Some Factors in the Establishment and Growth of Douglas Fir

by

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INTRODUCTION

The Pacific Northwest is one of the most important forest regions in the country and Douglas fir makes up 66% of the total stand of all species or approximately 340 billion bd. ft. In this region it reaches its best size and quality, and the densest and most rapidly growing stands. The original forested area of the Douglas fir region has been estimated variously at 11 million to 28 million acres, excluding agricultural lands. However since the white settlers came to this part of the country, logging and fire have reduced that area by 70%--20% is in such condition that it has failed to restock at sufficient density to furnish a full crop of the desired marketability. It is estimated that there are 2,500,000 acres in Oregon and 2,000,000 acres in Washington 20 to 120 years old which originated on old burns and 500,000 acres in the two states of second growth Douglas fir on cutover lands. Since seed for a future crop may be available when a crop is harvested and the mortality of seed and seedlings is very high under ordinary conditions following logging and burning, by controlling the factors which cause seedling mortality more desired stands may be produced. Thus a study of the factors governing the establishment and growth of Douglas fir is important. (6) (13)

REPRODUCTION

The loss of Douglas fir seedlings in restocking cutover lands is definitely related to the amount of seed and the time required to restock each individual area. Seed may come from the retreating edges of green timber, single trees and blocks of timber left uncut, or trees bearing cones within a season prior to cutting, if the slash on the area is left unburned. Providing there is a good cone crop and little seedling loss, trees from any of these sources may adequately seed an area in one year. Good seed crops occur usually every three to five years or more, and when a good stand of reproduction does follow, a large part may be lost due to weather and ground conditions.

Seedling Mortality

Shade is a vital factor in the survival of seedlings. It may come either from logs or slash or vegetation that follows logging, and it may be considered beneficial only to a certain point. If it gets too dense, it robs seedlings of light, soil moisture and growing space. Practically no heat injury occurs in the shade which accounts for the high survival in dense shade since heat injury is the greatest single cause of loss. Heat injury consists of cooking of the cambrium of tender stems of the seedlings at soil surface.

The heaviest seedling losses may be expected to occur during the first or second year after germination. The following table (Table 1) shows the results of a study of seedling mortality made in upper Wind River Valley, Washington in 1929 by Isaac. Plots were established on land that was logged and burned in 1920 and 1925.

Cause of Death	1928 Seedlings Amount of Shade				1929 Seedlings Amount of Shade			
	None %	Med. %	Dense %	Total %	None %	Med. %	Dense %	Total %
Heat Injury	71	40	2	53	79	10	0	62
Drouth	18	30	19	22	4	59	6	12
Other	3	4	9	4	11	9	24	12
Total	92	74	30	79	94	86	30	86
% alive end of season	8	26	70	21	7	14	70	14
1929 loss	6	10	18	9				
Total dead	98	84	48	88				
Total alive end of 2nd season	2	16	52	12				

Table 1.

(Total column refers to Total amount of shade)

The critical months for seedlings are April, May, and June when periodic hot dry spells occur before vegetative cover of shrubs is developed to shelter the seedlings. After the vegetative cover is established for the season, competition for soil moisture becomes severe as the soil dries out during the summer months.

The following figures show the rainfall for 1929 at the Wind River Experimental Forest for June, July and August --3.66", Trace, and .05" respectively, compared with an average of 1.86" for June, .44" for July and .99" for August. (7)

The most severe drought of the region occurred in 1929 when the rainfall reached an all-time low of 26.11" as indicated by the Portland weather bureau office . This was about 62.6% of normal. This condition probably caused the death of a large percent of the seedlings throughout the region. The next lowest rainfall of 27.16" for 1930 killed still more of those surviving the 1929 drought and devitalized others.(18)

Minor seedling losses listed under "Other" consisted of rodent and insect damage, mechanical injury and competition. Insect loss was most severe under dense shade, as cutworms were most active there.(7) Evidently under natural conditions "damping off" is not a serious contridutor to seedling mortality although it does exist.(3)

In an experiment on the effect of high temperatures on coniferous seedlings made by Baker, spot injury occurred when a temperature of 133 degrees F. was reached, at 137 degrees F. constriction and lopping of the stem occurred. The living tissues of younger seedlings of representative conifers were quickly killed when a temperature of about 130 degrees F. was reached but they withstood a temperature only a few degrees lower for some time. In nature, fatal temperatures are reached in seedlings only at the base of the stem where for a few m.m. above and below the soil level living cells may be killed. Heat injury ranged from mere discoloration on the sunny side of the stem to complete killing of the whole ring of tissues, making light colored or white spots or complete constriction at ground level.

Heat injuries are difficult to distinguish from "damping off". However in heat injury the edges of the lesions are more sharply defined and the damage occurs under different conditions. The degree of injury suffered by heat lesions varies with age, as the "hardening" of stem tissues reduces the tendency to lop over and hinders the entrance of pathological organisms. The temperature at the base of the seedlings may be largely influenced by the amound and position of the shade case by cotyledons and true foliage.

Surface soil temperatures ranging from 130 to 160 degrees F. have been repeatedly noted in temperate climates, especially in loose sandy and dark-colored soils, and injury has been noted with a maximum temperature as low as 120 degrees F. Other considerations of soil will be considered later in this paper. (1)

See Figure 1, page 6 for effects of heat on various seedlings.

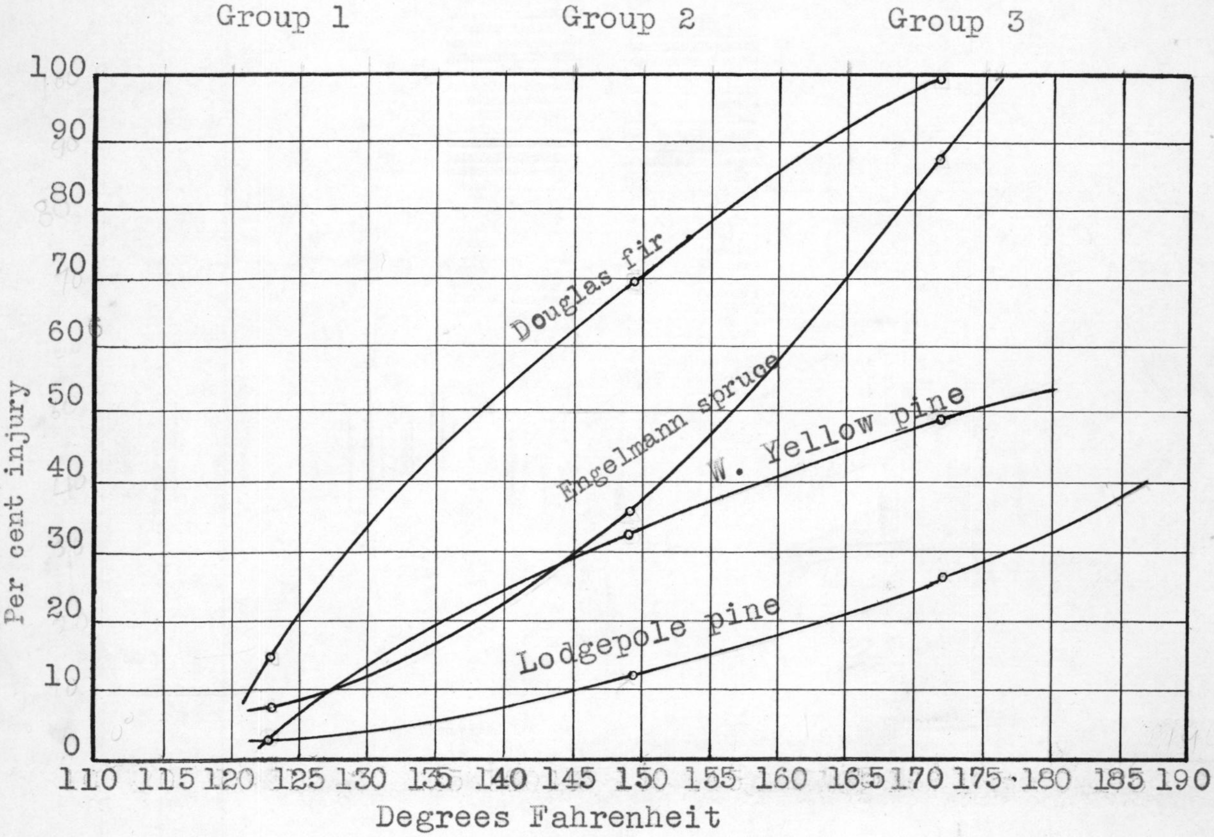

Fig.1 -Average extent of injury at various temperatures under direct radiation.

Data:	Group 1	Group 2	Group 3
Ave. Temperatures	122.86 F	149.45 F	172.22 F
Range	(111.4-135)	(142-154)	(161-181)
Ave. Period of Exposure	28 min	15 min	11 min
Range	(14-35 min)	(6-50 min)	(5-30 min)
Ave. Age	82 days	75 days	54 days
Range	(46-91 da)	(46-91 da)	(46-91 da)

(2)

Seed Selection

Proper seed selection will play an increasingly important part in our forestry program of the future. European studies based over a longer period of time than ours may prove enlightening. The following is an account by Omar Undseth of Long-Bell Lumber Company of principles to be considered. He bases his statements upon experiments made since 1890. "Within the same tree species different climatic races occur, the growth and development of which are adjusted by selection during many generations to local climatic conditions. Plants from seed gathered at high altitudes develop more slowly than those from low altitudes. Plants from a low altitude at high altitudes do not show greater height growth than plants from the same locality but after a short time they are surpassed by the latter. Plants from low altitudes start growing later than local plants.

"Plants raised from seed gathered at high altitudes, when planted at low altitudes suffer more by night frost than lowland plants but have more resistance against frost in the fall. High altitudes plants are better protected against drying up and chlorophyll death by severe isolation than low altitude plants because of peculiarly vigorous needle structure and thicker bark. They are also more resistant to mechanical injuries.

The root system of high altitude plants shows a stronger development although the actual size is less because of their slow growth. High altitude plants in lowlands more often die out during dry periods than local plants of the same age.

"The form of trees is inheritable, in so far as form is the product of particular qualities in the soil and in so far as the influence of these qualities during generations has been determinative. Krommelbein has by selection of straight rapid growing birches during six generations succeeded in producing a better race in these respects. Opperman in Denmark has shown that the form of "drooping beeches" and the so-called "twisted beeches" is inheritable quality. Zedderbauer has shown experimentally that wide spread branching is an inheritable quality in pines. Form is inheritable in the so-called "mutations", that is, nature's endeavor to create new races with other qualities other than the original ones.

Rapidity of growth is an inheritable factor and is dependent also on other conditions. It closely resembles growth energy of mother trees. (Local seed thus is to be preferred.)"

Experiments by Swedish forest experiments stations show that (1) the largest annual growth is in plants from local seeds, (2) pines moved to another climate produces a large percentage of the crooked trees, and

(3) pine of southern origin shows a large mortality and suffers especially from Phacidium infestans when moved to northern Sweden.

Concerning the quality of seed Undseth finds that "the largest cones yield the most and heaviest seeds. Heavy seed produced larger and stronger plants. The superiority is only temporary, probably because of stored food material. Forstmeister Mehner 1913 experiments with 1-0 showed plants from large seeds could withstand two days drying while plants from small seeds all died out although no difference could be seen in the size of the lots of plants.

"Seed from high altitude produced few plants, the germinating energy decreasing with altitude. Cones from low altitudes are larger and heavier than those from high altitudes. The size of seed and weight per 1000 seeds decreased with an increase in absolute altitude. Seed from high altitudes produces few plants, germination energy decreases with altitude and plant percentage decreases much faster than germination percentage.

"The age of the mother tree has an important influence on the quality of seed. Old trees yield small cones and small light seeds which produce weak plants. According to Busse, pine down to sixteen years will yield larger and heavier seeds which produce more vigorous plants than seeds from even 40 to 50 year old trees.

The difference will probably be evened out later when the plants become established, but the seeds from younger parents produce stronger plants for transplanting at one year and grow more rapidly to combat weeds in early years.

"Only local seed if available and only from trees with normal growth form and developmental ability should be used. If this is impossible, only seed from localities with as similar as possible climate should be used. In high altitudes avoid the use of seed from low altitudes. For lowlands and the south, seed from higher altitudes and the north can be used, but the plants will not be able to compete with native. Seeds should be collected only from healthy, vigorous trees with good stem form and not more than 80 years of age."(17)

In a study made in the northwest of this country Hoffman shows the following effects for parents on progeny in Douglas fir: Trees 15 years old produced seeds which averaged 35,000 per pound. Trees 600 years old produced seeds which averaged 57,000 per pound. Trees infected with conks produced as many cones as did sound trees, but with a lower percentage of fertilization. Cones from "conky" trees averaged 13,300 seeds per bushel of cones against 21,500 seeds to a bushel of cones from sound trees. Trees grown on poor rocky soil produced 62% of the seed produced by trees on good soil.

The following table (table 2) shows the influence on vitality of seed of age of the parent tree.

Age of parent	Germination of seed %	Growth of 1 yr. seedlings inches	% of buds that matured at end of first season
14-30	48.2%	1.6"	60.9
30-75	46.0	1.6	57.5
75-200	45.6	1.6	61.1
200-300	42.7	1.5	50.7
300-400	38.8	1.4	58.5

Table 2

"Conky" trees 20 to 450 years old produced a smaller percent of viable seed than healthy trees on similar soil as shown in Table 3.

Condition of parent	Germination of seed %	Growth of 1 yr. seedlings inches	% of buds that matured at end of first season
Healthy	47.4%	1.4"	56.2
"Conky"	34.7%	1.5"	58.9

Table 3 (5)

Some authorities believe that some of these factors do not carry from parent to progeny. Munger and Morris in their study of parent-seedling relation state that the results of their work gave no basis for a belief that poor site quality of the area upon which the parent grows lessens the vigor transmitted to the progeny. However the study did not cover a sufficient length of time to show whether over a longer period poor site quality might weaken the strain. In no cases were growth of infected and uninfected progeny significant.(15)

It may be said in defense of Hoffman's statement concerning "conky" trees that trees in a weakened condition were in that state because they could not resist infection that their more healthy neighbors were able to resist. The individual plants' cells of the healthy tree were probably more resistant.

Seed Flight

After burning or logging an area reproduction is dependent on the distribution of seed by the wind from adjacent seed trees. A record of seed fall from one light and one heavy crop was obtained in a study by Isaac. Many crowns extended half the length of the boles. Cones were produced on all parts of the crown in a heavy year, in a light crop they were close to the top only. In the heavy crop at 100 feet from the edge of the timber 203,000 seeds to the acre were found. At 200 feet the fall was 40,600 seeds per acre. From that point out decrease was irregular--there was no seed at 700 feet while at 900 feet there were 8700 per acre.

During the light crop at 100 feet from the timber there were 26,100 seeds per acre; at 200 feet, 29,000 per acre. This dropped off to 2000 at 500 feet. There were no sound seeds further than this.

The record for the Douglas fir virgin stand was obtained for a light year only. 40,000 seeds to the acre were found at 100 feet. Beyond that the fall was irregular. There were 14,500 seeds to the acre at 800 feet but there were less at some intermediate points. No sound seeds were found beyond 800 feet. A heavy crop would probably increase distribution both in density and distance. The following graph shows the effect of release on seed flight, Douglas fir seed being released in a 7 m.p.h. wind.

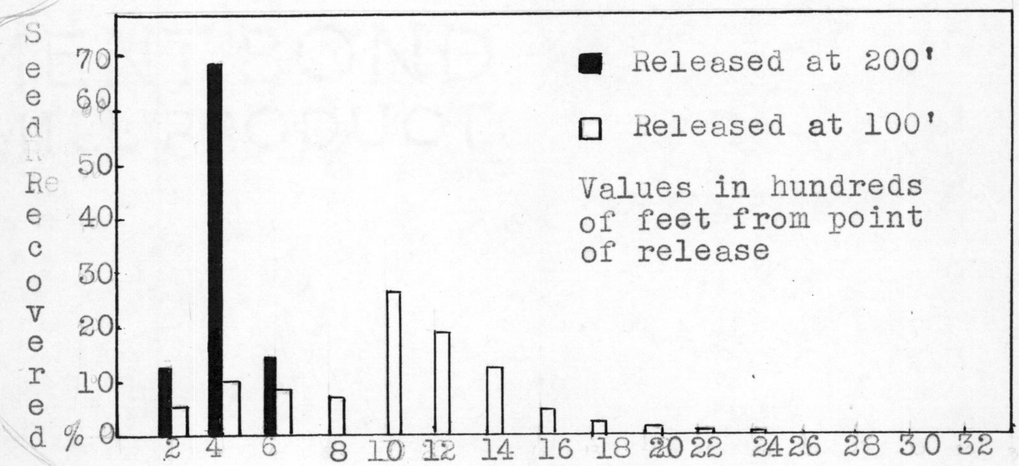

Fig. 2

The velocity of the wind when seed is being shed is a prime factor in seed distribution. Doubling the height of release more than doubles the distance of dissemination. This is probably the result of greater wind velocity at higher elevations.

When seed was released at 200 feet in a 6.5 mile wind, the heaviest fall was at 1000 feet from the point of release; the greatest distance at which seed was found was 1800 feet from the point of release. In an 8 mile wind the greatest densities of fall were at 1200 and 1400 feet with the end of the flight at 2600 feet. In a 23 mile wind the heaviest fall was at 1600 feet, the end of the flight at 3200 feet. Therefore the increase in distance at which the heaviest fall occurs is somewhat less than directly proportional to the increase in wind velocity.(2) Figure 3 depicts this graphically.

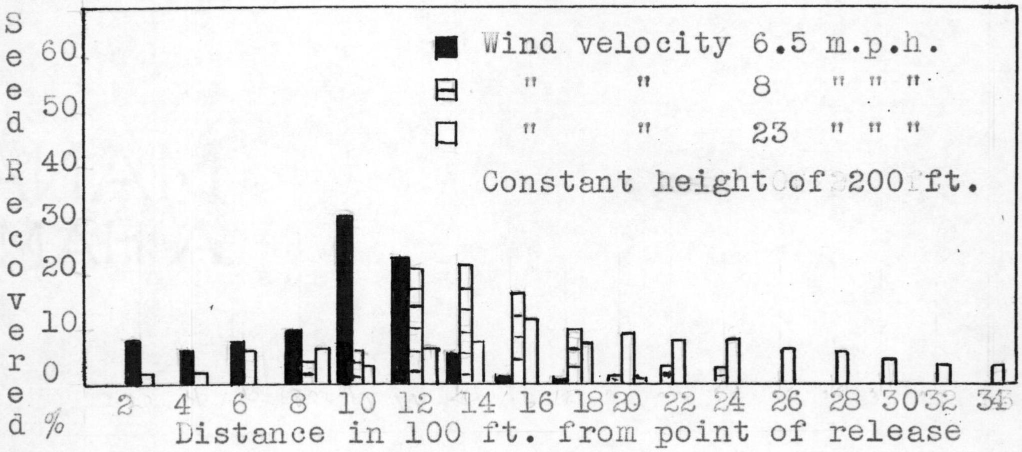

Fig. 3 (8)

Soils of the Douglas fir Region

The soils of the Douglas fir region vary in texture and other characteristics from gravel to clay, the most common being loam. The soil type, texture and character are important factors in establishing the growth rate of forest trees. The characteristics of the surface layer is of greater significance than those of the subsoil. The layer of duff averages 1.5".

Logging practices have had a great effect on the soil. The law requires disposal of slash which is usually burned. This reduces fire hazard but deprives the soil of its protective cover and future source of organic matter. It also leaves the soil coated with a black, charred debris which increases the capacity to absorb heat which in turn kills seedlings.[9]

The slash fire changes the fertility and moisture-holding capacity of the soil. The changes in the soil have a deleterious effect on the survival of Douglas fir seedlings while the surface temperature of adjacent unburned, natural-colored soil remains so low as to cause no injury to seedlings.[10]

Heavily burned soil showed depletion of nitrogen supply, breakdown of colloidal structure, dehydration of secondary minerals present and a more or less complete destruction of organic matter. The slash fire also destroys the duff. There is a loss per acre of 89% of the organic matter in the duff, a change in duff reaction from highly acid to alkaline, escape of 435 pounds of nitrogen per acre, an increase in the supply of plant nutrients available in surface soil, and a loss of a considerable part of the mineral nutrients contained in the duff.[11]

Sample	Organic matter Before fire %	Organic matter After fire %	Total Nitrogen Before fire %	Total Nitrogen After fire %	Nitrogen-Carbon ratio Before fire %	Nitrogen-Carbon ratio After fire %
Cutover area:						
Duff	88.53	9.72	0.92	0.34	1:57	1:17
Rotten log	98.62	--	.29	--	1:165	---
Min. soil at depth of--						
0-3 in.	5.69	3.54	.12	.12	1:27	1:18
3-6 in.	3.72	3.13	.09	.10	1:24	1:18
6-12 in.	3.40	2.79	.09	--	1:22	--
12-30 in.	2.21	2.48	.06	--	1:21	--
Adjoining old-growth timber area:						
Duff	78.7	--	.87	--	1:52	--
Rotten log	97.4	--	.33	—	1:171	--

Table 4
Organic content, Nitrogen content, and Nitrogen-Carbon rating of Wind River soil before and after a heavy slash fire. (9)

The presence of litter may prevent light showers from reaching the soil but undoubtedly it also retards the evaporation when the ground is soaked by heavy rains. Generally it tends to lower the soil temperatures and thus may retard germination. (12)

Influence of Various Cutting Methods

A study of various cutting methods was made by Roeser with Douglas fir, Englemen spruce, *Pinus flexilis*, Western yellow pine and *Populus tremuloides* in a merchantable stand 265 years old. The altitude was 9100 feet, the slope 35% with a north exposure. Approximately 78% of the larger trees over six inches DBH were Douglas fir. The soil on the plots is a granitic gravel.

Only 9% of the fir seedlings were alive after the first year. One half died during the following three years--most likely most of them died during the second year. The mortality rate after the third year is low, available moisture being the determining factor of survival.

During the early part of the year, moisture conditions are more favorable in the old growth stand. Wind and isolation are at a minimum. The selection and shelterwood follow in order. Because of its exposure, soils of the clear cut areas have the lowest percent of soil moisture for the whole season. Since soil moisture appears to be a controlling factor in Douglas fir reproduction any considerable amount of early germination on the clear cut area is made difficult. This type of an area has less seasonal variation and a more even supply of moisture than under any other system because of the small amount of tree growth. In the original stand, seedlings accustomed at first to plentiful moisture, not stimulated to deep rooting, easily succumb as this moisture is rapidly exhausted by the roots of older trees. This study was made in the Rocky Mts. but probably the same relationships between cutting methods will exist in this region, but the position in relation to the height axis will be changed. This is the only study made on this subject for Douglas fir.

Douglas fir seedling growth under various cutting methods

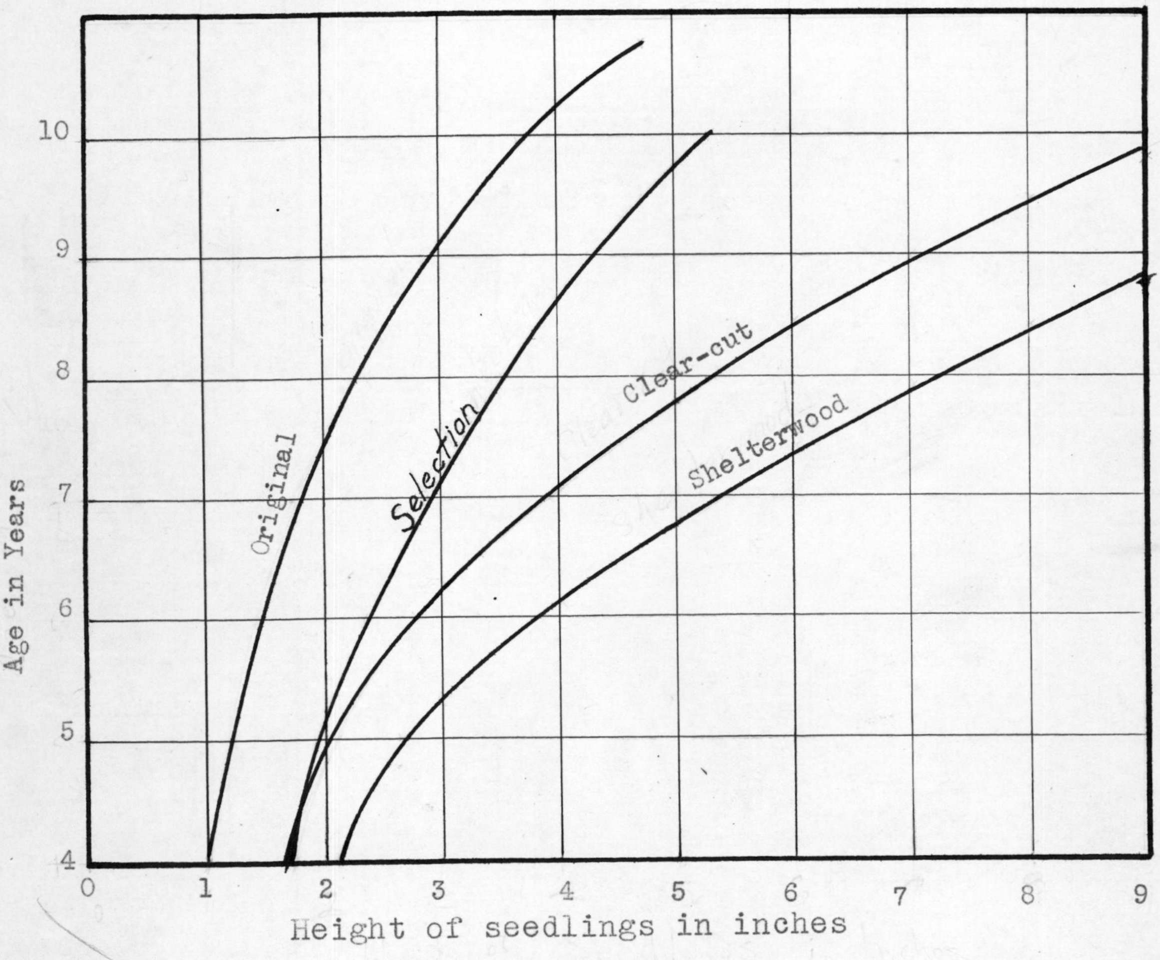

Fig. 4

Douglas fir will reproduce successfully on a light intensity of 85%. In a stand having a light intensity of 27.24% reproduction averaged most abundant at points of least light. The soil moisture decreases with increases of light, but moisture is the controlling factor of seedling growth. The total soil moisture varied directly with the organic matter in the soil, while the available soil moisture varied inversely with it. (16)

Figure 4 shows by graph the growth of the seedlings in the Douglas fir stands. (page 18) (16)

Mycorrhiza

It has been known for a long time that most of the common conifers usually possess ectotrophic mycorrhizas, but very little work has been done on other plants. There are varying opinions as to its beneficial effect. Mc-Dougall believes that there is no evidence that it is of benefit to host plants in that they aid in absorbing materials from the soil as formerly believed. He says that the consensus is that this fungi is parasitic on roots of higher plants and that the latter receive no benefit. It is probable that no great harm results, but when they become too abundant they may interfere with root functioning. (14)

On the other hand Hatch thinks that the cause of many nursery and plantation failures has been traced to the lack of a biological factor in the soils. He sites the example of a forestation project in Australia. Fourteen nurseries were started in widely separated areas, seeds germinated and produced seedlings which were healthy for the first few months. After that their growth gradually diminished and many died. In the same soils agricultural plants thrived and in some spots pine seedlings grew normally and these were found to possess mycorrhizal fungi while all the other pines lacked them. Some of the seedbeds where then inoculated with soil containing mycorrhizal fundi and in these the plants soon recovered and showed no further difficulties.(4)

Kessell also sites a nursery failure similar to the Australian one. Pine seedlings grew to a size sufficient for field planting but always remained yellow and weak and never over 4 inches in height. After they failed to respond to other treatments, they were inoculated with a mycorrhizal fungi and the same spectacular results occurred as those sited by Hatch.(11)

Jones found that mycorrhiza is found in comparatively old agricultural land where leguminuous crops have been grown repeatedly but that newly cleared forest lands in which legumes are not numerous and semiarid lands are least infected. (10)

Thus is might be possible that a lack of mycorrhiza is responsible for the failure of certain areas to respond to planting and seeding, although in the past it has not been considered to a great extent in re- and afforestation work. However with the disclosures of its importance, it will probably play an increasingly important part.

CONCLUSION

To insure future crops of Douglas fir of the desired quality, more consideration of hereditary and environmental factors will be necessary than has been given heretofore. In the past, reproduction has been dependent upon natural reseeding for logged-off and burned-over areas. If programs of planting are started when the forested areas are placed under a program of sustained yield with planting and if we take cognizance of what European foresters indicate, we can expect a gradual diminishing of the vigor of these planted stands. European experience has shown that planted stands have a tendency to succumb to enemies that natural regenerated stands, owing to their survival over inhibitory conditions. If these factors are taken into consideration in planning a forestation program so that the most vigorous stock will be grown, we may expect high quality crops in the future.

Little work has been done in the study of hereditary factors governing Douglas fir. More work in this field should prove beneficial, as the experiments that have been made in the past have not covered a sufficient length of time to yield satisfactory data.

BIBLIOGRAPHY

1. Baker, Frederick
   1929. The Effect of Excessively High Temperatures on Coniferous Reproduction. Journal of Forestry, vol. 27. pp.949-975.

2. Bates, C. G. & Roesser, Jacob
   1924. Relative Resistance of Tree Seedlings to Excessive Heat. U.S.D.A. Dept. Bul. 1263. pp. 1-16

3. Hartley, D., Merrill, T. C., & Roads, A. S.
   1918. Seedling Diseases of Conifers. Journal of Agricultural Research, vol. 15 No. 10. pp. 521-558

4. Hatch, A. B.
   1930. The Role of Mycorrhiza in Afforestation. Journal of Forestry, vol. 34. pp. 22-29.

5. Hoffman, J. V.
   1921. The Adaptation of Douglas Fir. Ecology, vol. II

6. Isaac, Leo A.
   1938. Factors Affecting Establishment of Douglas Fir Seedlings. U.S.D.A. Cir. No. 486. 45 pp.

7. ----
   1930. Seedling Mortality. Annual Cruise, vol.11. pp. 26-29.

8. ----. Seed Flight in the Douglas Fir Region. Journal of Forestry. vol.

9. Isaac, Leo A. & Hopkins, Howard
   1937. Forest Soil of the Douglas Fir Region and Changes Wrought upon it by Logging and Slash Burning. Ecology, vol. 18, no. 2

10. Jones, Fred R
    1924. A Mycorrhizal Fungus in the Roots of Legumes. Journal of Agricultural Research, vol. xxiv, no. 9.

11. Kessell, S. L.
1927. The Dependence of Pine on a Biological Soil Factor. Empire For. Jour. 6:70-74.

12. Krauch, Herman
1936. Some Factors Influencing Douglas Fir Reproduction in the Southwest. Journal of Forestry, vol. 34. p. 601.

13. McArdle, Richard E. & Meyer, Walter H.
1930. The Yield of Douglas Fir in the Pacific Northwest. U.S.D.A. Tech. Bul. No. 201.

14. McDougall, W. B.
1922. Micorrhizas of Coniferous Trees. Journal of Forestry, vol. XV, no. 3.

15. Munger, T. T. & Morris, William G.
1936. Douglas Fir Seed of Known Source. U.S.D.A. Tech. Bul. 537. pp. 1-40.

16. Roeser, Jacob Jr.
1924. A Study of Douglas Fir Reproduction under Various Cutting Methods. Journal of Agricultural Research, vol. 28, no. 12. pp. 1233-1242.

17. Undseth, Omar
1929. Seed Selection, A Fundamental of Silviculture. Journal of Forestry, vol. 27, no. 6.

18. U.S.D.A. Weather Bureau
1938. Annual Meteorological Summary with Comparative Data. Portland, Oregon