Seed Source Variation in Induced Moisture Stress Germination of Ponderosa Pine[1]

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Differences between seed sources of ponderosa pine in ability to germinate under conditions of induced moisture stress suggest that natural selection has differentiated the species into distinct ecotypes in Colorado.

Environmental diversity of moisture availability found over relatively short distances in the Western United States suggests that ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.) has differentiated into distinct ecotypes adapted to local conditions (*5, 6*). This localized adaptation to site conditions must be considered in the design of management strategies affecting initial seedling survival, establishment, growth, and potential for future natural regeneration.

Investigations of the effect of moisture stress on pine seed germination have demonstrated that moisture availability for germination is an important selective force (*1, 3*). Only seeds capable of germinating and growing under the moisture regime of a given area contribute to the progeny generation.

This study determined whether or not ponderosa pine seeds collected from trees throughout the range of the species in Colorado differed in ability to germinate under several artificial moisture-stree treatments. Additionally, the experimental sampling design tested whether or not tentatively delineated seed collection zones in Colorado (*2*) conform to expected biological zone boundaries.

Methods

Seventy-six individual ponderosa pine trees were sampled for seed cones from 11 of the 18 seed collection zones in Colorado that contain ponderosa pine (fig. 1). At each collection location, the latitude, longitude, elevation, slope percentage, and aspect were recorded. Two 25-seed replicates from each tree received each of three moisture-stress treatments. Ater a 30-minute surface sterilizaton soaking in 0.8-percent sodium hypochlorite solution and rinsing with

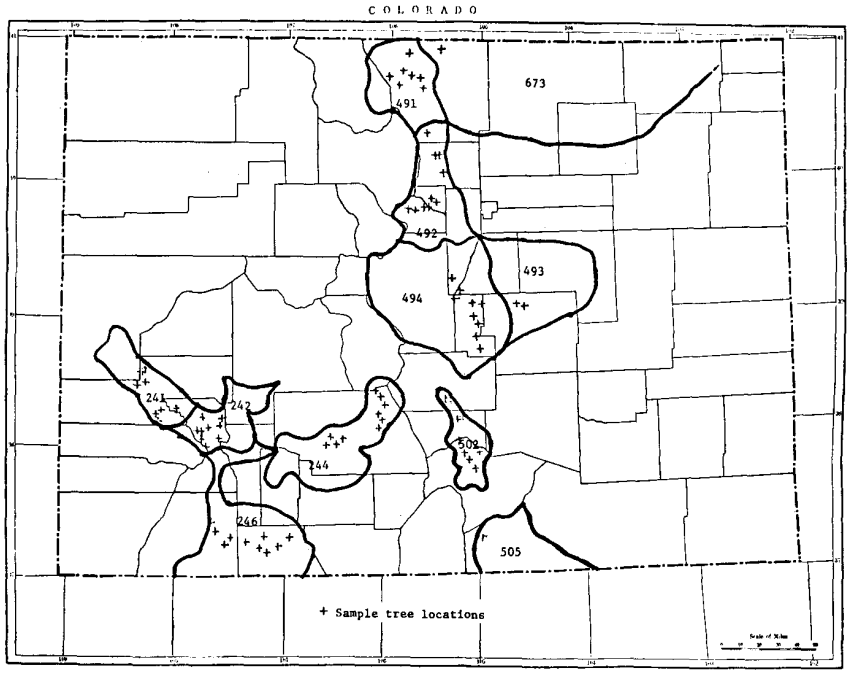

Figure 1.—*Sampled seed collection zones and tree locations.*

[1]This study was carried out cooperatively between the Colorado State Forest Service and the Forest and Wood Sciences Department, Colorado State University, under Gilbert H. Fechner.

sterile water, seeds were subjected to moisture stress in several solutions. Substrate water potentials of 0 (control), -4, and -8 bars were prepared by adding polyethylene glycol (PEG-4000) to distilled water (*4*). Seeds placed in petri dishes on blotter paper moistened with moisture-stress solutions germinated in a growth chamber with a 16-hour photoperiod at 30° C and 8 hours of darkness at 20° C. Germination was tallied every 2 days, and total germination was calculated after 20 days.

Results and Discussion

For each water-stress treatment, seed-zone germination means were calculated by pooling data from individual trees within a zone. Table 1 summarizes the treatment means by zones. Under no water stress, germination percentages ranged from 61 (zone 242) to 100 (zone 505). At -8 bars, no germination took place at all. At -4 bars, values were intermediate to those recorded at 0 bars and -8 bars, ranging from 14 percent (zone 246) to 76 percent (zone 505). Analysis of variance and subsequent mean separation by least significant difference (LSD) indicated significant differences ($a = 0.05$) between seed zones based on -4 bar germination after 20 days (table 1).

Table 1.—*Mean germination values by seed zone for each of the three treatments*

Seed zone	Moisture stress, bars		
	0	- 4	- 8
	Germination percent		
246	63.3	14.3a[1]	0
241	55.2	14.8a	0
244	66.6	16.6a	0
242	61.4	18.6ab	0
491	87.6	24.4ab	0
502	80.0	28.8ab	0
492	61.7	35.1b	0
494	79.9	36.4b	0
673	96.0	44.0bc	0
493	66.0	50.0c	0
505	100.0	76.0c	0

[1] Mean values followed by the same letter are not significantly different at $a = 0.05$ by least significant difference (LSD).

The -4 bar germination data showed relative resistance to dry site conditions. Thus, a high germination percentage at -4 bars indicated a selective advantage for germination under conditions of low moisture availability. Seed-zone ranking on the basis of high to low germination established a gradient of xeric to mesic environments.

A correlation analysis relating the site characteristics of latitude, longitude, elevation, aspect, and slope to seed germination showed longitude as the only variable significantly correlated to -4 bar seed germination (table 2). Furthermore, the

Table 2.—*Pearson product-moment correlation coefficients with 20-day germination percentages*

Variable	Correlation coefficient
Latitude (degrees north)	0.12354
Longitude (degrees west)	-0.27592*
Elevation (meters)	0.03383
Aspect	- 0.00125
Slope percent	0.02744

*Significant at $a = 0.05$

correlation was negative; as longitude increased, germination percentage at -4 bars decreased.

The results suggested that germination responses of the sampled seed sources reflected an environmental gradient of moisture availability. Sources adapted to germination under more xeric conditions represented seed zones east of the Front Range (zones 673 and 493) or in the dry, south-central part of the State (zone 505). Sources adapted to the most mesic conditions (i.e., lowest germination at -4 bars) represented seed zones in the southwest part of the State (zones 241, 242, 244, and 246). The remaining seed sources represented seed zones in the central, mountainous part of the State (zones 491, 492, 494, and 502).

These data demonstrated that differences exist between

ponderosa pine seed sources with regard to germination ability under moisture stress. The significant decrease in adaptation to germination under dry conditions as the location of the sampled seed sources varied from east to west implied a longitudinal differentiation of ponderosa pine into at least three geographic provinces in Colorado: the dry plains and foothills east of the Front Range; the climatically variable central mountain area; and the moist southwest, including the San Juan Mountains. These regions of ponderosa pine should be considered in making management decisions related to the biology, ecology, and genetics of the species.

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