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A study of seed germination and establishment of seedlings of lodgepole pine in different soil types under certain bog conditions

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A STUDY OF SEED GERMINATION AND ESTABLISHMENT OF SEEDLINGS OF LODGEPOLE PINE IN DIFFERENT SOIL TYPES UNDER CERTAIN BOG CONDITIONS

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INTRODUCTION

Lily Lake is one of hundreds of subalpine glaciated lakes in the Uintah Mountains, which are located in the northeastern part of Utah and extend as a range in an east to west direction. They represent Utah's only claim to a typical Northern Rocky Mountain Flora (Cottam, 1930). Lily Lake is in the Wasatch National Forest in T1S, R9E, S31, at an elevation of 10,500 feet. This lake has a bottom of muck and is classified as a sphagnum lake or moorland lake according to its shore conditions (Tanner, 1931). Sphagnum moss, sedges, grasses and blueberry (*Vaccinium*), typical acid bog flora, are important components of the surrounding meadows. Lily Lake is a small lake (750' x 450') with a maximum depth of 16 feet, and is immediately surrounded by a sphagnum-carex meadow that grows in a highly organic soil. The meadow consists of a wet part adjacent to the margin of the lake and a drier part that intergrades into a fringe of blueberry shrubs (Christensen and Harrison, 1961). A mesophytic upland conifer forest, with lodgepole pine (*Pinus contorta*), Engelman spruce (*Picea engelmanni*), and subalpine fir (*Abies lasiocarpa*) as the dominant species, form the major plant types in the forest adjacent to the meadow zone.

According to Cottam (1930), a few small, slow-growing lodgepole pines occur associated with the blueberries on the dry meadow area. Firmage (1969) stated that lodgepole pine invaded the dry meadow fringe bordering the lake, as this tree has a higher tolerance of moisture and requires more light than spruce and fir in the forest. However, he provided no experimental evidence for these observations. Lodgepole pines, sparsely distributed on the dry meadow zone, look stunted and fail to attain their maximum growth potential. The majority of the lodgepole trees in dry meadow were between 15 and 25 years old with a height of 2 to 4 feet. For comparative purposes, the growth rates of some small *Pinus contorta* trees, measured in a logged-over area, achieved a height of 2 to 3 feet in about five years (Firmage, 1969).

The objective of this study was to measure the depth to the water table, kind of soil, temperature, light, and to determine their influence on seed germination and establishment of lodgepole pine seedlings.

Geology

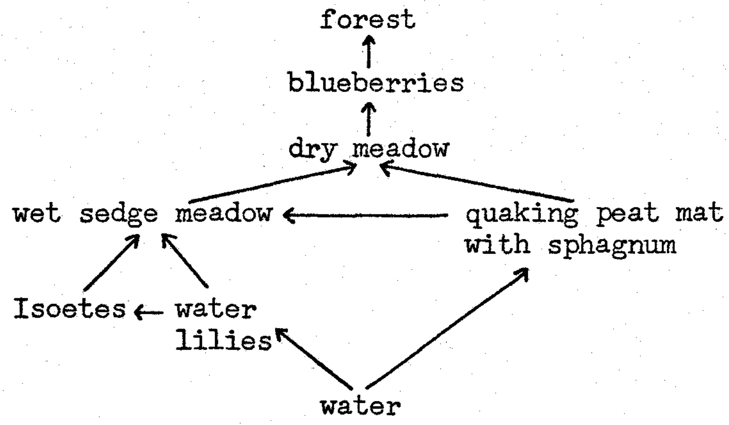
The Uintah Mountains of Utah are distinct in the fields of geology and geography as a classical example of dome mountains, as well as for an east-west axis which stands in marked contrast to most mountain ranges of North America (Cottam, 1930). These mountains rise out of the plateau country to the north and south and reach a maximum elevation of 13,525 feet. The range is about 35 miles wide in its central portion and about 150 miles in length. More important is the fact that the range represents a broad anticline with the high elevation broken into great jumbled masses of loosely piled, pre-cambrian quartzite rocks. Even the highest peaks consist of immense piles of loose rocks rather than the solid masses that comprise most high mountains in the west. The Uintah Mountains are entirely lacking in igneous rocks or evidence of volcanic action of any kind (Hayward, 1952). This range is the most extensively glaciated area in Utah. It is estimated that there are over 1000 lakes in this glaciated region, and they form the source for Utah's only acid bogs with typical acid bog flora (Tanner, 1931).

Literature Review

The ecological study of lodgepole pine (*Pinus contorta*) in the Rocky Mountain area has been of considerable interest to many ecologists. Clements (1910) made a study to determine the life history of lodgepole burn forests at altitudes of from 7,500 to 8,500 feet in Estes Park, northern Colorado. He noticed that the great majority of cones in a lodgepole forest open naturally without the aid of fire. Apparently the seeds are released by the action of dry air and heat. Mason (1915) gave a good background on the life history of lodgepole in the Rocky Mountains, and stated that lodgepole requires considerable light from above for its best development provided sufficient soil moisture is available, and also that it will not reproduce satisfactorily without considerable direct light.

Bates made a study (1917) on the biology of lodgepole pine as revealed by the behavior of its seed, and presented a detailed paper (1930) dealing with the general qualities of lodgepole pine cones and the production, extraction, and germination of seed. Cottam (1930) made a preliminary report on some unusual floristic features of the Uintah Mountains, noting particularly the lodgepole pine in the typical acid bog flora, such as sphagnum moss and vaccinium. Haasis and Thrupp (1931) made a study of temperature relations of lodgepole pine seed germination and suggested that seed produced in colder climates may be expected to germinate more quickly at lower temperature than those from warmer climates, and vice versa. Dunnewald (1934) listed some soil factors which resulted in the failure of lodgepole plantings and concluded that physical and chemical differences in soil account for as much as 50% reduction in germination and that steam sterilizing encourages loss from mold and wilt rather than decreasing them. Gail and Long (1935) conducted an ecological study of site, root development and transpiration in relation to the distribution of Pinus contorta. During the experiment, they compared lodgepole pine with ponderosa pine. The results of this study showed that the transpiration rate of P. contorta was slower than that of Pinus ponderosa when both species were in a quiet atmosphere. Also, they found that lodgepole pine has a shallower absorbing system and less extensive lateral roots than has ponderosa pine, which results in the usual limitation of P. contorta to protected sites. Kozlowski (1949) made a study of light and water in relation to growth and competition of some forest tree species. He noted that pines, in general, grown in full light, made more height growth, and had greater dry weight of foliage, stems, roots and total dry weight, than did shade-grown pine. Although he did not include lodgepole pine in his report, his information was valuable to this study. A study of Moss Lake, a small bog lake in the subalpine forest of the Uintah Mountains, conducted by Stutz (1951) described the ecology and floristics of the sphagnum lakes in this area and stated that lodgepole pine is one of the three dominant species in the upland mesophytic forest.

Christensen and Harrison (1961) presented a paper on an ecological study area at Lily Lake and included the floristics, succession pattern, and PH measurements of sphagnum lakes. According to them, the mesophytic forest is composed of three dominant species: Picea engelmanni, Abies *lasiocarpa*, and *Pinus contorta*. The successional relationships were generalized in the following diagram:



This diagram implies that a forest of fir, spruce and pine will eventually replace *Vaccinium* as the climax.

Stephens (1966) reported that lodgepole pine grows only on two general soil groups in the area: (a) well and excessively well drained, moderately coarse textured soils; and (b) poorly and very poorly drained, organic soils. It does not grow on the medium and moderately fine textured soils, or on moderately well drained, moderately coarse and coarse textured soils.

A study of conifer invasion into meadows surrounding small lakes and ponds in the Uintah Mountains was conducted by Firmage (1969). Lodgepole pine appears to be invading the dry meadow area, but it fails to attain its maximum growth rate there. He concluded that the trees are not able to attain a growth rate rapid enough to become the dominant species and convert the meadow into a forest.

METHODS AND PROCEDURES

Soil texture, organic matter content, and hydrogen-ion concentration of soil samples were determined in order to study the correlation between soil characteristics and seed germination. Scarification by chemically disrupting the seed coat and stratifying seeds with cold temperature treatments were methods used for determining germination requirements of dormant seeds. Seeds were planted in three different soils collected in the field to help determine if differing characteristics affect seed germination. Experiments were conducted to determine the effects of different light intensities, temperatures, and depths to the water table on seedling establishment of _Pinus contorta_.

All measurements of soil characteristics, effects of planting depth, water depth, temperature, and light on the growth of lodgepole pine were conducted in the laboratory and greenhouse. Visits to Lily Lake were made during the first week of September, 1970 and soil samples, seeds and lodgepole seedlings needed for the experiments were obtained at that time.

Soil Analyses

Soil samples were gathered from three different zones: a zone of wet meadow surrounding Lily Lake, a zone of dry meadow and the mesophytic upland forest. Each sample was a composite of soil collected to a depth of six to ten inches and was transferred to the greenhouse, mixed, and screened through a quarter inch mesh sieve.

The Boyoucous Hydrometer method was employed to determine the mechanical analysis of these soils (Boyoucous, 1936). Total organic matter percentage of the soil sample was determined by placing a portion of the sample in an oven at 41°C for twenty four hours to remove the water, then weighing before oxidizing in a muffle furnace at 816°C for three hours, and finally reweighing. The loss on oxidation was assumed to be principally organic matter. The hydrogen-ion concentration was determined with a Beckman Research PH meter.

Experiment on Scarification

Pine cones were collected from mature trees near Lily Lake and seeds were extracted by heating the cones at 70°C in the oven for four hours, since lodgepole pine cones seldom open at maturity. According to Bates (1930), this temperature treatment gives the best results for germination.

A chemical scarification technique (Crocker and Barton, 1953) was used to determine if the hardness of the seed coat influenced the germination ability of the embryo. Seeds in lots of 100 were placed in gooch crucibles containing concentrated sulfuric acid. Eleven lots of lodgepole pine seeds were placed in this acid for different duration: control, 1, 2, 5, 10, 15, 20, 30, 40, 60, and 90 minutes. Some seeds were removed after each of the above treatment periods, washed off thoroughly with distilled water, and then placed between two moistened pieces of filter paper in closed petri dishes. The seeds were kept moist and at room temperatures of 25°C throughout the remainder of the experiment. At regular intervals seeds were examined to see if they had germinated.

Experiment on Stratification

The physical stratification technique (Crocker and Barton, 1953) employed variable cold temperatures to hasten germination of seed. Lodgepole pine seeds were grouped into twenty four lots of 100, dusted with ceresan (an organic mercuric fungicide) and placed between two moistened pieces of filter paper in petri dish kept in the dark. They were incubated at four different temperatures: $0^{\circ}C$, $5^{\circ}C$, $15^{\circ}C$, and $25^{\circ}C$ respectively, with durations from two, four, six, eight, twelve and sixteen weeks. At one day intervals these seeds were examined to determine germination. Germinated seeds were then planted in standard greenhouse soil (one part each of sand, loam and peat moss) in order to investigate other requirements of the seedlings.

Germination in Different Soils

Three lots of 100 seeds were planted in flats of soil from the three regions of the study area. A planting depth of one fourth inch was adopted, since this depth gives the best results according to Bates (1930). These flats with seeds were watered regularly and observed for germination. A check was made each day for seeds that had germinated and the number of seedlings was recorded. From these data, germination percentage for each day was calculated.

Light Intensity Experiment

Lodgepole pine seedlings obtained from the germination experiment were grown for about six months. After having reached a uniform height of about two inches, the root and shoot lengths of twenty healthy plants were measured. Seedlings then were planted into milk cartons in standard greenhouse soil and allowed to grow for another week before placing them under different intensities of light. Twenty seedlings were grouped into five groups of four plants each. Screens were arranged on a greenhouse bench so as to yield different light intensities. One group without screen was used as control. Three wooden frames were built with one, two, and three layers of cheese-cloth covering the top and four sides to reduce the light intensity to three fourths, one half, and one fourth of full sunlight as measured with a light-meter. Groups of plants were placed in each of these light conditions. A wooden box covered completely with black cloth was used as a dark room. At twelve-day intervals, one plant was measured from each treatment. These plants were washed out of the soil, and cut off at the juncture between the root and shoot. The shoot length and the root length were measured, whereas the shoot and root were weighed respectively after drying in an oven at $105^{\circ}C$ for four hours.

Apparent Photosynthesis Rate

To check for apparent photosynthesis as affected by light and temperature, eighteen young trees about six to eight inches tall were transplanted into plastic pots approximately seven and half inches deep and four inches in diameter and allowed to adjust to greenhouse condition for one month. Two sets of nine plants were transfered to $7^{\circ}C$ and $17^{\circ}C$ walk-in temperature boxes. After having grown at a light intensity of 750 foot candles for five weeks, each plant was tightly covered with a transparent plastic bag and CO_2-free air was flushed through from a tank by means of a connected rubber tube. After ten minutes, CO_2 concentration of the air within the bag was determined on an Infrared Carbondioxide Analyzer, Beckman Model 2-15. The average CO_2 concentration in ppm was recorded for each individual plant. The light intensity was then reduced to 250 foot candles, while temperature in the boxes remained the same. At the end of five weeks at 250 foot candles, apparent photosynthesis determinations were again made. After establishing CO_2 output at 250 foot candles and 750 foot candles, points between these light intensities were computed. These data were used in establishing apparent photosynthesis rates.

Water Table Experiment

The lodgepole trees used in the apparent photosynthetic rate experiment were used in the water table experiment. These plants were grouped into four sets of three individuals each: one set was watered from the top, the second was immersed in an aluminum tank with a water depth of one inch covering the bottom of the pot, the third stood in water three inches deep, whereas the last set was placed in a tank with water depth at five inches. Water depths were adjusted daily to maintain these depths. Growth of new foliage and new shoots was noted at three-day intervals for fifty days. These plants were photographed before the experiment began, and were again photographed at the end of fifty days to show the growth attained in differing water table depths.

RESULTS

Soil Analyses

Mechanical analysis of the soil, from three sample locations of the three different zones, showed only slight variations in texture for two of them (Table 1). The soil from the wet meadow zone was mostly a sphagnum-carex peat with organic matter content as high as 90.0%. Hydrogen-ion concentration (PH) varied between sample zones, and was acid in all samples, ranging from a low of 3.6 in the wet meadow to a high of 5.1 in the dry meadow. Variations for the percentage of organic matter also occurred between zones, ranging from a high of 90.0% in the wet meadow immediately surrounding the lake, to a low of 42.8% in the mesophytic upland forest. Results as shown in Table 1 were an average of three replicates.

Experiment on Scarification

Lodgepole pine seeds scarified with concentrated sulfuric acid had an increased percentage of germination over non-treated seeds. The seeds scarified for one minute gave the highest total germination. Germination percentages decreased gradually with increasing duration of scarification. Seeds treated over twenty minutes gave results similar to untreated seeds. If germination occurred at all, it mostly took place during the first week (80%), with no germination after three weeks (Table 2).

Table 1. Hydrogen-ion concentration, percentage of sand, silt, clay and organic matter of soils studied during the summer of 1970.

Sample Zones	Soil Texture			Hydrogen-Ion Concentration	% of Organic Matter
	% Sand	% Silt	% Clay		
Wet Meadow Zone	Texture Undetermined			3.6	90.0
Dry Meadow Zone	73.6	23.2	3.2	5.1	71.8
Forest Zone	69.0	26.8	4.2	4.8	42.8

Table 2. Lodgepole pine seed germination after scarification with concentrated H_2SO_4, 100 seeds in each petri dish (average of three replicates).

Date	Length of H_2SO_4 Treatment in Minutes*								
	0	1	2	5	10	15	20	30	40
Oct. 6	8	2	8	4	4	10	6	12	0
7	16	16	14	2	18	15	12	6	0
8	4	25	24	16	14	18	18	4	0
9	2	24	12	20	14	12	2	2	0
10	2	12	4	6	6	6	4	2	0
11	1	4	2	10	4	4	3	1	0
12	1	4	2	15	2	2	1	1	0
13	1	2	3	1	0	3	0	0	0
14	1	2	0	6	4	2	2	0	0
15	2	0	2	3	2	1	0	0	0
16	2	1	1	2	0	1	0	0	0
17	4	1	0	1	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0
19	2	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	0	0	0
21	1	0	0	0	0	0	0	0	0
**	66	84	86	56	82	82	88	83	0
Total %	48	94	72	86	68	74	48	30	0

*Treatments above 40 minutes are deleted because of no germination.

**Percentage of total germination accomplished during the first week.

Experiment on Stratification

The germination of lodgepole pine seed was most rapid with the greatest total percentage at constant room temperature of approximately 25°C. The germination of seeds initially kept in 15°C, then warmed up to 25°C, was only 85-90% as good as those kept at a constantly warm temperature. At 5°C, only 1-2% of total germination percentage occurred. At 15°C, approximately 10% germination occurred within three weeks. It seems that warming stimulates rapid germination either with or without a cold treatment. The 5°C treatment, although suppressing germination, eventually resulted in germination comparable to the treatment under 15°C. Evidently, cold treatment increased the germination percentage to a certain degree. The 0°C treatment failed because of fungal attack (Table 3).

Germination in Different Soils

Germination occurred one week earlier in soil from wet meadow than in soils from other zones. Also the total germination percentage varied in these three soils, ranging from 64% in wet meadow soil to as low as 13% in dry meadow soil. The wet meadow soil gave the highest percentage of germination and began the earliest, followed by forest soil and dry meadow soil. Two weeks after planting, *Fusarium* wilt appeared in both flats of meadow soil, and attacked the roots and stems of some plants causing them to curl up or wilt and die. However this symptom did not appear on plants growing in forest soil until the third week (Table 4).

Table 3. Germination percentage of lodgepole pine seeds at four different temperatures for six different periods. (September 21, 1970-February 11, 1971).

Period of Stratification	Percent of Germination	Temperature			
		0°C	5°C	15°C	25°C
2 Weeks	A	0	1	10	66
	B	*	77	60	11
	C	0	78	70	77
4 Weeks	A	0	2	13	71
	B	*	86	48	15
	C	0	88	61	86
6 Weeks	A	0	0	16	89
	B	*	*	70	4
	C	0	0	86	93
8 Weeks	A	0	0	15	83
	B	*	*	46	0
	C	0	0	61	83
12 Weeks	A	0	0	16	85
	B	*	*	47	0
	C	0	0	63	85
16 Weeks	A	0	0	19	89
	B	*	*	43	0
	C	0	0	62	89

A: Percentage of total germination accomplished during first two weeks.

B: Percentage of total germination upon release to 25°C.

C: Total germination percentage.

*This experiment was destroyed by fungi.

Table 4. Lodgepole pine seed germination, 100 seeds planted in each flat, March 23, 1971.

Date	Wet Meadow Zone	Dry Meadow Zone	Forest Zone
March 24	1	0	0
25	0	0	0
26	0	0	0
27	0	0	0
28	0	0	0
29	1	0	0
30	0	0	0
31	2	0	0
April 1	2	0	0
2	9 (1 Wilt)	0	1
3	0 (1 Wilt)	0	0
4	3 (2 Wilt)	1	0
5	4 (1 Wilt)	0	2
6	9 (1 Wilt)	0 (1 Wilt)	4
7	8 (3 Wilt)	0	1
8	3 (2 Wilt)	0	1
9	4	1	1
10	3	0	0
11	0	1 (1 Wilt)	0
12	1 (4 Wilt)	0	1 (3 Wilt)
13	1	2	0 (2 Wilt)
14	0 (4 Wilt)	0	1 (2 Wilt)
15	1 (2 Wilt)	1 (2 Wilt)	3 (1 Wilt)
16	0	3	0 (4 Wilt)
17	1 (2 Wilt)	0	1 (2 Wilt)
18	1 (2 Wilt)	0 (1 Wilt)	0 (2 Wilt)
19	2 (3 Wilt)	1	0 (1 Wilt)
20	1 (4 Wilt)	0	2 (1 Wilt)
21	1 (5 Wilt)	0 (3 Wilt)	0
22	0 (7 Wilt)	1	2
23	2 (6 Wilt)	0 (1 Wilt)	0
24	1	1 (2 Wilt)	1
25	1 (5 Wilt)	1 (2 Wilt)	1
26	2 (5 Wilt)	0	0
Total Percentage	64	13	22

Light Intensity Experiment

The plants growing under full sunlight for three different time intervals had the fastest development in both root system and shoot system compared with plants under three fourths, one half, and one fourth of full light, and under complete darkness. However, plants grown under three fourths of light had a more balanced growth of shoot and root systems. As the amount of light increased from zero to three fourths of full sunlight, the shoot length, root length, the shoot weight, and the root weight increased. After plants were kept in the dark for nineteen days, they started to wilt. All of them died after twenty four days, because photosynthesis failed to take place without light. From Table 5, it is evident that increased light intensity resulted in root length and root weight increase more than increases in the shoot portion.

Apparent Photosynthesis Rate

Relative photosynthesis varied greatly in different temperatures with light intensity kept the same. With light intensity at 750 foot candles, the average CO_2 concentration of nine plants kept in temperature of 17°C for five weeks was 576 ppm, whereas 173 ppm was the average CO_2 concentration of the nine kept at 7°C for the same duration. The lower the temperature, the higher the apparent photosynthesis. This held true when light was cut down from 750 foot candles to 250 foot candles (Table 6; Fig. 1).

Water Table Experiment

The greatest amount of new growth was found in plants in pots

Table 5. Effect of five different light intensities on shoot length, root length, shoot weight, and root weight of 15 lodgepole seedlings (six months old).

Light Intensity	Time (Days)	Percentage Increases in						Observations
		Shoot Length	Root Length	Shoot Root Ratio	Shoot Weight	Root Weight	Shoot Root Ratio	
Full Sunlight	21	2.6	7.5	0.35	3.4	8	0.34	New growth on both shoot and root obvious; plants green and healthy.
	33	3.3	12.1	0.28	8.2	20	0.41	
	45	0	12.7		8.2	26	0.31	
Three Fourths of Full Light	21	2.3	3.7	0.62	6.7	4.2	1.50	New growth observed, but not as good as ones in full light.
	33	0	12.2		7.5	14.3	0.52	
	45	11.0	10.8	1.01	7.8	10.5	0.74	
One Half of Full Light	21	0	3.4		1.1	20.0	0.06	A little growth can be seen; plants greyish green.
	33	0	5.2		5.5	8.1	0.68	
	45	5	7.6	0.65	4.8	8.0	0.60	
One Fourth of Full Light	21	0	1.5		0	2.0		The tips of pine needles turned yellowish.
	33	0	0		1.2	0		
	45	2.6	5.7	0.45	1.2	5.3	0.22	
In Dark Chamber	21	0	0		0	0		Plants turned redish-yellow and died.
	33	died	died		died	died		
	45	died	died		died	died		

Table 6. Apparent photosynthesis rate at different light intensities and temperatures.

Light Intensity in Foot Candles	CO_2 Concentration (ppm) at	
	7 °C	17 °C
750	173	576
250	330	603

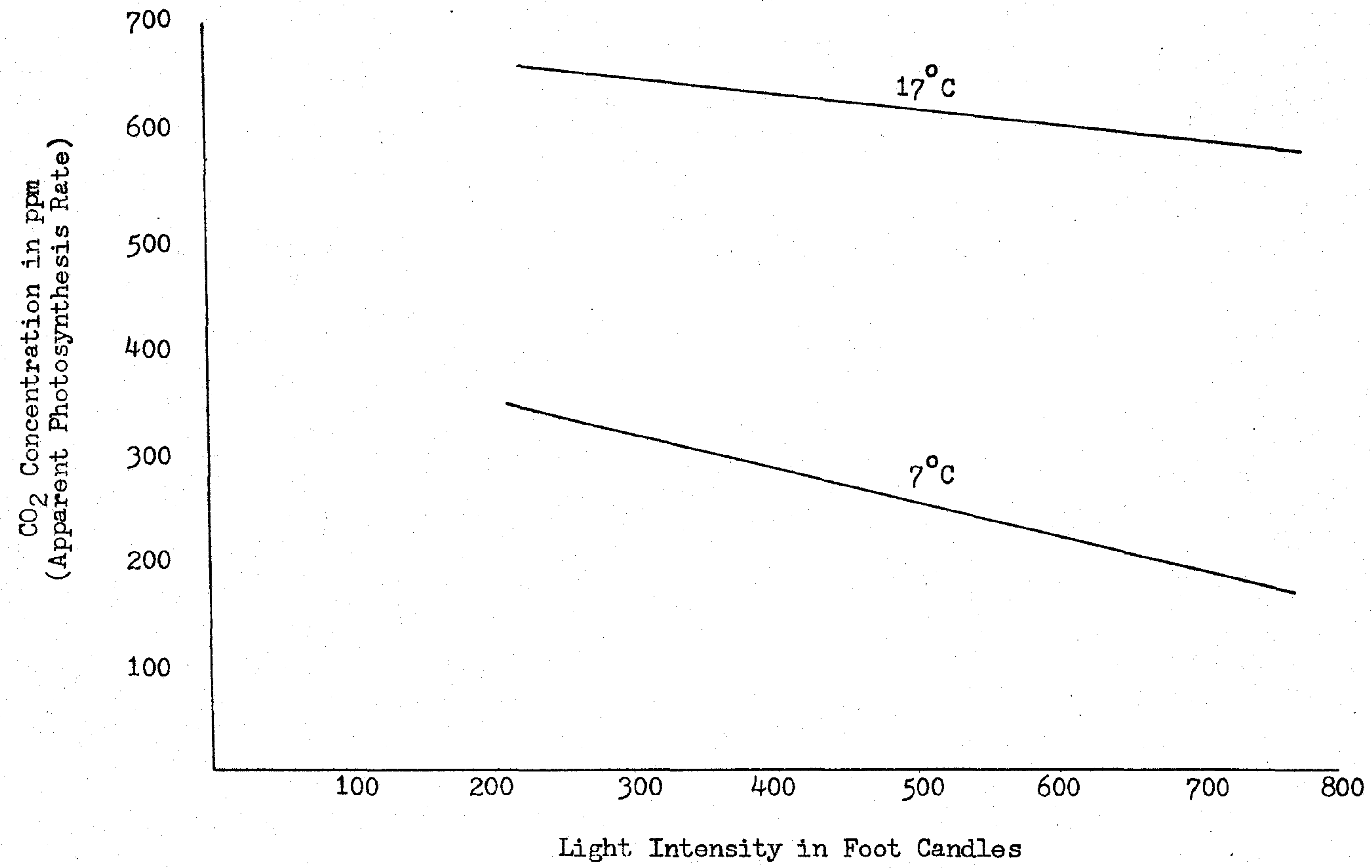


Fig. 1. Average CO_2 concentration (ppm) in captured air surrounding nine young lodgepole trees under different light intensities and temperatures.

which were submerged in a depth of one inch of water. The young tips were green and bushy. The best result was followed by three inches of water, and in water of five inches deep. The plants under control showed the least amount of new growth. The fastest growth occurred in plants following the same general pattern as above (Fig. 2-9).

Fig. 2. Lodgepole Saplings Taken at the Beginning of Water Table Experiment, February 22, 1971. (Watering from Top)

Fig. 3. The Same Set of Trees as Above Taken Fifty Days Later, April 11, 1971.

Fig. 4. Lodgepole Saplings Taken at the Beginning of Water Table Experiment, February 22, 1971. (with the Bottom of the Pot Submerged in 1" Deep Water)

Fig. 5. The Same Set of Trees as Above Taken Fifty Days Later, April 11, 1971. (No. 4 and No. 6 Were Reversed)

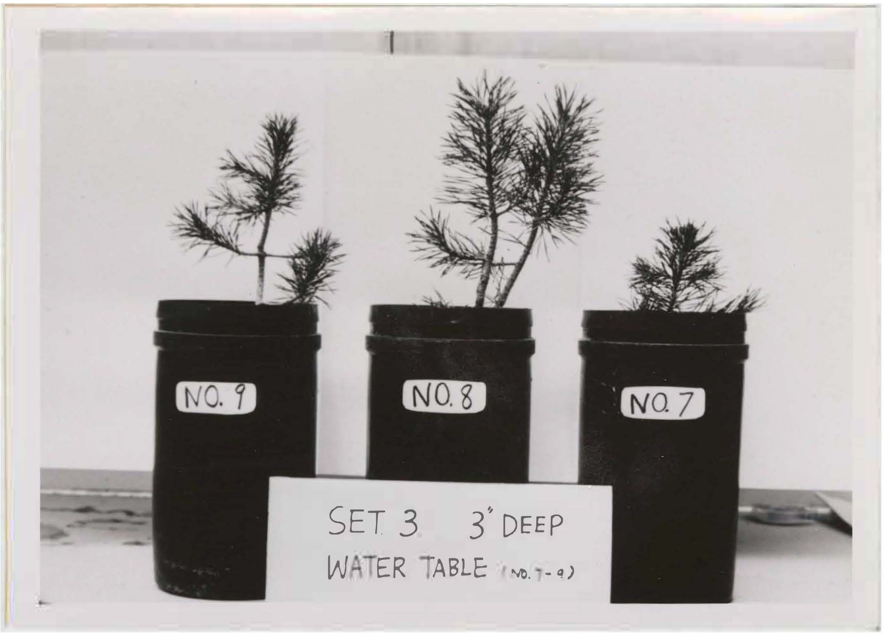


Fig. 6. Lodgepole Saplings Taken at the Beginning of Water Table Experiment, February 22, 1971. (with the Bottom of the Pot Submerged in 3" Deep Water)

Fig. 7. The Same Set of Trees as Above Taken Fifty Days Later, April 11, 1971.

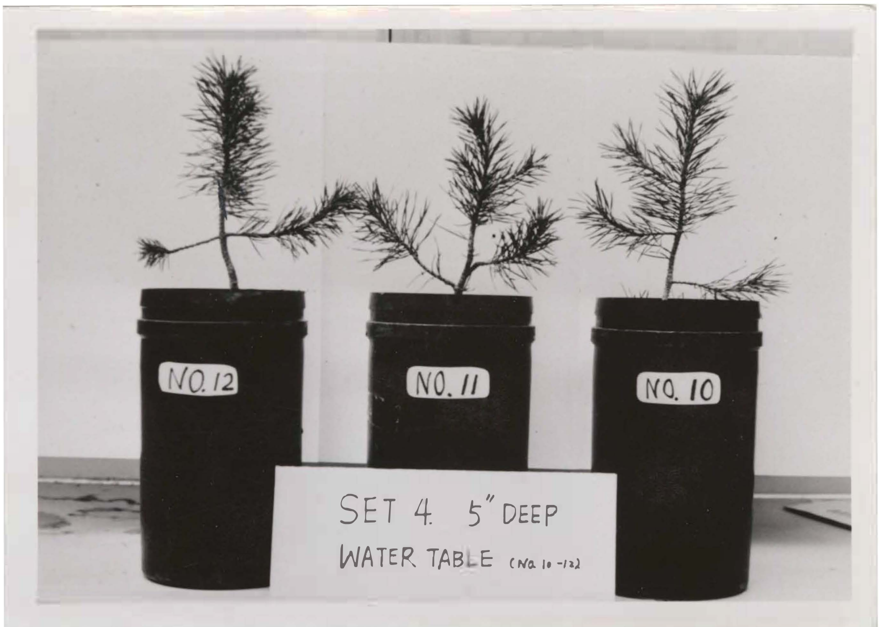


Fig. 8. Lodgepole Saplings Taken at the Beginning of Water Table Experiment, February 22, 1971. (with the Bottom of the Pot Submerged in 5" Deep Water)

Fig. 9. The Same Set of Trees as Above Taken Fifty Days Later, April 11, 1971.

DISCUSSION

The objective of this study was to determine the effects of the kind of soil, temperature, light and the depth to the water table on seed germination and establishment of lodgepole pine seedlings.

It seemed that the organic matter content of soil played an important role in the success of lodgepole seed germination. Total germination percent varied between wet meadow, dry meadow and upland forest. The greatest and the fastest germination was found in soil from the wet meadow zone, whereas the total germination percentage was as low as 13% in dry meadow compared with 64% in wet meadow soil and 22% in forest soil. Evidently, organic matter content and a low PH increased both total germination and germination rate. The low germination percentage in dry meadow soil might be attributed to the higher PH value. However, lodgepole seedlings growing in both dry meadow and wet meadow soil with high organic matter content suffered greater mortality than those in the mineral forest soil. This suggests that the higher water table in the meadow area caused poor aeration, which prevented seedlings from establishing successfully. The other possibility was that plants would be weaker and less likely to succeed in soils having a lack of mineral nutrients. It appears that the sparse distribution of lodgepole pine trees in dry meadow and the failure of lodgepole to change dry meadow to forest climax should be attributed both to the low germination rate of lodgepole seeds and the unsuccessful establishment of seedlings.

In the laboratory, lodgepole pine seeds treated with concentrated sulfuric acid for one minute gave the best germination, and 80% of total germination occurred during the first week in all treatments. It is safe to say that scarification did hasten lodgepole seed germination to a great extent by softening or breaking the hard seed coat. However, submergence over twenty minutes in H_2SO_4 did some damage to embryos and decreased the germination percent to as low as 48% compared with 94% germination in one-minute treatment. A forty-minute treatment killed all the seeds and no germination occurred. This suggests that in nature there must be some softening of the seed coat before germination can occur.

In the laboratory, seeds kept at constant room temperature (25°C) germinated the fastest, whereas seeds kept in low temperature (0°C, 5°C, 15°C) did not germinate until they were transfered to warm temperature. This effect of low temperature may be due to the temperature effect upon enzymes necessary for germination. As shown in Table 3, after seeds were transfered to 25°C from 5°C, most of the germination occurred (99%). The same thing happened to the seeds originally kept in 15°C for various periods of time. The reason that fungus infected almost all of the seeds upon release to 25°C from 0°C might be that fungus spores require cold for germination. As the results showed, 5°C stratification gave better results than keeping at constant room temperature, which in turn gave higher germination than at 15°C. It was expected that 0°C stratification might have given the greatest germination upon release to 25°C, if seeds had not been attacked and embryos killed by fungi. The data shown in table 3 was an average of three replicates. It seemed that fluctuating temperature did increase germination rate to a certain extent. These experiments suggested that a wintering over period of cold temperature stimulates germination percentage in nature.

Pinus contorta seedlings grown in three fourths of full sunlight had near equal growth in both shoot and root systems, followed by plants grown in one half of full light, full sunlight, and one fourth of full light. However, plants grown under full light grew the fastest in all treatments. If the greater root length and weight gain in these plants is due to increased storage of carbohydrate reserves, as it must in part be, then late summer drought might have less deleterious effects upon seedling establishment. Seedlings in the dark turned yellow and died after three weeks. Therefore, *Pinus contorta* was classified as a shade-intolerant species.

Snow in upland forest did not melt away as fast as that in dry meadow because of the shade from the tree canopy. This resulted in the lower temperature there, which favors photosynthesis rate more than respiration rate.

Lodgepole seedlings grew the best with the bottom of the pot submerged in one inch deep of water, since this species has shallow absorbing systems and not very extensive laterals. However, five inches of water did not give better result than those watered from the top; this could be attributed to O_2 deficiency. Plants grew normally along the forest edge, since the water table there was not so high as that in meadow area.

A cold period and then warm temperature and organic soils favor germination, but mineral soils on reduced light favor top growth. Cool temperatures favor photosynthesis, and short periods with water about five inches deep in the pots are not detrimental to growth. It therefore appears that some protection from full light at the forest border surrounding Lily Lake is best for establishment of seedlings. Besides, the snow cover can serve as a means for stratification, which in turn will increase germination percentage of seeds. The forest soil had better aeration than that in the meadow, since snow stayed in the forest area for a period of time instead of melting immediately. In fact, probably some of the melted snow from the slightly higher forest areas caused the surface accumulation of water in the meadow area which decreased aeration in the latter region.

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A STUDY OF SEED GERMINATION AND ESTABLISHMENT OF SEEDLINGS OF LODGEPOLE PINE IN DIFFERENT SOIL TYPES UNDER CERTAIN BOG CONDITIONS

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ABSTRACT

Soil texture, organic matter content, and hydrogen-ion concentration of soil samples were determined to find the correlation between soil characteristics, seed germination and seedling establishment of *Pinus contorta*. Scarification and stratification were treatments used for determining germination requirements of dormant seeds. Seeds were planted in different soils and experiments were conducted to determine the effects of different light intensities, temperatures, and depths of the water table on apparent photosynthesis rate and seedling establishment. Soil samples, pine cones, and young trees needed for the experiments were collected near Lily Lake, in the Uintah Mountains.

The greatest and the fastest germination was found in soil with high organic matter and low PH. Seedling establishment succeeded only in mineral soil. Lodgepole seedlings grown in three fourths of full light had the best growth in both shoot and root systems. Low temperature favored photosynthesis rate more than respiration rate. Lodgepole seedlings preferred a moderately deep water table, since this species has a shallow absorbing system and not very extensive lateral roots.