T H E S I S

on

PHYSICAL AND ECONOMIC FACTORS REGARDING
THE POSSIBILITY OF PRODUCING RAYON
IN THE DOUGLAS FIR REGION

Submitted to the

SCHOOL OF FORESTRY, OREGON STATE COLLEGE

In Partial Fulfillment of
the Requirements for the
Degree of

BACHELOR OF SCIENCE

by

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May 14, 1937

I N D E X

INTRODUCTION

The possibility of producing rayon in the Douglas Fir Region is a remote idea, yet this region possesses many of the necessary qualifications. The abundance of pulpwood species suitable to the production of sulphite pulp, and the abundance of water power are factors that should not be overlooked by prospective investors. The water transportation is also a factor that cannot be disregarded.

The United States produced 256,000 pounds of rayon in 1935. Wood pulp made up approximately 85% of the total of all raw materials used, and 90% of this pulp was manufactured from white spruce (Picea glauca) alone.

White spruce, the long-favored species of this industry, is being utilized much faster than it can be grown. Finland, Sweden, and Canada are depleting their spruce forests in much the same manner as the United States.

Manufacturers in this country are faced with the problem of securing new species for raw materials, and the logical place to turn is to the Douglas Fir Region of the Pacific Northwest. Whether they will ever manufacture rayon in this locality will rest on their decisions, but it will be only a matter of a few years until this region will have a boom in the production of sulphite pulp to be used for the manufacture of viscose rayon.

BRIEF HISTORY OF THE PRODUCTION OF RAYON

Discovery and Advancement

The idea of producing artificial silk, now known as rayon, was first suggested by Reaumur, a French physicist and naturalist in 1754. But it was not until after the discovery of nitro cellulose by Schoenbein in 1845 that attempts were made to produce threads which should imitate silk. One of the first experimenters with this new nitro cellulose was Audemars, who as early as 1855 took out a patent for transforming dissolved nitro cellulose into fine threads which at that time he called "artificial silk". But from the textile point of view, little progress was made until the successful work of Chardonnet. His labors have won for him the title of the "Father of the Artificial Silk Industry".

Chardonnet studied the silk worm closely, and he especially observed the processes of the silk worm in its cocoon formation. Working with the theory in mind that the silk worm produced its thread from the cellulose in the mulberry leaves, he undertook to produce cellulose artificially in much the same manner as the silk worm did. In 1884, Chardonnet produced his first synthetic fiber, using pulp obtained from the trunks and limbs of the mulberry tree as his chief source of raw material. In 1889, he was able to exhibit publicly a well grouped collection of specimen's of his product. The public exhibition was quite impressive to capitalists who provided for the erection of the worlds first artificial silk factory at Besancon, France. Within two years the technical difficulties of large-scale production had been overcome, and the problem of denitrating the cellulose and rendering it non-explosive had been solved. Soon the company was earning good profits and showing and selling and imposing array of goods. The factory continued to operate until the World War. Afterwards, it was bought and remodeled by the Du Pont interests, and today it is still operating.

This infant rayon industry grew from a production of a few thousand pounds from one factory in 1900 to nearly one billion pounds in 1935. The quantity of production now exceeds that of raw silk, and only cotton and wool production exceeds that of rayon.

Chardonnet Process

The Chardonnet Process (now commonly referred to as the nitrocellulose process) consists of converting cellulose obtained chiefly from cotton and wood pulp into nitrocellulose or gun cotton. The nitrocellulose is then dissolved in a mixture of alcohol and ether. This solution is then filtered and aged. Thereupon it is forced under high pressure through capillary orifices or spinnerettes under conditions favorable to solvent recovery. Thus the thread is formed. Several threads are then grouped together and passed through guides and wound on bobbins as rayon yarn. The rayon is then dried, denitrated with alkaline sulphides, bleached, washed, twisted and reeled or skeined. The fibre is lustrous, strong, and elastic. (See flow sheet, figure 1)

A successful modification to the Chardonnet Process by Lehner occurred several years later. Lehner found that it was more profitable to coagulate the cellulose nitrate thread in a water bath instead of depending simply on the evaporation of the solvents, alcohol and ether, in air.

Cupra-Ammonium Process

The first alternative process to make its appearance was the cupra-ammonium process of Despeisses in the year 1890. The mechanical processes were quite similar, but the chemical processes were different in detail. In this process, the cellulose is dissolved in ammoniacal copper oxide. The solution is then passed through capillaries or spinnerettes into a mixture of sulphuric acid and water, wound on glass bobbins, re-washed in acetic acid, dried, wound and reeled. This also produces a strong, lustrous, and elastic fibre. Cotton is the chief source of raw material. (See figure 2) Pauly modified the chemical and mechanical details of the cupra-ammonium process and subsequently raised the quality of this product.

Viscose Process

The development of the viscose process was the next technical advance of importance. A special study of alkali-cellulose and mercerizing reactions by Cross and Bevan in 1892 was responsible for the development of this new process. The digestion of the cellulose in alkali, and then the converting of this compound to a water soluble mixture by treating it with carbon bisulphide were the important contributions. The spinning and twisting of the individual unit viscose threads proved very troublesome in attaining quantity production. A stroke of genius by Topham effectively solved this problem and started the viscose rayon process on its road to supremacy. Viscose is forced through orifices of the spinnerette into the setting bath from which sixteen or more units are led up over a glass roller, from which they drop vertically into the "Topham" box. The rapid and remarkable growth of the viscose branch of the rayon industry may be laid indirectly to the development of the "Topham" box, the calibre and character of the research workers who solved different problems, and the faith, vision, liberality, and strength of its financial backers. The direct cause of the growth of the viscose process may be found in the fact that the materials required are cheap, of world-wide distribution, and therefore no expensive and troublesome recovering processes are required. (See figure 3)

Cellulose-Acetate Process

The next and last process to be developed commercially was the cellulose-acetate process. The process was first discovered as early as 1869, but the industry never got under way commercially until after the World War. This process uses cotton linters as the chief source of raw material, but wood and rayon waste are also used to some extent. The raw materials are mixed with acetic acid, acetic anhydride, and a catalytic agent. The resulting cellulose acetate is then mixed with acetone to form the spinning solution. After being forced through the spinnerettes, the threads are then coagulated into filaments in a current of warm air. (See figure 4)

Figure 1

Condensed Flow-sheet of Chardonnet
or Nitrocellulose Process

C O T T O N
(Nitration)

N I T R O - C E L L U L O S E
(Dissolve in Alcohol Ether)

A P P R O X 2 0 % S O L U T I O N
O F N I T R O - C E L L U L O S E
I N A L C O H O L E T H E R
(Spinning)

N I T R O - C E L L U L O S E F I L A M E N T S
(Denitration)

R A W C E L L U L O S E F I L A M E N T
(Bleaching-Washing)

C H A R D O N N E T S I L K
(Pure Cellulose containing less than 0.05%N.)

Note: Wood pulp may be used in this process. However, the Viscose Process is better suited to wood pulp.

Figure 2

Condensed Flow-sheet
of
Cupra-ammonium Process

C O T T O N
(Dissolve in Ammonical Copper-Oxide)

C U P R A - A M M O N I U M S O L U T I O N
(Spinning)

R A W C E L L U L O S E F I L A M E N T
(Bleaching-Washing)

C U P R A - A M M O N I U M S I L K
(Pure Cellulose)

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Figure 3

Condensed Flow-sheet
of the
Viscose Process

W O O D P U L P O R C O T T O N
(Digested with Caustic Soda)

A L K A L I - C E L L U L O S E
(Treated with Carbon Bisulphide)

C E L L U L O S E X A N T H A T E
(Dissolved in Caustic Soda)

V I S C O S E S I L K
(Pure Cellulose

Figure 4

Condensed Flow-sheet
of the
Cellulose Acetate Process

C O T T O N
(Treated with Acetic Anhydride)

C E L L U L O S E A C E T A T E
(Dissolved in Acetone)

C E L L U L O S E A C E T A T E S O L U T I O N
(Spinning)

C E L L U L O S E A C E T A T E F I L A M E N T S
(Bleaching-Washing)

C E L L U L O S E A C E T A T E S I L K - C E L A N E S E
(Cellulose Acetate Ester)

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THE ADAPTABILITY OF CERTAIN WOODS TO THE VISCOSE PROCESS

General

Any species of wood that is to be used for the production of viscose rayon must react favorably to the sulphite method of producing wood pulp. In producing sulphite pulp for rayon manufacture, the requirements are very exacting and sulphite pulp that is produced for paper making cannot be directly used without further treatment. A wood sulphite pulp that is used for paper making may be entirely unsuitable for making rayon. Any wood that has a high copper number and low alpha cellulose content is definitely excluded from rayon production. T. E. Curran, in charge of the section of Pulp and Paper at the Forests Products Laboratory stated "Two wood pulps may have approximately the same analytical values as determined by the available methods of chemical analysis, yet one may yield a satisfactory rayon whereas the other may not." This statement, no doubt, will acquaint the reader with the difficulties encountered when one is trying to place a new material in the raw resources list of the rayon industry. The only available certain procedure of evaluation appears to be an actual conversion test.

Suitability of Western Hemlock, Sitka Spruce, and Balsam Firs for Sulphite Pulp

The sulphite method is a term applied to a chemical pulping system for papermaking. The important factor is that the wood is heated under pressure with a solution of acid sulphite of calcium or magnesium. From this point, further treatment depends upon the use to which the pulp is to be put.

White spruce (Picea canadensis) is the ideal and standard sulphite pulp wood, and it is used as a basis of classification when other wood species are being analyzed for production of this pulp. The following data was obtained from the Forest Products Laboratory and is based upon tests made in their own converters.

White spruce (Picea glauca)
- Fiber length - 2.8 mm.
- Weight - 24 lbs. per cubic foot (bone dry)
- Sulphite pulp:
  - Yield - 1,030 lbs. per 100 cubic feet.
  - Character - Easily bleached and pulped
    Excellent strength and color
- Possible uses - Newspaper, wrapping paper, book paper, high-grade printings, rayon, and cellophane.

Western hemlock (Tsuga heterophylla)
- Fiber length - 2.7 mm.
- Weight - 23 lbs. per cubic foot (bone dry)
- Sulphite pulp:
  - Yield - 1,050 lbs. per 100 cubic feet
  - Character - Easily pulped, easily bleached, good strength, and fair color.
- Possible uses - Same as for white spruce.

Lowland white fir (Abies grandis)
- Fiber length - 3.2 mm.
- Weight - 23 lbs. per cubic foot (bone dry)
- Sulphite pulp:
  - Yield - 980 lbs. per 100 cubic feet
  - Character - Easily bleached and pulped, fair strength, excellent color
- Possible uses - Same as for white spruce.

Sitka spruce (Picea sitchensis)
- Fiber length - 3.5 mm.
- Weight - 23 lbs. per cubic foot (bone dry)
- Sulphite pulp:
  - Yield - 1,080 lbs. per 100 cubic feet
  - Character - Easily bleached and pulped, excellent strength and color.
- Possible uses - Same as for white spruce.

In analyzing the qualities of western hemlock, grand fir, and sitka spruce it is very apparent that these woods are suitable for the production of sulphite pulp. The yields vary little with that of white spruce, and the pulping characteristics are very satisfactory. Taking this factor into consideration, one is lead to believe that the western species offer a potential supply of raw material for the rayon industry. However, one must also bear in mind the statement of Curran regarding difference in analytical values that chemists have not been able to master. It is a known fact that western hemlock is being used for the production of sulphite pulp that is being shipped to eastern cities to be manufactured into rayon. Two mills, one at Shelton and one at Hoquiam, Washington, are producing approximately two hundred tons of sulphite daily. These mills are using strictly western hemlock and no attempt so far has been made to utilize sitka spruce and the balsam firs. Chemists of some of the paper and sulphite pulp mills of Oregon were of the opinion that western hemlock was the only one of the three that would be suitable. They based their opinions on observations of the three different fibers and the apparent alpha-cellulose of each species. The western hemlock has a shorter and thicker fiber that yields about eighty-five to ninety per cent alpha-cellulose. The minimum requirement of alpha-cellulose is approximately eighty-seven per cent as determined by experiments of rayon producers in the eastern United States, so ordinarily western hemlock would be near or above average.

From a questionnaire sent out to the Rainier Pulp and Paper Company at Shelton, Washington, the following data was received:

Species used - Hemlock

Per cent of alpha-cellulose - 88 to 90

Principal markets - United States, Europe, and Japan

Quality of product - Compares favorably with sulphite pulp produced from white spruce (Picea glauca).

This questionnaire places western hemlock in the first rank bracket of raw material to be used for rayon. Since there is no available data at hand on the qualities the balsam firs and sitka spruce except that put out by the Forest Products Laboratory on pulping characteristics, one can only generalize and speak in terms of estimation on their possibilities as a source of rayon manufacture. However, their sulphite pulping characteristics indicate that they do have more than ordinary possibilities for this method of utilization.

THE PULP WOOD INDUSTRY WITH SPECIAL REFERENCE TO THE DOUGLAS FIR REGION

General

The pulpwood industry of the United States requires approximately 1,032,000,000 cubic feet or 12,000,000 cords of pulpwood annually. At the present time, fifty per cent of these requirements are imported as paper, pulp, or pulpwood from Canada, Sweden, and Finland to the greater extent. Of this percentage of imports, sulphite pulp makes up approximately sixty per cent. Canada exports more pulpwood to the United States than Sweden and Finland, but the latter two, lead in the exportation of manufactured sulphite pulp.

The forests of United States could supply present pulp and paper requirements, and this could be done with the pulp and paper processes now in use.

Expansion of the domestic pulp and paper industry to provide for national self-sufficiency would have to take place primarily in the South, Pacific Northwest, and to a lesser extent in Alaska. The northeastern and lake regions, where the industry until recently has been concentrated, cannot be expected to yield much pulpwood for several decades. The expansion in the other regions would involve a substantial broadening of the base of species used, a trend that is all ready much in evidence.

Major dependence on imports has developed largely as a result of long-standing preference for spruce, which is peculiarly suited for newsprint paper, and for sulphite and mechanical pulps. These three comprise seventy-five per cent of the pulpwood requirements of the United States.

There is reason to believe that total future requirements, fifteen to twenty years hence, may be double present consumption. Studies in the trends of the paper industry alone show that pulpwood requirements might easily amount to 25,000,000 cords. The rayon industry would, no doubt, boost this figure to 30,000,000 cords.

Satisfaction of prospective pulp requirements of twenty-five to thirty million cords of pulpwood annually would contribute directly to the effective use of from one hundred to two hundred million acres of forest lands. In providing for all timber products, this would indirectly affect the use of the entire five hundred million acres of commercial forest land.

There are indications that the American pulp and paper industry, especially in the South and Pacific Northwest, will probably greatly enlarge its plant capacity in the next decade or two regardless of government aid or encouragement.

Taking all this into consideration, it is a plausible assumption that the Douglas Fir Region is going to be the highest ranking producer in the next twenty years. This region will probably rule over the Southern Region because the species here are more suited to high-class pulp and paper production, while those of the fast-growing southern forests are expensive to manufacture. Another plausible assumption is that the present conservation policy of the United States will tend to eliminate Sweden and Finland as exporters of sulphite wood pulp to the United States. Canada cannot continue to produce wood pulp at the present rate, for she is quickly depleting her forests. All these possible factors will tend to work for the benefit of the Douglas Fir Region, and to make it one of the outstanding commercial wood pulp producers.

Pulpwood Resources of the Douglas Fir Region

The Douglas Fir Region comprises that portion of the two states, Oregon and Washington, which lies west of the Cascade Mountain Range. In this region, there are 14,087 stands of timber of which pulp species comprise 3,827 stands and a volume of timber equal to approximately 38,000,000,000 cubic feet. Of this volume only 32,541,884,000 cubic feet are economically available as saw-timber size, and 25% of this volume lies in Western Oregon and the remainder in Western Washington. The species included as pulp wood resources are western hemlock, sitka spruce, balsam firs, and the Mt. Hemlock and Engelmann Spruce. As shown by tables 1, 2, 3, and 4 and figure no. 5, the western hemlock is the most prominent of all the species. The tables also show that the western hemlock is concentrated mostly in Washington and especially in the Puget Sound area. The chart shown in figure 5 shows clearly the relationship of the species with regard to volume and location. Oregon has more Mt. Hemlock and Engelmann Spruce and practically the same amount of sitka spruce, but Washington leads in the volume of balsam

Table 1

Volume of Western Hemlock 4 Inches And More
In D.B.H. Available For Cutting, By Ownership
In Thousands of Cubic Feet

Western Oregon

County	Private	National For.	Other Public
Clatsop	955,428		34,576
Columbia	40,599		1,336
Washington	64,800		1,815
Multnomah	8,690	4,573	3,945
Hood River	14,824	75,443	512
Clackamas	147,376	546,286	13,259
Yamhill	11,430	1,414	2,328
Polk	110,638	8,807	45,832
Marion	92,102	225,146	10,632
Benton	9,958	[illegible],749	11,252
Linn	577,712	380,646	71,609
Lane (Eastern)	222,267	385,375	53,237
" (Western)	23,821	48,327	2,909
Tillamook	532,060	62,552	60,938
Lincoln	293,933	67,721	54,407
Douglas (Eastern)	97,721	191,957	66,433
" (Western)	45,380	31,083	51,161
Coos	157,080	8,897	68,026
Curry	36,276	49,807	8,193
Josephine	92	2,638	986
Jackson	7,521	33,411	9,146
TOTAL WESTERN OREGON	3,449,708	2,124,832	572,432

Western Washington

County	Private	National For.	Other Public
Whatcom	303,957	256,830	96,729
Skagit	622,362	439,726	121,018
Snohomish	523,203	728,585	171,927
Island	5 5,619		500
San Juan	10,617		705
Clallam	1,330,914	997,108	236,888
Jefferson	540,083	981,001	630,627
Kitsap	20,794		2,166
Mason	32,227	324,768	7,113
King	940,924	322,977	109,228
Pierce	575,692	323,988	58,345
Thurston	45,960	[illegible] 211	2,158
Lewis	854,470	539,451	160,481
Grays Harbor	1,249,339	583,340	299,385
Pacific	1,385,658		142,912
Wahkiakum	306,340		65,428
Kowlitz	477,378	37,516	108,948
Clark	16,601		1,170
Skamania	108,368	785,584	18,172
Total -Wash.	9,350,416	6,321,185	2,233,900
GRAND TOTAL Ore.-Wash.	12,800,124	8,445,917	2,806,332

Table 2

Volume of Sitka Spruce 4 Inches And More In D.B.H. Available For Cutting, By Ownership In Thousands of Cubic Feet

Western Oregon

County	Private	National For.	Other Public
Clatsop	251,684		9,045
Columbia			
Washington			
Multomah			
Hood River			
Clackamas			
Yamhill	47	201	
Polk	892		
Marion			
Benton			
Linn			
Lane	15,432	20,222	764
Tillamook	203,163	40,082	20,528
Lincoln	172,697	15,571	19,420
Douglas	222,627	14,079	22,624
Coos	78,089	788	8,951
Curry	19,259	4,133	1,200
Josephine			
Jackson			
TOTAL W. Oregon	964,890	95,076	82,532

Western Washington

Whatcom	1,206	1,359	513
Skagit	3,598	4,033	785
Snohomish	10,823	2,219	1,182
Island	280		
San Juan			
Callam	237,076	42,392	236,128
Jefferson	101,593	126,051	81,717
Kitsap	40		
Mason	239	253	2
King	10,760	524	1,095
Pierce	18,491		1,145
Thurston	227		
Lewis	11,737	584	533
GraysHarbor	257,090	30,792	90,388
Pacific	243,591		25,263
Wahkiakum	45,786		9,826
Kowlitz	948	4	143
Clark			
Skamania	101	922	538
Total W. Wash. ----	943,586	209,133	449,258
Grand Total --------	1,908,476	304,209	531,790

Table 3

Volume of Balsam Firs 4 Inches and More
In D.B.H. Available For Cutting, By Ownership
In Thousands of Cubic Feet

Western Oregon

County	Private	National For.	Other Public
Clatsop	152,203		3,961
Columbia	3,584		45
Washington	6,867		260
Multnomah	4,358	1,751	139
Hood River	24,019	132,410	1,934
Clackamas	58,654	271,203	2,861
Yamhill	3,536	19	665
Polk	35,053	1,411	10,455
Marion	29,333	111,031	1,632
Benton	20,200	414	5,564
Linn	117,566	259,947	12,959
Lane	23,069	256,644	12,944
Tillamook	62,942	208	401
Lincoln	41,591	916	1,449
Douglas	89,781	539,190	64,864
Coos	57,155	1,655	54,001
Curry	53,712	10,331	2,654
Josephine	17,060	67,596	20,561
Jackson	154,931	535,469	215,801
Total W. Oregon	955,614	2,187,195	413,190

Western Washington

County	Private	National For.	Other Public
Whatcom	85,618	217,840	28,271
Skagit	237,774	321,299	45,829
Snohomish	132,620	467,867	80,841
Island	2,286		249
San Juan	139		
Clallam	179,300	348,080	77,213
Jefferson	57,197	524,943	403,895
Kitsap	118		177
Mason	949	97,370	45
King	413,352	279,069	25,515
Pierce	153,511	189,782	19,267
Thurston	2,122	4	99
Lewis	188,990	598,915	23,044
Grays Harbor	30,347	297,090	55,564
Pacific	102,480		8,316
Wahkiakum	62,657		16,856
Cowlitz	217,671	64,818	61,052
Clark	9,848		393
Skamania	88,069	753,591	6,178
Total W. Washington	1,965,048	4,160,668	852,804
Total - Ore.- Wash.	2,920,662	6,347,863	1,265,994

Table 4.

Volume of Mt. Hemlock And Engelmann Spruce
4 Inches And More In D.B.H. Available For Cutting,
By Ownership In Thousands of Cubic Feet

Western Oregon

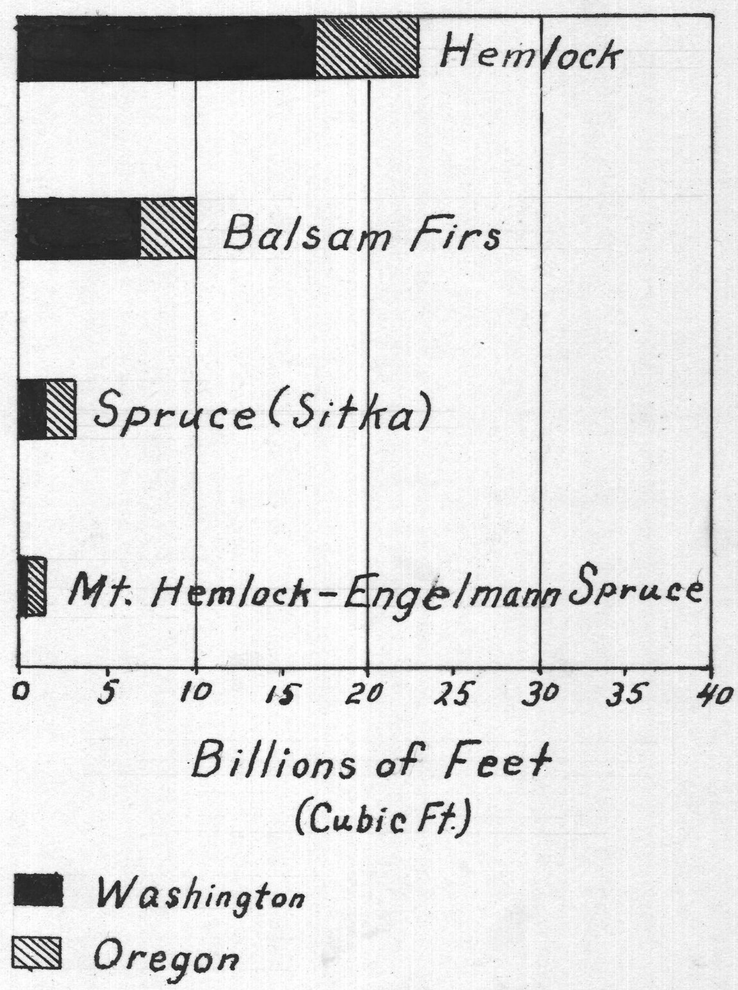
County	Private	National For.	Other Public
Clatsop			
Columbia			
Washington			
Multomah	18	110	
Hood River	325	50,142	26
Clackamas		94,877	
Yamhill			
Polk			
Marion		57,782	
Benton			
Linn	907	43,629	
Lane	4,567	491,281	258
Tillamook			
Lincoln			
Douglas		198,562	
Coos			
Curry		259	
Josephine			
Jackson		3,263	32
Total W. Oregon	5,817	939,905	316

Western Washington

County	Private	National For.	Other Public
Whatcom	281	6,512	
Skagit	520	10,808	61
Snohomish	6,761	114,663	5,003
Island			
San Juan			
Clallam		23,593	
Jefferson		7,713	
Kitsap			
Mason		2,153	
King	35,340	26,736	882
Pierce	633	3,079	
Thurston			
Lewis	52	42,329	
Grays Harbor		3,324	
Pacific			
Wahkiakum			
Cowlitz			
Clark			
Skamania	3,894	58,382	5,946
Total W. Washington	47,481	299,202	5,946
Total Ore. - Wash.	53,298	1,239,107	6,262

Figure 5.

Chart Showing The Comparative Volumes
Of Pulp Wood Species In Oregon And Washington
Suitable For Sulphite Pulp



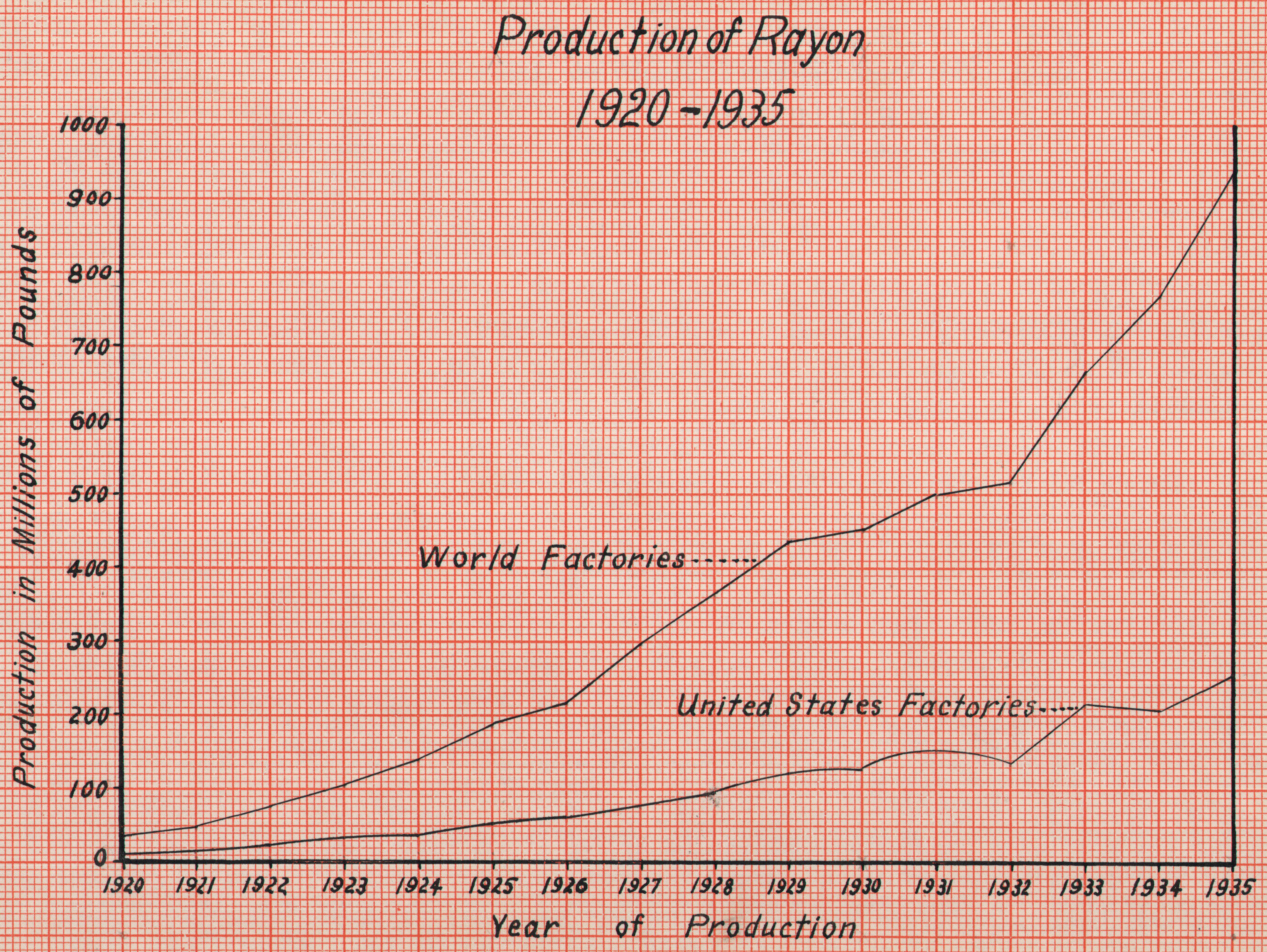

Production of Rayon
1920-1935
Production in Millions of Pounds
1000
900
800
700
600
500
400
300
200
100
0
World Factories
United States Factories
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
Year of Production

Figure 6

firs and western hemlock.

The installed pulp-mill capacity of pulp manufacturing centers of Western Oregon and Washington, based on a twenty-four hour daily capacity, is 3820 tons. Thirty per cent of this capacity is concentrated in Oregon with Oregon City having almost three-fourths of this total. The Puget Sound area including Port Townsend, Port Angeles, Everett, Tacoma, and Shelton have the greatest combined capacity of the producing centers of Washington. However, Longview has 390 tons daily capacity and Camas has approximately 490 tons daily.

Using a high converting factor of 200 cubic feet of wood to the ton of wood pulp, Western Oregon and Washington would consume 764,000 cubic feet of wood daily, and in 200 day year, the consumption would equal 152,800,000 cubic feet. The realizable mean annual growth of Oregon and Washington of all pulpwood species combined is 230,000,000 cubic feet. The potential annual growth is 852,000,000 cubic feet. Using the realizable mean annual growth as a basis, the figures show that Oregon and Washington can expand their present pulp capacity. The logical place for the expansion of the present capacity would be in the Puget Sound area of Washington in regards to the manufacture of sulphite rayon pulp. There the greatest volume of hemlock is concentrated, the shipping facilities are excellent, and the water power is readily available. Clatsop, Clackamus, Linn, and Tillamook counties offer the greatest possibility in Western Oregon, for it is in these counties that the western hemlock is most abundant.

Conclusion

The Douglas Fir has a better than average chance to become the leader in pulpwood production should the nation move towards self-sufficiency in this field. But it is very doubtful whether the Douglas Fir region will become important as a producer of rayon.

This region has power facilities, water transportation, and vast resources of growing pulp species that would make a better than average grade of rayon pulp. The main difficulties are that the industry would be a new one, the market and transportation costs would be too high, and the servicing industries necessary would not be at hand.

The logical solution to this problem is that the rayon companies all ready established in the middle west and the eastern United States will continue to increase their capacities. They will increase their supply of raw materials by closer cooperation and possible mergers with pulp companies on the pacific coast. One such merger is underway between an eastern Canadian firm and pulp producer in British Columbia.

The cost of establishing a rayon plant that produces three tons of rayon per day is $3,000,000. This is about the average size plant and no plant should even consider a capacity of less than one ton daily. The reason that the plant costs are so high lies in the fact that rayon is a highly specialized field and the equipment must be as nearly perfect as possible.

Avram states in his text that the greatest possibility of increasing the field of production lies with the textile plants already established. Cotton, and woolen or silk mills that have idle floor space could more cheaply install necessary equipment than other interests.

In 1931, the pulp produced in the Pacific Northwest could be delivered in Chicago and New York City on almost the same price as the pulp produced in the New England, Middle Atlantic, and Lake states. Water transportation of the pulp to New York City is so reasonable that unbleached sulphite pulp can be delivered there at a price ten to fifteen dollars cheaper. This adequately explains why the Douglas Fir Region will become a great producer of pulp, but will probably be very slow in breaking into the rayon production. Another definite reason is that water transportation is readily available and Japan, a great producer of rayon, is close at hand.

The cost of producing pulp in the Douglas Fir Region is fifty per cent lower than production costs in other parts of the United States with the exception of the south.

It may be well to consider that the Douglas Fir Region will likely become the greatest pulp producing section of the United States, but the region will never likely be a manufacturer of rayon. Rayon manufacturers are more likely to remain in established manufacturing centers and look to this region for their supply or raw material.

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