Rocky Mountains Southwest Great Plains

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Characteristics of 1-Year-Old Natural Pinyon Seedlings

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Pinyon seedlings on high elevation basaltic sites were larger than those on limestone sites. Additionally, seedlings growing away from the overstory were larger than those found under "nurse" trees. Partial shading is still considered necessary for seedling establishment. Lateral roots of 1-year-old seedlings were distinctly sparse in the surface 4 cm of soil.

Introduction

Pinyon-juniper woodlands occupy about 30 million acres in Arizona and New Mexico (Aldon and Springfield 1973). The primary conifers are *Pinus edulis* (pinyon), *Juniperus monosperma* (one-seed juniper), *J. osteosperma* (Utah juniper), *J. scopulorum* (Rocky Mountain juniper), and *J. deppeana* (alligator juniper). With the current increasing demand for fuelwood, these species are now considered more valuable than in the recent past (Ffolliot et al. 1979). These woodlands also provide important wildlife habitat, esthetic and recreational values, and unique tree products including pinyon nuts, fence posts, and Christmas trees (Springfield 1976). Therefore, the goals of many National Forests in the Southwest are shifting from management of the woodlands for range to management by silvicultural prescription for fuelwood production while maintaining the other woodland values. However, very little information is available about fundamental characteristics of pinyon regeneration and early growth. The objectives of this study were to provide basic information on above- and below-ground growth characteristics of 1-year-old natural pinyon seedlings and about the general occurrence of natural pinyon regeneration. This information should help managers develop silvicultural prescriptions for promoting natural pinyon regeneration.

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Methods

In early May 1985, pinyon seedlings just beginning their second growing season were chosen for study at each of three sites in northern Arizona. The seedlings were selected for measurement of shoot and root size characteristics for correlation with edaphic and climatic factors. These seedlings were the result of a good seed crop in 1983 which subsequently germinated, probably in the summer of 1984, because spring precipitation was below normal.

The three study sites were Red Mountain, 42 km northeast of Flagstaff at an elevation of 2,080 m; Walnut Canyon, 15 km east-southeast of Flagstaff at an elevation of 1,950 m; and Winona, 23 km east of Flagstaff at an elevation of 1,890 m. The Red Mountain soils are of basaltic origin; Walnut Canyon and Winona soils are limestone.

At each site, 10 pinyon seedlings were located by selecting every fifth seedling encountered on a random compass bearing. Their position within the stand was categorized as either under a tree canopy or outside the canopy in the interspace between trees.

The seedlings were extracted from the ground by washing the soil from their root systems with a 250-gallon pumper. When the taproot and all lateral roots were free, the taproot depth was measured and the seedling was bagged and placed on ice. Soil bulk density was determined using the sand-funnel method (Black 1965a) in the upper 6 inches of soil immediately adjacent to the spot each seedling was lifted. The soil removed for bulk density measurements was bagged and returned to the laboratory for particle size analyses (Black 1965b) and for determination of moisture retention curves. Moisture retention curves (percent soil moisture vs. soil water potential) were developed using thermocouple psychrometers (Campbell et al. 1966). A simplified estimation of water availability was calculated as the difference in moisture content between −1/3 bar and −30 bars as determined from these curves. A common definition of available water between field capacity (−1/3 bar) and the permanent wilting point of corn (−15 bars) is invalid for other species (Eddleman and Nimlos 1972). The choice of −30 bars as the soil water potential beyond which pinyons cannot extract water is purely speculative; but because of the harsh climate in which they thrive, a level less than −15 bars seems a certainty.

In the laboratory, crown length, taproot length, and number and length of all lateral roots longer than 1 mm were measured. The shoots and roots were separated and dried for 48 hours at 75 °C. All seedling parts were then weighed on an analytical balance to the nearest 0.01 mg.

Analysis

Crown lengths, taproot lengths, number and length of lateral roots, and shoot, root, and crown weight of seedlings from the different sites were tested using analysis of variance. If significant differences were indicated, these characteristics were compared using Tukey's multiple range test.

Results and Discussion

The total biomass of northern Arizona pinyon seedlings just entering their second growing season averaged about 18.5 mg, which was evenly distributed between shoots and roots (table 1). Seedling heights averaged 5.3 cm, with less than one-half being crown length. Seedlings growing in deep organic matter had the longest hypocotyls. Taproots averaged 20.5 cm long, with laterals adding about 50% more root length.

Several previously unreported growth features deserve attention because of their importance. There was a distinct lack of shallow lateral roots. Only 7% of about 400 lateral roots measured were in the upper 3 cm of soil. Only 3 roots were found less than 1.5 cm from the soil surface, and only 3 seedlings out of 30 had any laterals in the upper 2 cm of soil. About one-half of the laterals were found between the depth of 4.5 to 8.5 cm (fig. 1). Because organic matter normally decreases with mineral soil depth, organically-derived nutrients also become less available with soil depth (Everett et al. 1986a). This factor was certainly not critical enough to result in lateral root growth within the immediate surface horizon. Everett et al. (1986b) also found no feeder roots of mature pinyon (*Pinus monophylla*) in the surface organic layer or immediate underlying mineral soil. A probable explanation is that moisture and temperature vary greatly in the upper 5 cm of soil, and much less below 5 cm; therefore, the active rooting zone would occur in areas of more reliable moisture and less severe temperatures.

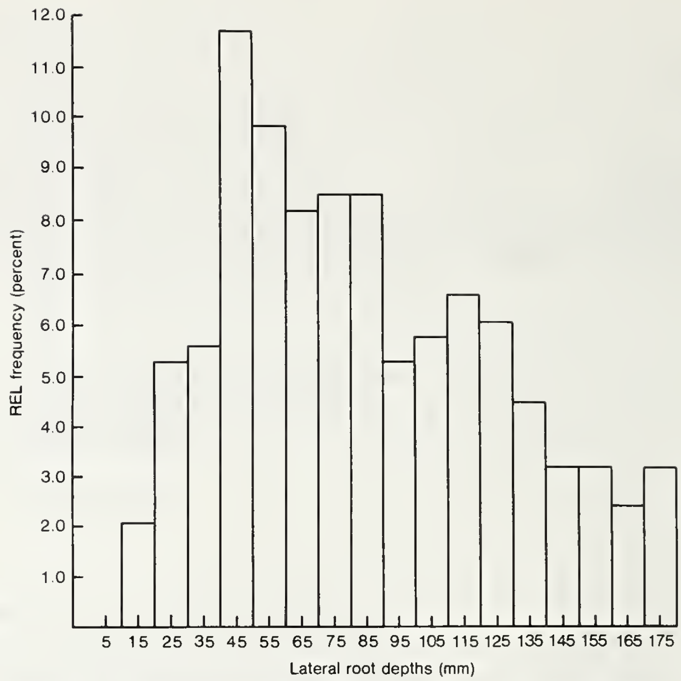

Figure 1.—Vertical distribution of lateral roots of young pinyon seedlings.

Table 1.—Morphological characteristics of 1-year-old pinyon seedlings from three sites in northern Arizona.[1]

	Average	Red Mountain	Winona	Walnut Canyon
Total weight (mg)	18.48	21.34a	18.99ab	15.12b
Shoot weight (mg)	9.50	10.53a	9.72a	8.25a
Crown weight (mg)	6.67	7.53a	6.77a	5.69a
Root weight (mg)	8.98	10.81a	9.27ab	6.87b
Shoot/root	1.06	1.04a	1.16a	1.23a
Total height (cm)	5.3	4.9a	5.1a	5.5a
Crown length (cm)	2.5	2.3a	2.7a	2.4a
Taproot length (cm)	20.5	26.7a	17.3b	17.5b
Taproot depth (cm)	17.5	22.2a	15.3b	15.1b
Total lateral root length (cm)	11.1	14.6a	11.8ab	6.8b
Aver. lateral root length (cm)	0.8	0.9a	0.9a	0.7a
Aver. number lateral roots	13.5	18.4a	13.3b	8.7c

[1]*Within rows, values with different letters are significantly different at the 5% level.*

In the Southwest, pinyon-juniper woodlands generally occupy the elevational zone below the ponderosa pine type, thus encountering some of the driest, warmest climatic conditions occupied by conifers. Because of this climate, survival and growth depend primarily upon moisture availability, which can vary greatly by the amount and depth of soil tapped by a plant's root system. Apparently, much of the energy from the large pinyon seeds (0.20 gm/pinyon seed compared to 0.03 gm/ponderosa seed) and from first year photosynthesis is used for rapid taproot growth (Daubenmire 1943). Baker (1972) indicated that plants with larger seeds generally occupy drier climates because the greater seed energy is used for expeditious root growth for drought avoidance.

The taproots of the 1-year-old seedlings averaged about 17 to 27 cm long depending on site (table 1). The longest taproot of the 30 seedlings was 38 cm; the shortest was 11 cm. Because most of this root growth took place during the first growing season, a 20- to 30-cm taproot length would be considered sufficient to sustain most pinyon seedlings in northern Arizona during a year of near normal growing season precipitation like 1984. In addition to growing a long taproot into soil zones where moisture is available for a longer period, pinyon seems to have the ability to tolerate extreme drought by physiological mechanisms such as reduced transpiration (Daubenmire 1943).

In a comparison of seedlings from different sites, the Red Mountain seedlings showed some superior growth qualities over those from the other two sites (table 1). Root differences stand out, but shoot and crown differences were not significant. The shoot/root ratios calculated from the dry weights are probably misleading from a transpiration/absorption standpoint, because the very small, but dense crown average less than 3 cm long compared to a range of root lengths from 24 to 41 cm. A surface area measurement would have given a better indication of root importance.

Physical soil properties from the three sites were examined to determine if they may have contributed to the seedling root differences. Table 2 shows soil characteristics from the three sites. Bulk densities were similar; but about 10% more clay and 20% less sand was found in the Red Mountain soils. These particle size distributions likely result in more available moisture in the Winona and Walnut Canyon soils (table 2), given equal precipitation. However, the lesser amounts of clay and greater potential moisture availability at those two sites did not result in larger pinyon seedlings.

Unmeasured site factors which could have determined the seedling size differences are soil fertility and precipitation. The Red Mountain soils are of basaltic origin and, therefore, generally considered more fertile than the limestone soils found at Winona and Walnut Canyon (Clary and Jameson 1981). There are no weather stations within 35 km of Red Mountain; but general interpretation would suggest that the site of highest elevation (Red Mountain–2,080 m, Walnut Canyon–1,950 m, and Winona–1,890 m) would have the greatest precipitation (Green and Sellers 1964). However, any real precipitation and soil fertility differences between sites are purely speculative.

Because pinyon seeds are wingless, it is generally assumed that without the help of birds or rodents, these seeds fall directly beneath seed trees (Gottfried 1986). However, hundreds of seeds were observed by the author up to 3 m beyond the dripline of many seed trees during the good seed year of 1986. Strong winds blowing seeds from high in the trees presumably caused the dispersal.

Seed dispersal leads to regeneration dispersal, and most reports indicate that the majority of natural pinyon regeneration is found under the canopies of larger trees (Everett et al. 1986b; Gottfried 1986). Without measurements, it also was apparent in this study that more 1-year-old pinyon seedlings were growing under trees than away from them. But enough were present in each microsite to make morphological comparisons between seedlings growing under overstory canopies and those found beyond the dripline within interspaces between trees where little or no surface organic matter had accumulated. At each of the three sites, 4 of the 10 seedlings were excavated from microsites beyond overstory canopy. It was obvious by their juxtaposition with nearby mature trees that these seedlings were shaded during part of everyday, but not like the dense more complete shading which influenced the rest. Table 3 shows that even though the seedlings from the two microsites had similar shoot weights, the interspace seedlings had heavier crowns (shoot minus hypocotyl). They also had heavier roots, which resulted from longer laterals, not longer taproots or more lateral roots. Reasons for this could be greater sunlight for more photosynthesis, greater soil moisture because of reduced interception by canopies and duff, or greater soil temperatures during the season of most rapid growth. Meagher's (1943) research pointed out that watered and 50% shaded pinyon seeds had more rapid germination and better seedling survival than either watered or shaded, which were better than no watering or shading.

Table 2.—Physical soil properties from three pinyon sites in northern Arizona.

	Bulk density	Particle size distribution Sand	Silt	Clay	Moisture availability[1]
	gm/cm³	---------	%	---------	%
Red Mountain	1.23	26	41	33	11.2
Winona	1.22	45	32	23	13.0
Walnut Canyon	1.18	47	29	24	14.9

[1]*Moisture availability equals the difference in percent moisture by weight between retention at −1/3 bar and −30 bars.*

Table 3.—A comparison of characteristics of pinyon seedlings growing under trees and within interspaces between trees at three locations in northern Arizona.

	Interspace site	Under canopy site
Total weight (mg)	20.84	16.91
Shoot weight (mg)	10.15	9.06
Crown weight (mg)	7.79*	5.95*
Root weight (mg)	10.70*	7.84*
Taproot length (cm)	21.1	20.1
Lateral root (numbers)	13.8	13.3
Total lateral root length (cm)	14.4*	8.8*

**Indicates significant difference in seedling characteristics between microsites at the 5% level.*

He showed no differences in seedling height growth, but didn't measure weights of shoots or roots. His study compared seedlings receiving no shading and 50% shading, while this study compared seedlings with approximately 100% shading with those having a great deal less (approximately 30–60%).

A cursory observation during root examination indicated that 25% of the interspace seedlings were obviously mycorrhizal, while none of the seedlings grown under dense canopies had distinct infections. This circumstance, which has been observed in other forest types because of light and photosynthetic differences (Hacskaylo and Snow 1959), could also have influenced growth.

Conclusions

Results indicate that initial growth is superior on the generally more fertile basaltic sites and sites which receive the greatest precipitation. This implies that these sites are likely to respond more favorably to pinyon management. Also, seedlings growing in partial shade showed better early growth than those growing directly under mature trees in complete shade. However, because many more seedlings become established under "nurse" trees than in interspaces, the implication is that once establishment occurs, these trees should be harvested to reduce competition but that their crowns should be left to provide partial shading. More detailed research is needed to verify these preliminary findings.

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