RELATION BETWEEN HEIGHT GROWTH OF LARCH SEEDLINGS AND WEATHER CONDITIONS

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It is a common experience in passing through stands of coniferous seedlings ten to thirty feet tall to notice the rapidly growing leaders of the dominant trees. A casual glance will show a surprising variation in the rate of height growth of the same tree in different years. The obvious explanation that occurs to one is that this variation is due to a corresponding variation in the weather in the different years.

On looking more closely, however, one is disappointed to observe that whereas one tree grew more rapidly this year than last, its neighbor just reversed the process and grew more rapidly last year than during the present season. This fact raises the question as to whether or not there really is any relation between rate of height growth and annual variation in weather, and, if so, what that relation is.

An opportunity for following up this question presented itself during the past year, in connection with the work of securing growth data on western-larch seedlings. Measurements of 153 trees were taken in two 20-year-old stands at the Priest River Experiment Station in northern Idaho; 41 in one stand November 18, 1916, and 112 in the other, May 11, 1917.

Both stands were on level terraces not far from Priest River, the one measured in May being on an upper bench about 50 feet above that measured in November. Soil in both cases was sandy silt, that on the lower bench being somewhat the finer, with a less porous subsoil. Soil-moisture conditions on the lower bench are better, because of seepage from above and due to a more moisture-retentive soil. Climatically both sites may be considered identical, being not more than one-eighth of a mile apart. A meteorological station has been maintained on the upper bench, about half way between the two stands, since the fall of 1911, furnishing a daily record of temperature, precipitation, wind, sunshine, soil temperature, and other physical factors.

Trees were selected at random within small restricted areas and the following measurements were taken of each:

1. Diameter breast high.
2. Age on stump, cut as nearly as possible at ground line.

TABLE 1.—*Summary of November 18, 1916, Series*

Tree description.				Mean annual height growth, 5-year period, feet.	Departure from 5-year mean annual height growth.									
					1912.		1913.		1914.		1915.		1916.	
Age, years.	Number of trees.	Range in d. b. h., inches.	Range in height, feet.		Feet.	Rank.	Feet.	.	Feet.	Rank.	Feet.	Rank.	Feet.	Rank.
14........	5	0.7–2.3	11–24	1.49	—0.15	5	+0.03	3	+0.13	1	+0.09	2	—0.11	4
15........	3	1.6–3.1	17–26	1.74	—0.21	5	—0.04	3	+0.13	2	—0.11	4	+0.23	1
16........	3	0.0–2.4	7–21	1.41	—0.18	5	+0.07	2	+0.19	1	—0.01	3	—0.08	4
17........	6	0.6–2.7	9–25	1.55	—0.30	5	+0.12	3	+0.22	1	—0.20	4	+0.15	2
18........	7	0.6–3.5	12–21	1.31	—0.01	3	+0.02	2	+0.15	1	—0.12	5	—0.02	4
19........	4	1.0–2.1	13–20	1.34	—0.31	5	+0.14	2	+0.26	1	—0.09	4	+0.01	3
20........	7	1.2–2.9	16–23	1.41	—0.22	5	+0.05	3	+0.15	1	—0.07	4	+0.10	2
21........	6	2.2–3.7	23–30	1.67	+0.11	1–2	+0.11	1–2	±0.00	3	—0.06	5	—0.04	4
Total..	41	0.0–3.7	7–30	1.49	—0.16	5	+0.06	2	+0.05	1	—0.07	4	+0.03	3

TABLE 2.—*Summary of May 11, 1917, Series*

Age, years.	Number of trees.	Range in d. b. h., inches.	Range in height, feet.	Mean annual height growth, 5-year period, feet.	1912. Feet.	1912. Rank.	1913. Feet.	1913. Rank.	1914. Feet.	1914. Rank.	1915. Feet.	1915. Rank.	1916. Feet.	1916. Rank.
10........	2	0.3–1.0	7–11	1.13	—0.08	4	+0.02	2–3	+0.17	1	+0.13	5	+0.02	2–3
11........	8	0.1–2.0	6–21	1.53	—0.38	5	+0.03	4	+0.11	3	+0.11	2	+0.12	1
12........	14	0.0–1.7	4–20	1.38	—0.19	5	+0.01	2–3	+0.17	1	+0.01	2–3	—0.01	4
13........	8	0.4–1.5	8–19	1.49	—0.05	3	—0.29	5	+0.15	2	—0.08	4	+0.21	1
14........	9	0.2–1.6	5–17	1.07	—0.09	5	±0.00	3	+0.02	2	+0.12	1	—0.05	4
15........	11	0.3–1.4	7–19	0.99	—0.03	3	+0.09	2	+0.13	1	—0.04	4	—0.16	5
16........	14	0.4–4.4	9–30	1.50	—0.06	4	+0.05	2	+0.11	1	—0.11	5	+0.02	3
17........	18	0.8–4.0	12–30	1.56	—0.03	4	+0.02	3	+0.11	1	—0.18	5	+0.08	2
18........	13	1.4–4.7	17–32	1.70	+0.02	3	—0.06	4	+0.08	2	—0.14	5	+0.09	1
19........	5	1.3–2.3	15–22	1.57	+0.17	1	—0.01	4	+0.07	2	—0.31	5	+0.06	3
20........	7	1.0–3.3	17–30	1.58	+0.12	2	+0.09	3	+0.13	1	—0.15	4	—0.17	5
22........	2	1.8–3.0	19–27	1.81	+0.24	2	+0.14	3	+0.29	1	—0.31	5	—0.28	4
Total..	112	0.0–4.7	4–32	1.46	—0.05	5	—0.01	2	+0.11	1	—0.03	4	—0.02	3

3. Total height.

4. Distance between annual nodes of height growth on the main axis for the past five seasons.

Some difficulty was experienced in getting the complete growth for the last season on some of the trees, since the extreme tips of larch seedlings of this size are very weak and brittle. When the trees were struck at the base with an ax, the sudden whipping of the tip through the air caused the last few inches to be snapped off from about one-third of the trees measured in May—40 out of 112. Such trees with broken tips were discarded in the November work.

The tips were usually scattered beyond recovery, but enough were recovered to permit of a close estimate of the average length of such broken tips. There was little variation in the cases observed and it was estimated that the length would average at least three inches. It would, if anything, be a fraction over this; so that the figure is conservative. Accordingly an addition of three inches was made to the 1916 height growth of each of the trees with broken tips measured in the spring series.

The figures were first assembled by grouping the trees in one-inch diameter classes. This was not found to be satisfactory, because of the wide variation in ages of trees in each group. The effect of the natural acceleration in height growth, which may be expected with increasing age at this period in the life of the tree, was open to question and made it difficult to draw fair conclusions as to the effect of climatic changes in the different years.

Because of this question as to the effect of age, the trees were then grouped by years of age as counted on the stump. While it is difficult in such work to determine the age in all cases to the exact year, it is thought that the age of a majority of the trees was determined correctly. Tables 1 and 2 summarize the data by age-groups.

TABLE 3.—*Summary of Tables 1 and 2, Showing Rank in Height Growth by Seasons*

Rank in height growth.	Summary of rank in height growth, by years.				
	1912.	1913.	1914.	1915.	1916.
First	2	1	13	0	4
Second	2	7	5	3	4
Third	4	8	2	1	3
Fourth	3	3	0	7	7
Fifth	9	1	0	8	2

NOTE.—In case of a tie each season is given the higher rank.

The most striking fact brought out by the tables is the consistent lead in height growth shown for the season of 1914. This is true of the different ages in each series, independently, as well as in the averages. 1914 takes first rank in at least one case for all of the thirteen ages included, with the exception of 11 and 13 years, which are in third and second rank respectively. In no case does 1914 fall below third rank and is third only twice out of twenty times.

The relationships of the other seasons are also fairly constant, although they show more variation than does 1914. The averages for the two series show an identical ranking for each of the five seasons. The individual ages check with the rank shown by the averages in a sufficient number of cases to show a fair consistency throughout.

Seasonal change in weather is clearly the dominant factor influencing rate in height growth between the ages included in the study. A tabulation of the data in Tables 1 and 2 so as to group height growth according to the year of the tree's age, rather than season, showed no well-defined relation between year of age and relative height growth. This holds true of the individual trees as well as the averages for each age. It may reasonably be concluded, therefore, that the influence of age at this period in the life of the tree is subordinate to changes in the weather and physical factors which affect tree growth directly or indirectly.

The fact that height growth was so consistently greater in 1914 than in the two years just preceding or following raises the question as to whether the season of 1914 differed from the others in any marked way. A detailed analysis of all the climatic records obtained during this period is scarcely within the scope of this study. Furthermore, the growth data are hardly intensive enough to warrant such a procedure. It is felt, however, that the relationships between growth and climatic changes can be indicated, at least in a general way, by limiting the comparison to three factors: air temperature, precipitation, and cloudiness.

Air temperature can, it is thought, be expressed in sufficient detail for this study by using the mean monthly temperature—the mean of the daily means of the maximum and minimum readings. Precipitation needs a somewhat more detailed treatment, since its distribution and the length of dry periods have an important influence upon growth. The amount of sunshine can be indicated in a general way by the number of days in each month classified as "clear" (0.0 to 0.3 cloudy), "partly cloudy" (0.4 to 0.7 cloudy), and "cloudy" (0.8 to 1.0 cloudy).

General observations of larch indicate that height growth starts in the latter part of April or first of May and is practically complete for the season by the middle or end of July. Climatic records for the months of April, May, June, and July are, therefore, all that need be included in a study of the direct relation between climatic variations and rate of height growth. A summary of the climatic data for these months in the years 1912, 1913, 1914, 1915, and 1916, for meteorological station number 3 at the Priest River Experiment Station, is given in Tables 4, 5, and 6.

The observations which form the basis of the climatic records were made by Forest Service officials in co-operation with the U. S. Weather Bureau. Standard meteorological instruments were used.

In temperature, the year 1914 shows somewhat higher figures than the other years, ranking first in the months of May and July and ranking slightly the highest for the four-months' period as a whole. A lead of 2.1 degrees above the average for the month of May, in the year 1914, would indicate more than ordinarily good growing conditions, particularly if accompanied by plenty of moisture. There is, however, a considerable and rather inconsistent variation in temperature for the five years as a whole, and it seems doubtful if much weight can be given the indications of mean monthly temperature taken separately.

A definite lead is shown by the year 1914 in the number of "clear" days, both in the average and for the months of May, June, and July—the growing months. This, when coupled with the higher than average temperature conditions in that year, would be favorable to an unusual amount of growth, other factors being equal.

Precipitation figures, in the form of monthly totals, are contradictory and show no distinct tendencies. The response which the growing plant makes to differences in amount of precipitation is apt to be very indirect unless the amounts approach the minimum needed by the plant. Excessive amounts beyond what the plant requires and can utilize under the given temperature and light conditions will produce little, if any, effect in the form of growth. It is evident from the figures in Table 6 that in some months an exceptionally heavy precipitation occurred, which was probably more than the trees could utilize fully. Moreover, this was often largely concentrated during short periods, making a considerable portion of the total unavailable for the use of the tree because of heavy loss in run-off.

In order to determine whether an analysis of the daily precipitation would bring out any relationships between rainfall and growth the daily amounts were platted, as shown in figure 1.

TABLE 4.—*Air Temperature*

Factor.	Year.	April.		May.		June.		July.		Four months.	
		Amount.	Rank.	Amount.	Rank	Amount.	Rank.	Amount.	Rank.	Amount.	Rank.
Air temperature Five-year average of mean monthly temperatures	5 years	44.1	..	50.1	..	57.0	..	61.3	..	53.1	..
Departure from five-year monthly mean, by years..	1912	—0.7	3	+1.4	2	+3.6	1	—0.7	4	+0.9	2–3
	1913	—2.3	5	—0.7	4	+1.1	2	—1.5	5	—0.8	4
	1914	+0.5	2	+2.1	1	—1.4	3	+2.6	1	+1.0	1
	1915	+4.1	1	+1.1	3	—1.6	4	—0.1	2	+0.9	2–3
	1916	—1.7	4	—4.1	5	—1.6	5	—0.3	3	—1.9	5

TABLE 5.—*Cloudiness*

Factor.	Year.	April Amount.	April Rank.	May Amount.	May Rank	June Amount.	June Rank.	July Amount.	July Rank.	Four months Amount.	Four months Rank.
Number of "clear" days, by years	1912	0	5	7	3	12	3	8	4–5	7	5
	1913	12	2–3	19	1–2	13	1–2	23	2	17	2
	1914	12	2–3	19	1–2	13	1–2	27	1	18	1
	1915	14	1	2	5	10	4	9	3	9	3
	1916	11	4	5	4	8	5	8	4–5	8	4
Number of "partly cloudy" days, by years...........	1912	24	1	11	2–3	7	4	11	2	13	1–2
	1913	9	2	4	5	5	5	5	4	6	5
	1914	8	3–4	7	4	10	3	2	5	7	4
	1915	8	3–4	16	1	12	2	15	1	13	1–2
	1916	7	5	11	2–3	16	1	10	3	11	3
Number of "cloudy" days, by years	1912	6	5	13	2–3	11	2	12	1	11	1
	1913	9	3	8	4	12	1	3	3–4	8	4
	1914	10	2	5	5	7	4	2	5	6	5
	1915	8	4	13	2–3	8	3	7	2	9	2–3
	1916	12	1	15	1	6	5	3	3–4	9	2–3

TABLE 6.—*Precipitation*

Factor.	Year.	April.		May.		June.		July.		Four months.	
		Amount.	Rank.	Amount.	Rank.	Amount.	Rank.	Amount.	Rank.	Amount.	Rank.
Precipitation											
Mean monthly precipitation for five-year period........	5 years	2.14	..	2.70	..	2.63	..	2.07	..	2.39	..
Departure from five-year monthly mean, by years..	1912	+0.32	2	—0.02	2	—0.49	4	+0.51	2	+0.08	2
	1913	—0.81	5	—0.46	5	+0.68	1	—0.85	5	—0.36	5
	1914	+0.44	1	—0.34	4	+0.31	3	—0.24	3	+0.04	3
	1915	+0.20	3	+0.95	1	—1.10	5	+0.98	1	+0.25	1
	1916	—0.14	4	—0.11	3	+0.60	2	—0.41	4	—0.02	4
Number of days with 0.01 inch or more of rain, by years	1912	13	3	12	5	8	5	16	1	12	3–5
	1913	12	4	13	3–4	14	3–4	8	3–4	12	3–5
	1914	16	1	13	3–4	15	1–2	4	5	12	3–5
	1915	9	5	21	1	14	3–4	15	2	15	1
	1916	15	2	16	2	15	1–2	8	3–4	14	2
Number of days with 0.10 inch or more of rain, by years	1912	6	3	8	3–4	7	3	7	1–2	7	2–5
	1913	5	4–5	8	3–4	9	2	4	3–5	7	2–5
	1914	5	4–5	9	2	10	1	4	3–5	7	2–5
	1915	7	2	10	1	6	4–5	7	1–2	8	1
	1916	9	1	7	5	6	4–5	4	3–5	7	2–5

A study of the chart brings out the fact that the rainfall in 1914, while only average in amount, compared to the other years, was very evenly distributed during the period of most rapid height growth. Good soaking rains occurred regularly at intervals of from four to ten days from the middle of April to the middle of July, with smaller showers between in most cases. The two rainy periods in June were probably exceptionally favorable to growth. In each case a heavy rain was preceded by lighter showers, giving the ground a chance to become soaked to a good depth. The rainy period was then followed by a week or so of warm, growing weather, with an abundance of soil moisture available to the roots.

In contrast to the year 1914, the other seasons show much more prolonged periods during which no heavy soaking rains occurred. Much more irregularity in the quantities of rain during the different rainy periods is also shown. Some were merely a series of light showers which would not be able to penetrate the soil to any great depth. Others, again, were heavy isolated rains which were concentrated over short periods and preceded or followed by several days of dry weather, leading to maximum loss from run-off and evaporation. The effect upon growth of regularity or irregularity of distribution of rainfall within the limits here shown is, of course, purely a matter of speculation, but it is not unreasonable to think that moisture conditions in 1914 were at least fully as favorable, if not more so, than in any of the other years.

In conclusion, it must be admitted that the data here presented are inadequate to definitely establish any clear relationship between height growth and climatic factors. Yet there is a consistent, if somewhat circumstantial, series of indications which all lead to the tentative conclusion that the year 1914, with its relatively high temperatures, its maximum of sunny days, and its sufficient and evenly distributed rainfall, produced favorable growing conditions which were directly reflected in the greater height growth shown for that year. Temperatures in other years were just as high or higher; there were just as many clear days, and rainfall was just as great and as evenly distributed. Yet in no case were all these favorable factors combined in the same years and months to the extent shown in 1914.

Taking the evidence of average amount of growth in the different years as a basis, it seems justifiable, therefore, to conclude that rate of height growth of larch seedlings does vary in accordance with variations in weather conditions from year to year, and that the most favorable conditions for rapid height growth are produced in the North

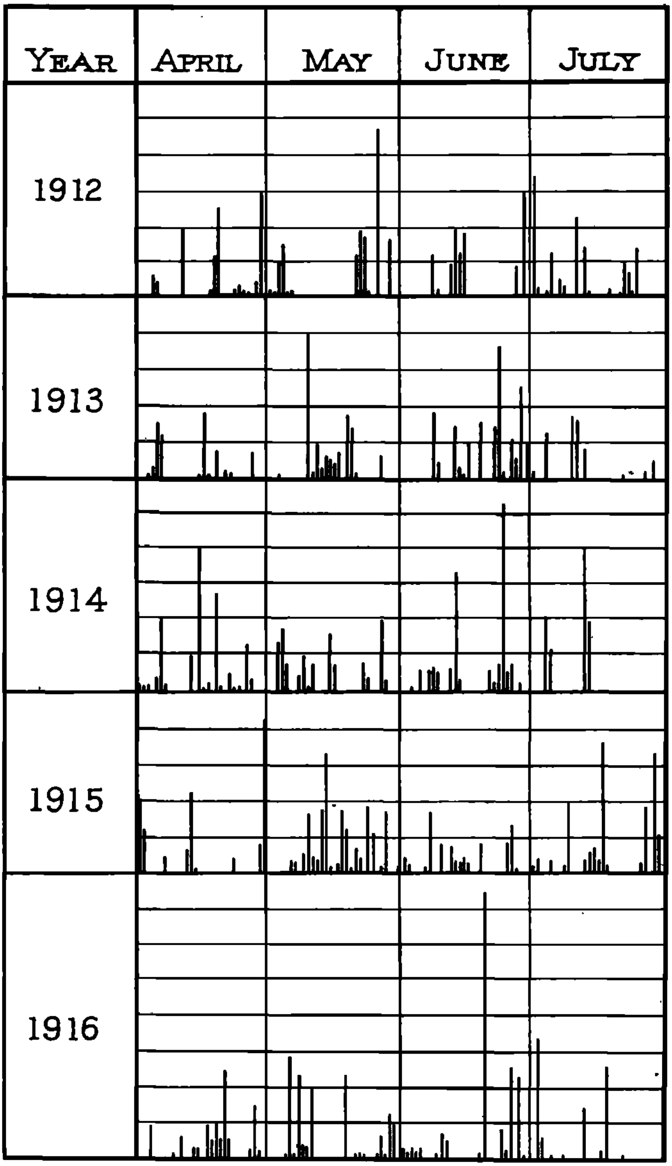

FIG. 1.—*Daily precipitation*

Idaho region by a combination of temperatures somewhat above the average, coupled with a high percentage of clear days, with an average amount of precipitation evenly distributed in the form of good rains at intervals of four to ten days preceded and followed by lighter showers. This conclusion, while in harmony with the laws of plant physiology, must, however, be considered tentative until supported by more intensive study, and is presented at this time with the hope of stimulating discussion and further study along the lines indicated.