. 1.— The average springwood and summerwood growth of 7 trees, Plot A, that received irrigation during the growing seasons of 1927, 1928 and 1929, in comparison with the growth of previous years. The curve shows that the 1927 summerwood growth was somewhat less than the 1926 summerwood growth. This indicates that the irrigation given the trees in 1927 was not so effective in summerwood production as the comparatively heavy natural rainfall of the year of 1926.

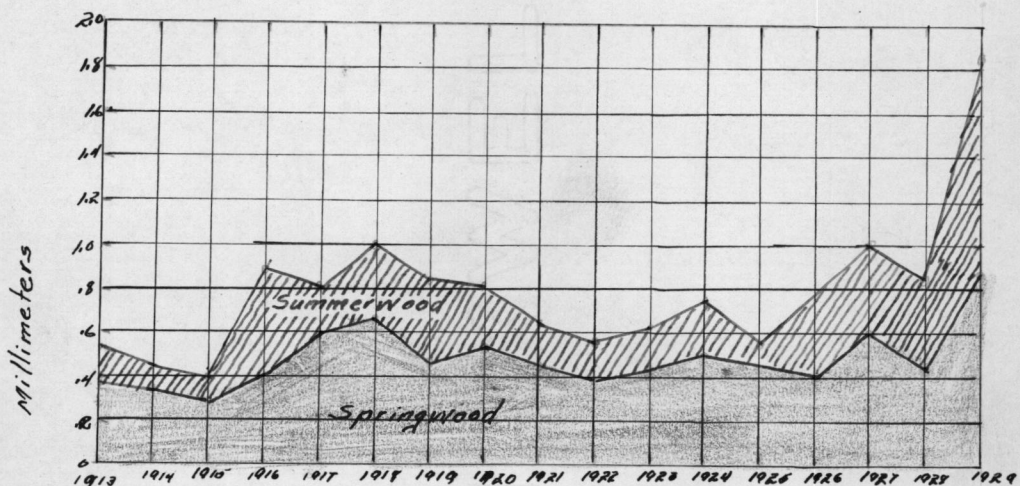


Fig. 2.— The average springwood and summerwood growth of 6 trees, Plot B, that received irrigation and a complete fertilizer during the seasons 1927, 1928 and 1929, in comparison with the growth of previous years. The dip in the curve for 1928 is explained by the fact that the time off irrigation on this plot was cut in half in order to lessen leaching of the fertilizers and to lessen runoff.

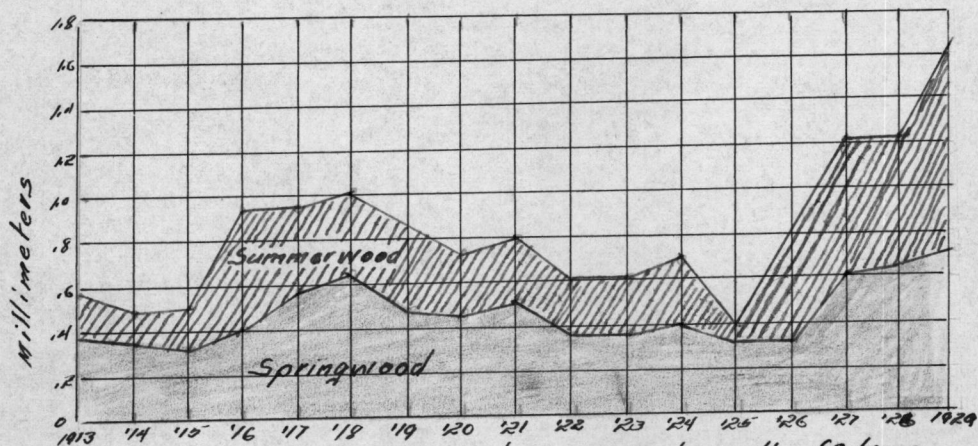


Fig. 3— The average spring and summerwood growth of 9 trees, Plot C, that received irrigation and a nitrate fertilizer during the growing season of 1927, '28 and '29, in comparison with the growth of previous years. The irrigation resulted in a complete leaching of the nitrate fertilizer from the upper layers of the soil in less than two weeks.

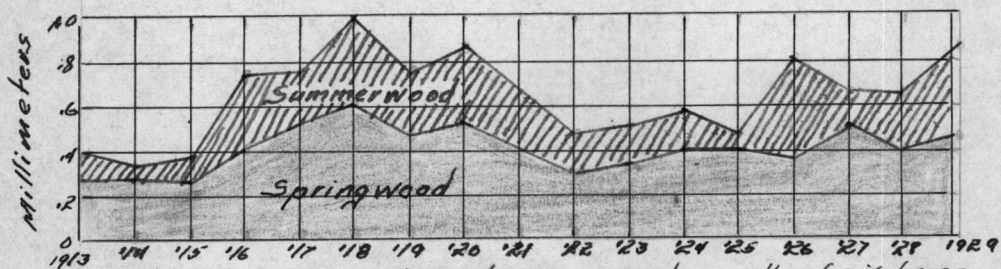


Fig. 4— The average spring and summerwood growth of six trees on the untreated check plot C, during the growing season of 1927, 1928 and 1929 in comparison with the growth in previous years. The natural precipitation for 1929 was the highest on record since 1913.

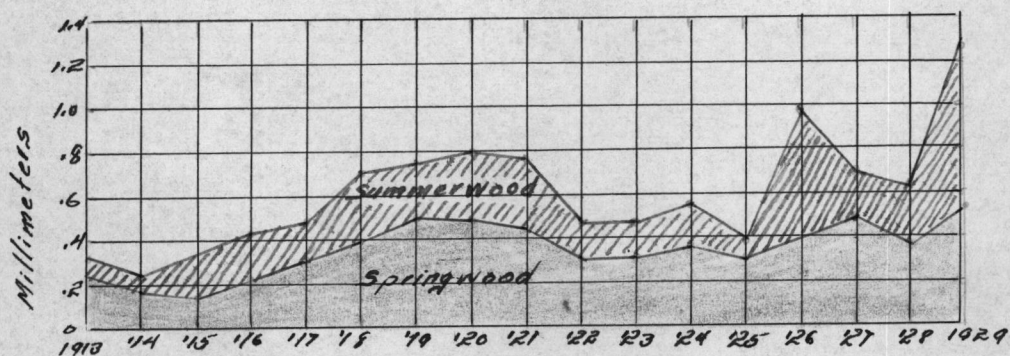


Fig. 5.— The average springwood and summerwood growth of six trees, Plot E, that received irrigation from July 1, to November in the years 1927, 1928 and 1929, in comparison with the growth in previous years.



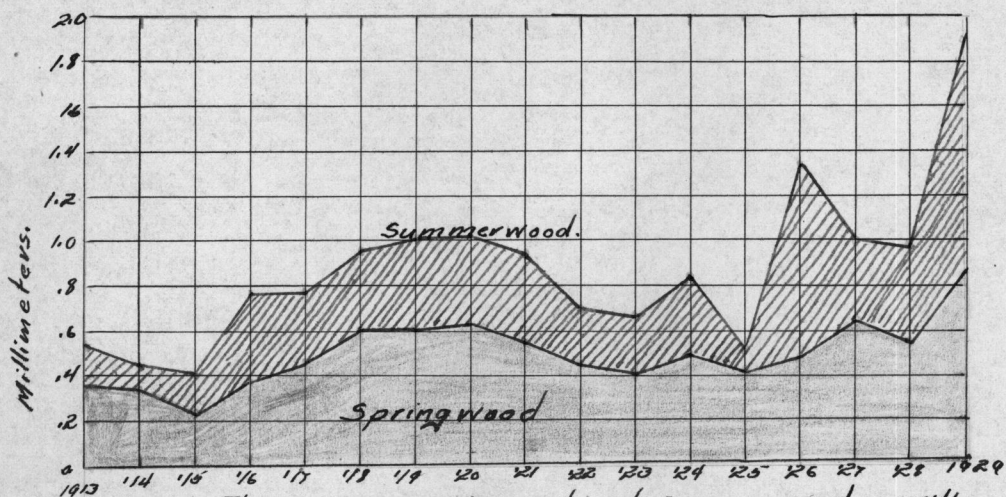


Fig. 6.— The average springwood and summerwood growth of five trees, Plot F, that received a complete irrigation from March to June 30, during the growing season in comparison with previous growth.

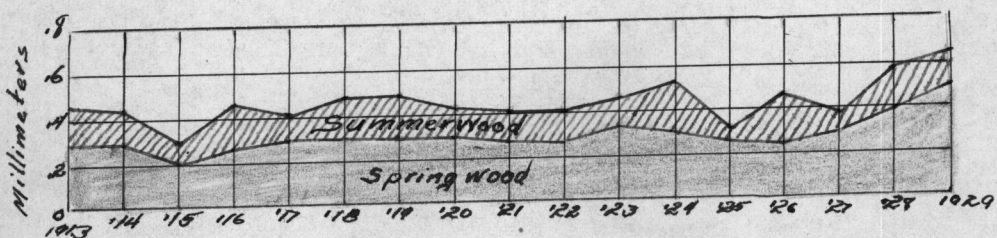


Fig. 7.— The average springwood and summerwood growth of seven trees, Plot G, that received a complete fertilizer but no irrigation during the year of 1927, 1928 and 1929 in comparison with growth in previous years.

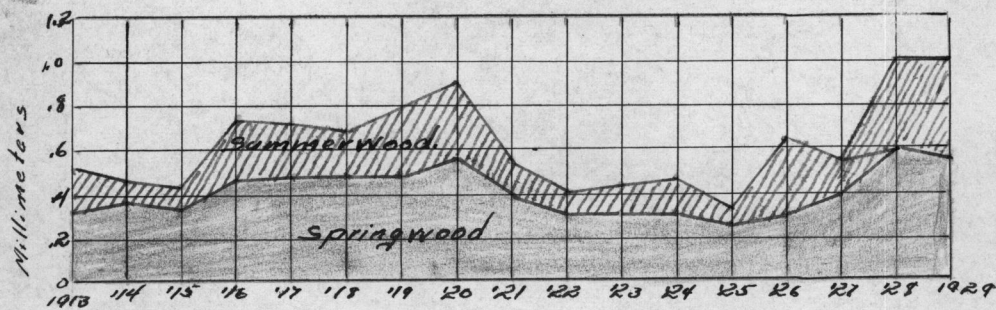
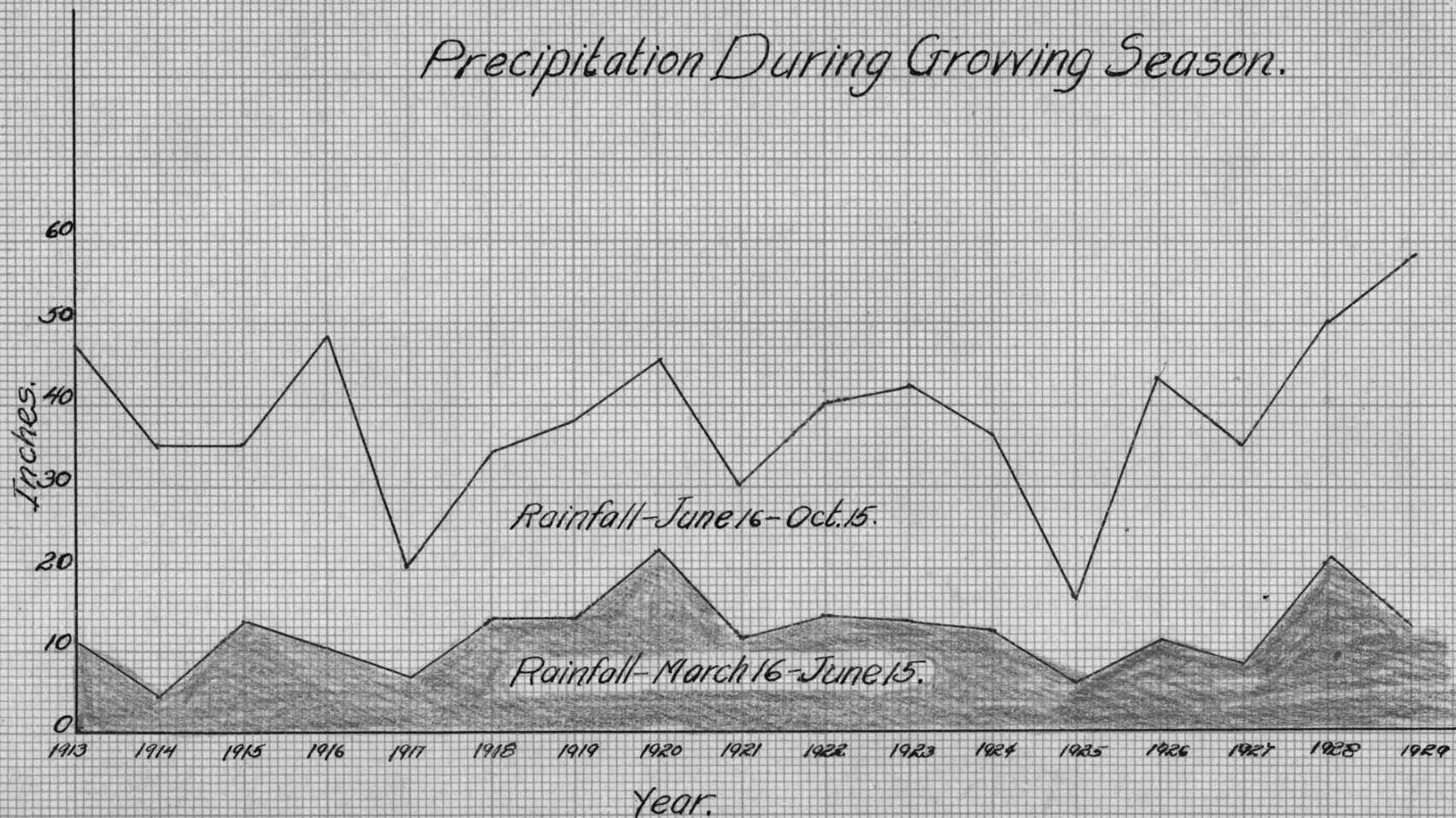


Fig. 8.— The average springwood and summerwood growth of seven trees plot H that received Nitrate fertilizer but no irrigation during the years 1927, 1928, and 1929, in comparison with the growth of previous years.

# Precipitation During Growing Season.



(Taken from Jour. of For., 24: 786-1931.)



### Seasons of Springwood and Summerwood Formation.

Paul and Marts (12) found that in 1927 and 1928 the current annual growth ring showed that the springwood portion was formed between the beginning of cambial activity, about March 1, and a varying date in May and June (depending upon seasonal conditions) when production of summerwood commenced. They found also that there was an average of four weeks difference in the time of beginning of summerwood formation between the years 1927 and 1928: the early rainfall in the second year was more than twice that in the first, and was reasonably well distributed in time of occurrence. Summerwood production continued, when conditions were favorable, until late in the autumn: the growth of the ring was still incomplete in a portion of the trees on December 10, 1929.

### Wood Formation in Relation to Precipitation and Fertilizers.

The average radial growth of the trees on each plot for 14 years before and the three years of treatment are presented in graphs. Fig. 1 to 8 inclusive. Table 2 below compares the average percentage increase in the springwood portion, the summerwood portion, and the total ring-growth during the treatment and before it.

Table 2.

Plot	No. of trees	Treatment	Percentage increase, decrease(-)		
			Springwd	sum.-wd	Total ring width
A.	7	Irrigation only March to Dec.	45.4	165.9	96.5
B.	6	" plus complete fertilizer	42.0	136.6	74.5
C.	9	" " nitrate "	57.7	131.6	88.6
D.	6	check plot (No treatment)	12.9	24.3	16.8
E.	6	Irrigation only July to Dec.	40.0	94.6	61.5
F.	5	" " March to July.	45.1	89.9	63.9
G.	7	Complete fertilizer, no irrigation	40.4	-8.9	23.5
H.	7	Nitrate fertilizer. No irrigation	31.6	86.8	50.1

The results of these investigations show that a fairly close correlation exists between the amount <sup>of</sup> moisture available and the formation of summerwood in longleaf pine. The results of systematic irrigation of the trees, throughout the season of growth, for three years, indicates such a correlation most forcibly.

Complete fertilizers without water appear to stimulate springwood growth, whereas nitrate fertilizer without water appear to stimulate summerwood production. However, as indicated in Fig. 9, unusually heavy rainfall occurred in 1928 and 1929, indicating that perhaps moisture as well as the fertilizers were effecting growth.

Lodewick's investigations (13) confirm those found by Paul and Marts (12). After conducting an investigation very similiar to that carried on by Benson H. Paul under the auspices of the Forest Products Laboratory, Lod<sup>e</sup>wick makes the following conclusion:

"The precipitation during the latter part of the growing season (from June 1 to July 1 until Oct. 15) exerted the principal controlling influence on summerwood production".

"The precipitation accompanying the period of springwood formation showed a fair qualitative correlation with the width of the springwood. Quantitatively this correlation was poorer than that for summerwood; in fact, over a period of years, the width of springwood was almost constant irrespective of rainfall."

Douglass (14) concluded as follows: "In a considerable number of cases, but especially in the dry climate groups this (correlation between precipitation and diameter growth) has been found to be in the neighborhood of 70 percent, which is



raised substantially by applying a formula to allow for some degree of moisture conservation."

Douglas (14) also found that variations in the annual rings coincided with the climatic cycles, which he attributed to solar activity. The sun spots appear to effect tree growth through their influence on precipitation.

Burn (15) working in Vermont forests says, "There can be no direct correlation between rainfall and diameter growth." He contends that rainfall is not a measure of soil moisture which is a reasonable statement. Doubtlessly much water is lost, nevertheless more moisture under ordinary circumstances should be made available for the tree with the consequent increase in available conductable material. Differences in the flow of materials through conductive tissues appear to be the chief cause for their structural differentiation, both in primary and secondary wood (16). Nearly all cases of increased vascular development, whether involving an increase in length, caliber, or number of the elements, or thickness of the walls, can be referred to increased conduction; this may result either from high transpiration, or from an increased flow of structural material. (16)

Lablolly Pine (*Pinus taeda*) and Shortleaf pine (*Pinus echinata*).  
Uses.

Shortleaf and lablolly pine are used principally for building lumber such as interior finish, flooring, ceiling, frames and sashes, wainscoating, weatherboarding, joists, lath, and shingles; for boxes and packages in the form of veneers, and in cooperage for the manufacture of slack barrels. (11)

The wood of shortleaf is especially fitted to work of the house carpenter because of its comparative freedom from resinous matter, its stiffness, and ease of working. (11) The wood of these two trees is also used for construction purposes, in bridge and trestle work, and heavy building operations where conditions are not such as to require longleaf pine. (11)

Considering the uses to which shortleaf and loblolly pine are put, various qualities of material would be desired. The timber grower will be interested in producing the material from which he can get the highest net returns. Obviously, he will then be desirous of growing his timber in a manner which will yield the highest percentage of grade B and Better and No. 1 Common. For the other common material, strength and freedom from large loose knots will be the properties sought since such material is suitable for general construction work.

Relation of Certain Forest Conditions to the Quality of Loblolly Pine.

Benson H. Paul (17), under the auspices of the Forest Products Laboratory, made a detailed investigation of the effect of old growth hardwoods left from an earlier stand; the effect of second growth hardwoods; the effect of growing space; and the effect of the rate of diameter growth upon the quality of lumber produced. His conclusions are as follows:

The total net per acre lumber values were from \$100 to \$150 higher on plots without old growth hardwoods than in adjoining areas containing old-growth hardwoods left from an earlier stand. (17) The old growth hardwoods shaded the young pine to the extent that the small pine trees were stunted in growth,



and in some cases prevented the growth of pine entirely.

Plots having a considerable number of second-growth hardwoods, in mixture with the pines, showed increases in the percentage of B and Better lumber as the basal area of the hardwoods increased. There was, however, a lowering of the net value per acre of the lumber obtained when the basal area of the hardwoods exceeded 25 percent of the basal area of the stand, since the total amount of pine lumber was decreased on account of the space occupied by the hardwoods, most of which were unmerchantable.

The relation of growing space, as measured by crown size, to the grades and values of lumber obtained from even-aged second-growth loblolly pine trees in the stands considered, indicated that the greatest profit per tree may be obtained from the trees with large crowns. (over 24 ft. in diameter). But the greatest profit is obtained when the stand is fully stocked with trees having crowns of medium size. The fact that the larger crowned trees showed a general tendency toward the production of a higher percentage of B and Better lumber as the diameter of the tree crowns increased, is attributed to the fact that the trees with larger crowns maintained a faster rate of growth and produced a considerable quantity of clear wood after natural pruning of the lower portion of the bole had occurred. (17)

There was an opposite tendency in the relation of crown size to the percentage yield of No. 1 and C lumber from that found with the B and Better grade. In this case the trees with smaller crown yielded higher percentages of No. 1 and C

than the trees with larger crowns. This may be explained by the fact that the trees with small crowns standing closer together than the large crowned trees shed their lateral branches before they had developed to a stage which would produce large knots in the resulting lumber. (17)

Benson H. Paul (17) in the same study in working out a relation between growing space and value per tree of second growth loblolly pine trees divided the stand into three groups, namely:

1. Trees with crowns from 12 to 17 feet in diameter.
2. Trees with crowns from 18 to 24 feet in diameter.
3. Trees with crowns 25 feet and more in diameter.

The average crown spread, the average d. b. h. and the average net value of the trees in each group are shown in table

3. The possible results from maintaining a forest in the average condition indicated by the three crown size groups is also included.

Table 3. (Taken from Jour. of For. 30: 15.)

Crown size and value of average tree in different crown-size groups				Possible return, number of trees and lumber value of a fully stocked acre.		
Crown dia. groups		Averaged d.b.h. of trees included	Average net value Per acre	No of trees	d.b.h. range	Total net value.
Range	Ave.					
Feet	Feet	Inches			Inches	
12-17	14	12.6	\$0.79	171	10-16	\$135.09
18-24	20	15.7	\$3.11	96	11-19	\$298.56
25+	28	18.3	\$4.45	54	15-22	\$240.30



The above table is based upon the value of the stand for lumber production. For the production of poles and piling, the smaller sized group would be a great deal more valuable since this smaller sized group has greater specific gravity and consequently greater strength. (15)

The Application of Silviculture in Producing Quality Southern Pine.

The results of the experiments described above show more or less clearly that soil moisture and fertility, and growing space are the factors the forester must work with in order to produce longleaf pine timber of uniform high strength.

Although irrigation of the southern yellow pine forests can not be recommended, the results of experiments in irrigation indicate that silvicultural measures should be of such a nature as to conserve moisture. As Paul points out, it is not so much a matter of irrigating as it is a matter of conserving the rainfall. The soil in this region is of such a texture that runoff is rapid. (12) The exclusion of forest fires, a satisfactory stocking of the forest areas, and an admixture of broadleaved species with the conifers are all silvicultural measures that would increase the organic content of the soil, the soil fertility, and the capacity of the soil for the retention of water.

The Forest Products Laboratory has found that if a second-growth southern pine stand contains a substantial mixture of second-growth hardwoods of about the same age as the pine, a higher proportion of the lumber is in the best grades. (20)

The hardwoods exert a beneficial influence in causing an earlier natural pruning of the stems of the young pine trees. The broadleaved trees cast a heavier shade than the pines and as a result hasten the death of the lower pine branches while the latter are yet of small diameter. (20) As has been indicated in the discussion of loblolly and shortleaf pine, 20 to 25 percent of the stand should be of hardwoods.

Other advantages accrue from growing hardwoods in mixture with pines. Hardwood leaves decay more rapidly than the resinous needles of pines and restore plant food to the soil more quickly. (20) Also the hardwood leaves bring about the formation of humus much more rapidly with the consequent greater water holding capacity of the soil, which is of utmost importance in producing a high percentage of summerwood. (20)

The best results with respect to grade and net value in second-growth loblolly and shortleaf pine are obtained when the conditions during the early life of the stand are such that natural pruning of the side branches takes place followed later by stand conditions that promote fairly rapid growth and the development of individual trees of larger size. (17) This crowding of the stand will produce wood of greater strength also, because relatively slow growth during the first years of a trees life, followed by a uniform or faster rate of growth as the tree increases in circumference, produces wood of the highest quality. (17)



D O U G L A S   F I R  
(*Pseudotsuga taxifolia*)

Uses and desired qualities.

Douglas fir is used principally for structural purposes, especially beams and timbers for bridge and trestle work. It is also used extensively for building purposes and for interior finish.

Benson H. Paul (21) says that the management of a stand of Douglas fir should be focused upon the following objectives:

1. Relative freedom from large and loose knots.
2. Uniformity of growth rate.
3. Production of dense wood for specific purposes and non-dense for other uses.

Therefore the quality of wood desired will be governed by the use to which it is to be put. The first two objectives however are applicable to almost any use desired.

Strength in Douglas fir.

As in the southern pines, Douglas fir, is dependent for its strength upon the amount of summerwood in each annual ring. Chalk (22) in investigating the growth of Douglas fir in England found that most of the springwood of Douglas fir is formed during the months of May and June, and the summerwood during July and August, and it is logical to suppose that each will be effected by the particular conditions governing its own period of formation. If the conditions of these two periods are very different the amounts of springwood and summerwood may be expected to vary independently.

Such was actually found to be the case. Fig. 10 shows the spring and summerwood volumes of four trees in ten successive years (22). The springwood volumes have been plotted in one group and the summerwood in another. It will be seen that in both groups the fluctuations synchronize in all four trees if allowance is made for the trend of growth in each tree. (22) The summerwood curve seems to follow the precipitation curve very closely.

The fluctuations of the springwood do not agree with those of the summerwood, and the two must be regarded as varying independently. For example, 1922 was favorable to springwood formation but unfavorable to summerwood. (22)

Chalk (22) concludes from ~~this~~ investigation that springwood is more dependent on temperature than upon rainfall. The curves in Fig. 10 certainly indicate a greater fluctuation in the springwood. Summerwood, however, synchronizes with the precipitation curve.

Since the structure of Douglas fir wood resembles that of the southern pines, it is reasonable to assume that the same factors that affect southern pine also affect Douglas fir in a similar manner.

The application of silviculture in growing quality D. F.  
Size of knots.

The size of knots and the duration of lateral branches in a young stand of Douglas fir are greatly influenced by the density of the stand. (21) Very dense young stands cause the lateral branches to fall off when they are small and when the diameter of the tree is small. Trees of this sort will produce a maximum amount of clear lumber as the knots will



Fig. 10. Volume of Springwood and Summerwood.  
(Taken from Oxford Forestry Memor #10 p.24)

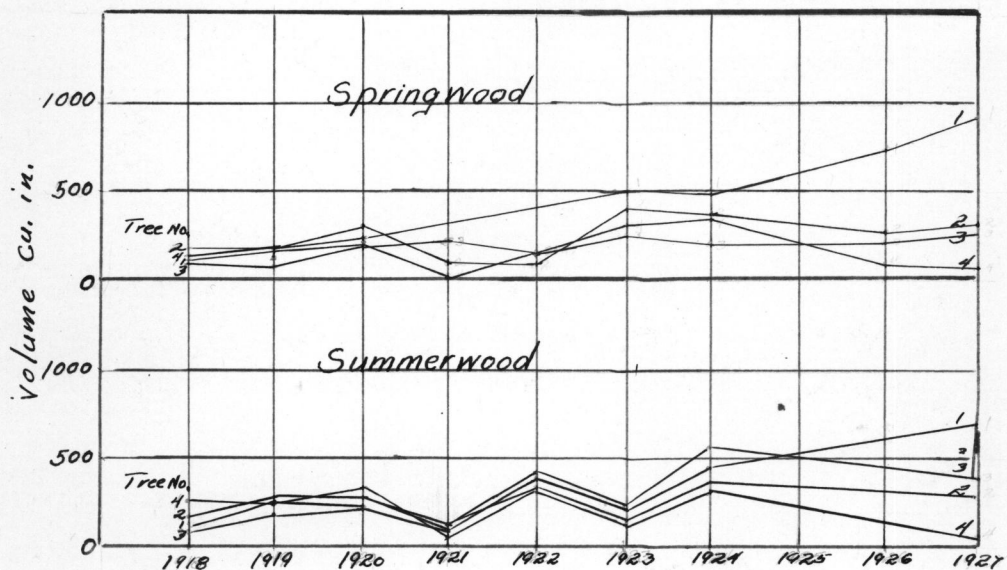
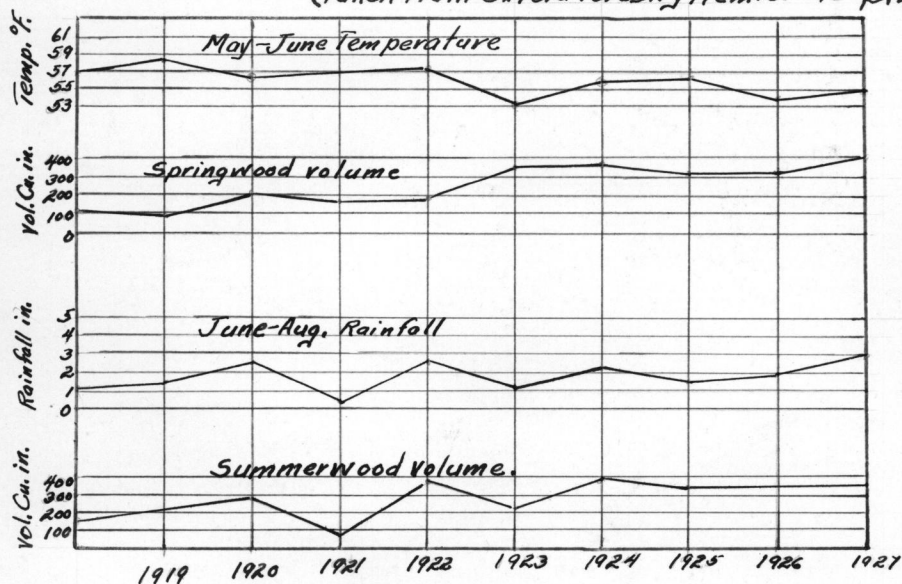


Fig. 11. Correlation of Springwood and Summerwood  
Volumes with Climatic Conditions  
(Taken from Oxford Forestry Memor #10 p.26.)



be confined to a relatively small central cylinder and these will be small. (21) Therefore, stands of second-growth Douglas fir which have not a sufficient density of stocking to cause the dropping of lateral branches when young should be supplemented by planting in order to obtain sufficient stocking. Pruning the lateral branches has also received some attention.

Pruning will influence not only the quality of the final yield but also the amount of wood produced. (23) It appears that most investigators agree that the height growth of the trees will decline as well as the diameter at d.b.h. However, many investigators find that the diameter increases higher up on the stem, resulting in a tree with less taper. Schenstrom (23) explains this phenomena of increased diameter growth higher up in the tree by accepting Johnson's theory of trees changing their form to withstand changing stresses. When trees are pruned, the form point, or the geometrical center of the crown is raised. Wind or other stresses, therefore, apply a stress higher up in the tree causing the consequent change in form.

Pruning as yet is not practiced to any great extent commercially, and a great deal more data on the profitableness of such procedure is required before it will be practiced by timber growers as a whole.

#### Maintaining uniformity of growth.

Uniformity of growth can hardly be maintained without recourse to thinnings. (21) Even if the lateral branches have fallen the removal of some of the trees is desirable. (21)



These removed trees can be utilized for piling or poles. Thinnings will also tend to cause the remaining timber to be of larger size on a shorter rotation.

Methods of producing heavy or dense wood.

The methods for producing dense wood in second-growth Douglas fir are similiar to those necessary for natural elimination of lateral branches. (21) Relatively heavy wood will be found all the way to the center of trees which originated in dense stands. (21) The production of dense wood will continue as long as the stands are not so closely crowded that the trees are stagnated or the stand is not opened up too much by thinning. (21) The production of dense wood, however, usually requires a moderately slow rate of growth, since the annual rings must contain at least one third summer-wood in order to be classed as dense. (21) In trees of rapid growth it is seldom that the proportion of one third summer-wood can be maintained. (21) Consequently the production of dense second-growth Douglas fir lumber will require a longer rotation to obtain trees of a given size than for the production of less dense material. (21)

## C O N C L U S I O N

The results of investigations regarding the production of quality timber indicate that regulation of growing space is the tool which foresters can use most easily. (7) All trees seem to be very susceptible to changed conditions in regard to growing space.

In the southern pine region the growing of hardwoods in mixture with the coniferous species seems to be of major importance, both in regard to growing space and to increasing the water holding capacity of the soil by the formation of humus. The retention of precipitation is one of the major problems in growing quality southern pine.

In coniferous species such as the southern pines and Douglas fir the quality of the final product depends to a great extent upon the relative percentage of summerwood. Spacing seems to have a distinct influence upon the relative proportions of springwood and summerwood grown each year. As indicated by experiments with loblolly and shortleaf pine close spacing will cause a greater proportion of summerwood to be formed in each annual ring with the resulting higher specific gravity. There is, however, an optimum for spacing, too dense stands causing a decrease in summerwood production. Thinnings should be made at regular intervals in order to maintain this optimum of growing space. Prevention of forest fires will help maintain soil fertility.

Broadleaved species cannot be crowded so severely as the



conifers. (7) The more space the greater the specific gravity in most cases. It therefore becomes the problem of the forester to correlate the spacing with the quality of wood desired and volume production so that maximum net return are forth-coming.

As indicated elsewhere in this paper strength is not always a desired quality in many species. What is quality wood for ~~one~~ timber grower may not be quality wood for another. The uses to which certain kinds of wood are put will always be the criterion of what constitutes quality wood, and it will be the forester's duty to produce the kind of wood desired.

LITERATURE CITED

- (1) Koehler, Arthur and Benson H. Paul  
1929. Discussion of research on the relation of growth factors to the quality of wood produced in forest trees.  
Forest Products Lab. Mimeographed Report.
- (2) Brown, N. C.  
1922. The place of utilization in American forestry.  
Jour. of For., 20: 135-138 Feb.
- (3) Koehler, Arthur.  
1925. How forest products research effects forestry practice.  
Southern Lumberman, 121: 179-181 Dec. 19.
- (4) Upson, A. T.  
1922. Better forestry through better utilization, Jour. of For., 22: 29-37. Jan.
- (5) Clapp, E. H.  
1921. A national program of forest research, p. 19.
- (6) Shreve, F.  
1924. Growth in trees and massive organs of plants.  
The growth record in trees.  
Car. Inst. of Wash. Pub. #350.
- (7) Paul, Benson H.  
The application of silviculture in controlling the specific gravity of wood.  
U.S.D.A. Tech. Bul. #168-1930.



- (8) Boisen, A. T. and J. A. Newlen.  
1910. The Commercial hickories.  
U.S.D.A. F.S. Bul #80.
- (9) Paul, Benson H.  
1925. How growth effects quality in hickory and ash.  
Wood Working Industries. Feb. 1926.
- (10) Paul, Benson H.  
1929. The quality of Appalachian hickory.  
Southern Lumberman April 6, 1929.
- (11) Betts, H.S.  
1909. Properties and uses of the southern pines.  
U.S.D.A. Forest Service Circular #164.--1909.
- (12) Paul, Benson H., and Ralph O. Marts.  
1931. Controlling the proportion of summer wood in  
longleaf pine.  
Jour. of For, 5:24: 784-796.
- (13) Lodewick, Elton J.  
1930. Effect of certain climatic factors on the diameter  
growth of longleaf pine in western Florida.  
Jour. of Ag. Res. 5:41:349-363.
- (14) Douglass, A. E.  
1919. Climatic cycles and tree growth: A study of the  
annual rings of trees in relation to climate and  
solar activity.  
Car. Inst of Wash. Pub. #289.
- (15) Burns, George P.  
1929. Studies in tolerance of New England, Forest trees.  
IX Rainfall and width <sup>to</sup> ~~to~~ annual rings in Vermont  
forests.

Vt. Ag. Exp. Sta. Bul. #298-June 1929.

- (16) Coulter-Barnes, and Cowles.

1931. A textbook of botany-Vol. 3. Ecology.

- (17) Paul, Benson H.

1932. The relation of certain forest conditions to the quality and value of second-growth loblolly pine lumber.

Jour. of For., 30:4-21--1932.

- (18) Paul, Benson H.

1927. Producing dense southern pine timber in second growth forests.

Southern Lumberman, Sept. 17, 1927.

- (19) Paul, Benson H. and Luxford, R.F.

1928. Relation of growing space to specific gravity and strength of second-growth redwood.

West Coast Lumberman. 54:17,32.

- (20) Paul, Benson H.

Mixed stands produce pine lumber of higher grade.  
Forest Worker.

- (21) Paul, Benson H.

1932. Improving the quality of second-growth Douglas fir. Jour. of For., 30:6: Oct. 1932.

- (22) Chalk, L. M.A. D.Phil.

1930. The formation of spring and summer wood in ash and Douglas fir.

Oxford Forestry Memoir #10;-1930

- (23) Schenstrom, S.R.

1931. Pruning Experiments in second-growth stands of



Douglas fir.

Forestry Chronicle (Canadian) Dec. 1931.

(24) McDougal.

1921. Growth in trees.

Car. Inst. of Wash. Pub. #307. p.(3-4).

(25) "Busgen and Munch.

Structure and life of forest trees.

pp. 180-181.