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SOIL MOISTURE AND THE DISTRIBUTION OF LODGEPOLE AND PONDEROSA PINE

A REVIEW OF THE LITERATURE

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R. W. COWLIN, DIRECTOR

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Robert F. Tarrant
Pacific Northwest Forest and Range Experiment Station

U. S. Department of Agriculture

Forest Service

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Despite a number of published studies and observations of the factors affecting the distribution of lodgepole pine (Pinus contorta var. latifolia) and ponderosa pine (Pinus ponderosa), some misunderstanding still exists as to the significance of the extensive stands of lodgepole pine in the ponderosa pine zone of Oregon and Washington. At times there even have been proposals to destroy the lodgepole "weed" stands and replant the areas to economically superior ponderosa pine. These proposals were based on the assumption that lodgepole stands are the direct result of fire and represent encroachment onto ponderosa pine sites.

A roundup of pertinent published information on lodgepole-ponderosa pine relationships should help eliminate some common misconceptions. The growth habits of these two species have been studied in some detail, and many sound observations have been made. Because of the many different investigators who have worked on the subject, however, the findings have not been brought together in a manner best suited to pointing out the more important factors involved in the site requirements for each species. This paper will attempt to summarize and draw conclusions from published knowledge of the effect of soil moisture on lodgepole-ponderosa pine occurrence. Since the material is about evenly divided between observational information and the results of systematic study, the ideas of observers will be discussed first and then compared with findings from more formal studies.

OBSERVATIONAL STUDIES 1913-1947

One of the earliest references is that of Kerr (5) who reported on the distribution of lodgepole and ponderosa pine in the Walker Basin area of south central Oregon in 1913. Kerr observed that both lodgepole and ponderosa pine have a deep taproot and make their best growth in a loose, sandy or gravelly soil. He noted further that ponderosa pine always is confined to slopes and other sites where drainage is excellent, while lodgepole pine will grow under almost any condition of drainage. From these observations, Kerr concluded that ponderosa pine distribution in the Walker Basin area is dependent almost entirely on the depth of the water table--that is, this species will not tolerate conditions of excess moisture in the root zone. He stated that where lodgepole pine does occur on well-drained sites, its growth is limited only because of the greater age, height, and fire resistance of the ponderosa pine overstory.

Lodgepole pine areas were held to be increasing somewhat because of fires and subsequent more rapid establishment of the militant lodgepole. Kerr also held the view that it is unlikely that ponderosa pine will retake any of its former areas once lodgepole pine has become established.

A good general summary of the site requirements of ponderosa pine is quoted from Munger (8):

Western yellow pine (ponderosa) grows and thrives on nearly every variety of soil within its range; it is one of the first trees to get a foothold on the disintegrating recent lava flows of central Oregon and its ability to thrive on almost soilless steep talus slopes is remarkable. It grows also on loamy clay soils, on loose sand and on the deep, light fragmental pumice stone of central Oregon; but on cold, peaty, or heavy, moist soils, such as those adjacent to meadows, it is usually not found. It grows well on land which is too dry for any of its associates. (It seems to prefer well drained, loose soils; but an increase in moisture, provided the soil is well drained, makes for more rapid growth. Occasionally, but not usually, it grows on situations where the water table is within 4 or 5 feet of the surface during the growing season. It is, therefore, uncommon on flats and bottom land, and is distinctly a tree of the slopes. Exceptions occur, notably the form which occurs west of the Cascades in the Willamette Valley and which inhabits moist river benches.

A statement by L. F. Henderson (9), Curator of the University of Oregon Herbarium, gives further insight into the soil requirements of the Willamette Valley type of ponderosa pine:

A remarkably strange thing is the way the ponderosa pine exists in scattered spots throughout the Willamette Valley Wherever they exist I have always found the soil of a very gravelly nature and well suited to the growth of this pine.

In 1947, Leighty (7) made a partial survey of the Pringle Falls Experimental Forest in south central Oregon. From observations of vegetation and soil types, Leighty concluded that ponderosa pine does not thrive on soils having a fluctuating high or moderately high water table. He reasoned that ponderosa pine possibly can adjust its root system to a permanently high water table that fluctuates very little, but that on such sites lodgepole pine competes more successfully.

When the natural habitat of the two species is considered, Leighty observed, lodgepole pine seems to have a higher moisture requirement than ponderosa pine. The natural habitat of lodgepole pine under well-drained conditions is at higher altitudes above the ponderosa pine belt (about 5,500 feet in the area studied), where precipitation is higher and where more rain falls during the summer.

In the areas occupied by lodgepole pine at elevations ranging between 4,500-5,000 feet, conditions of greater soil moisture exist than on areas of like elevation normally dominated by ponderosa pine. These are held to be natural lodgepole sites.

Leighty concluded his observations by questioning the theory that fire is the cause of the pure lodgepole pine stands in the Pringle Falls area:

In the area mapped no certain evidence was found that would indicate that fires have had a principal influence on the distribution of these two species. If fires have had a material influence, the distribution of the two species should be more haphazard in relation to the soils and topography.

Completion of the Pringle Falls Experimental Forest soil survey by the writer (12) strengthened the observation made by Leighty that occurrence of the two pine types is affected by soil drainage (table 1).

The inability of ponderosa pine to compete on natural lodgepole sites may be seen in several plantings on the Deschutes National Forest in central Oregon. Failure of the plantings came not so much from seedling mortality as from the intense competition offered by encroachment of lodgepole pine. Ponderosa pine was planted in 1928 on the old Odell Ranger Station site on the Little Deschutes River, in 1934 and 1938 at Snow Creek, and on the Crescent Siding Burn in 1944. In the three older plantations, volunteer lodgepole pine has come back onto the site in numbers far exceeding those of the planted stock, and completely overtops it. On the Crescent Siding Burn, natural lodgepole regeneration has already gained numerical superiority over the planted ponderosa pine, is making much more rapid height growth, and will soon suppress the planted trees.

Table 1.--Soil conditions as they affect lodgepole and ponderosa pine occurrence on the Pringle Falls Experimental Forest

Soil type	Soil depth	Drainage conditions	Timber type
Lapine loamy coarse sand 2 - 7 percent slope	Pumice over brown-stony loam at 33 - 54 inches	Very rapid through pumice; moderate through loam. No water table evident	Nearly pure ponderosa pine; a few scattered lodgepole pine.
Lapine loamy coarse sand 15 - 25 percent slope	Pumice over bed-rock at 24 - 38 inches	do.	Pure ponderosa; some sugar pine on higher north slopes.
Lapine loamy coarse sand 0 - 2 percent slope	No obstructions to drainage. Depth unlimited	Very rapid	Pure ponderosa; open pure lodgepole, or more often, a mixture.
Lapine loamy coarse sand 2 percent + slope	do.	do.	Predominantly ponderosa pine.
Lapine loamy coarse sand over compact subsoil 0 - 2 percent slope	Pumice to 50 - 60 inches over hard layer	Variable below pumice. Intermittent water table at 4 - 5 feet	Predominantly dense pure lodgepole pine.
Wickiup loamy coarse sand 0 - 1 percent slope	Pumice to 50 - 60 inches over cemented layer	Rapid through pumice. Intermittent high water table below pumice	Dense pure lodgepole.
Wickiup silt loam 0 - 1 percent slope	Variable. Generally cemented layer at 60 inches or less	Poor, due to intermittently high water table. Moderate through silt loam layers	Dense or very dense pure lodgepole pine.
Dilman silty clay loam 0 - 1 percent slope	Silty clay loam over heavy clay layer at 13 - 24 inches	Very poor	Not timbered.
Untyped rough stony land 15 percent + slope	Shallow to rock outcrop	Very rapid	Pure ponderosa; sugar pine and white fir on high north slopes.
Marsh and muck	Variable. Water table causes constant effect of shallowness	Very poor	Not timbered.

FORMAL RESEARCH 1923 - 1945

One of the most intensive studies was carried on by Bates (1) who dealt with the physiological requirements of Rocky Mountain trees. He studied the problem from several approaches; by measurements of water used in relation to growth and leaf exposure of 3- to 9-year-old trees; by comparisons of sap density; by measurements of soil moisture; and by observing the effects of temperature and winter drought. The following is a summary of Bates' findings and must be considered applicable only to the seedling stage of development.

Seedlings of lodgepole pine are small and frail and in the first two or three months develop scarcely more than half the root length produced by ponderosa pine. Lodgepole pine shows far less drought resistance than does ponderosa pine.

On dry, hot sites where moisture fluctuates rapidly, ponderosa pine is pre-eminently adapted--by reason of large seeds which produce large sturdy seedlings and by its prompt deep-rooting characteristic. Considering its xerophytic tendencies, ponderosa pine is an extravagant user of water. Probably this comparative extravagance helps protect the seedling from excessive heat. Survival is dependent on the roots reaching a layer of soil which does not dry out dangerously through insolation. Ponderosa pine cannot grow in competition with trees, grasses, and herbs that draw heavily on moisture in the upper soil layers. The large moisture demands of ponderosa pine, which grows where precipitation normally is low, can be supplied only in open stands which permit first a deep penetration of the roots and later their extension into a large area of soil.

Lodgepole demands a great deal of light and moisture during the growing period, but it does not have the prompt germination and deep rooting habits of ponderosa pine. Lodgepole pine, therefore, is adapted only to sites with a steady supply of moisture.

Pearson (10), in a greenhouse study of the transpiration habits of conifer seedlings, observed that within three months after germination the taproot of ponderosa pine seedlings had reached to a depth of from 6 to 10 inches in the soil. His conclusion was that this aggressive deep-rooting characteristic of ponderosa pine was a chief reason for its suitability for extremely dry sites.

Of all factors which figure in survival on a dry site, depth of root penetration during the seedling stage is undoubtedly the most important.

Larsen (6) studied the climatic controls conditioning the forest types of the Northern Rocky Mountains. He set forth the following climatic requirements for the two pines under discussion:

	<u>Ponderosa pine</u>	<u>Lodgepole pine</u>
Mean annual temperature range	44° - 50° F.	35° - 40° F.
Annual average rainfall range	17" - 22"	20" - 25"

In addition to these climatic requirements, Larsen found that ponderosa pine requires a growing season of 180 - 241 days, but for the subalpine lodgepole-Douglas-fir type length of the growing season is usually less than 150 days. Growing season was defined as the period during which the mean air temperature averages above 43° F. The temperature figures given here may shed additional light on the preference of ponderosa pine for sloping ground which besides being well drained is warmer than the more level, moister areas on which lodgepole pine grows best.

In 1931, Howell (4), in California, made a study of the reason for the occurrence of small patches of lodgepole pine, a few square rods to several acres in size, in an otherwise pure stand of ponderosa pine. He states that the lodgepole pine stands were clearly not the result of fire. Soil sampling revealed impeded drainage beneath the lodgepole stands. The perched water table was caused by a slight topographic depression and clay accumulation. Howell concluded with the statement:

Western yellow pine (ponderosa) cannot endure any excess of moisture. It will not survive in saturated soil whereas lodgepole pine can survive and reproduce under such conditions.

Roeser (11) studied the transpiration capacity and heat injury of coniferous seedlings under controlled conditions of heat and moisture. He concluded:

Western yellow pine (ponderosa) seedlings are (the) most consistent in transpirative functioning during the first year. Because of rapid growth and early development of protective stem tissue, they are better protected than are the other species against excessive heat. Most important is that this species, in very early age, is apparently more quickly stimulated to increase its transpiration under conditions of extreme exposure (to heat) than are the seedlings of any of the other species. Since it (ponderosa pine) seems to endure prolonged exposure more successfully than the others, size and bulk appear to be the determining factors when such conditions exist. All things considered, Western yellow pine (ponderosa) is well adapted to meet the demands made upon it in early life by the xerophytic conditions of its natural habitat.

The distribution of lodgepole pine was studied by Gail and Long (3) in 1935 by both field study and greenhouse methodology. Since this is one of the few studies in which lodgepole pine was the primary species, the following conclusions are of special interest:

The taproot of the seedlings of lodgepole pine grown in saturated soil appeared inhibited, but there were many short, stubby laterals just below the surface of the water. This would seem to be an adaptation to oxygen deficiency.

Lodgepole pine has a shallower absorbing system and less extensive laterals than has ponderosa pine.

The transpiration rate of lodgepole pine was increased by wind much more than was that of ponderosa pine.

The transpiration rate of lodgepole pine was less than that of ponderosa pine when both species were in a quiet atmosphere.

The lateral roots of ponderosa pine were inhibited when seedlings were grown in saturated soil, possibly because of the effect of the low oxygen content of the soil.

The submerged organs of ponderosa pine grown in saturated soil developed excessively at about the junction of the root and stem, just below the water level.

The usual limitation of lodgepole pine to sheltered sites appears to be due to its shallower and less extensive root system, and to the excessive increase in its rate of transpiration when subjected to wind.

Fowells and Kirk (2) studied the availability of soil moisture to ponderosa pine. In addition to showing the adverse effect of root mutilation on seedling survival, they found that ponderosa pine seedlings showed no evidence of wilting at a condition of less than 4 percent soil moisture, although the accepted wilting point for the soil in question was about 7 percent. From this study, the authors concluded that planted ponderosa pine, once established, can survive even when the soil moisture content falls far below the accepted wilting point.

DISCUSSION

Because much of the foregoing research was done outside the ponderosa pine region of the Pacific Northwest, literal application of all the findings cannot be made to this part of the country. For instance, the temperature and precipitation figures given in table 2 do not apply exactly to all of the far western pine region. There will be found other exceptions to the general conclusions, as must be expected in attempting to analyze data gathered outside the region. Yet, throughout all of the literature runs the connecting link of the importance of soil moisture conditions in determining the occurrence of the two pine species. All of the findings to date indicate that ponderosa pine is partial to well-drained sites and lodgepole is partial to more poorly drained sites.

In the pine region of Oregon and Washington there are large areas of what might be called "transitional" condition, where the influence of soil moisture is not sufficiently strong to mark the site positively as being suited to one species or the other. Interpretation of conditions in these areas is difficult because of the lack of local ecological study; but from the clear-cut examples of site preference found at either limit of the soil moisture range, it is evident that moisture condition of the site is an important factor in the development of the pine types. If young trees of both species are present, the best guide as to which is the most desirable species for the site is the condition of thrift and crown growth rate of the young trees.

Despite the scarcity of basic ecological information, it is considered that the development of a forest soil classification for the pine region of the Pacific Northwest would identify sites most favorable for lodgepole pine, ponderosa pine, or for a mixed-species type.

Table 2.--Discussion of reported characteristics of lodgepole and ponderosa pine

Characteristic	Ponderosa pine	Lodgepole pine
Seed and seedling size	Large seed. Large sturdy seedlings	Small seed. Frail seedlings.
Early rooting habits	Penetrates 6 - 10 inches into soil within first 3 months after germination	In first 3 months of germination produces scarcely one-half the root length of ponderosa.
Root type	Deep taproot and wide-spread deep laterals	Deep taproot and restricted laterals.
Soil preference	Loose sandy or gravelly, rocky, thin talus. Well drained	Clay, wet gravelly or sandy with poor drainage.
Topography preference	Sloping	Flat.
Tolerance to condition of continuous high soil moisture	Intolerant	Very tolerant.
Drought resistance	High	Comparatively low.
Water requirement	High "extravagant user of water"	High
Rainfall requirement ^{1/}	17 - 22 inches	20 - 25 inches
Mean annual temperature requirement ^{1/}	44 - 50 degrees F.	35 - 40 degrees F.
Transpiration characteristics	Transpires readily under conditions of extreme exposure	Less than that of ponderosa in quiet atmosphere but four times the rate in wind.

^{1/} Reported for Rocky Mountain conditions.

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