Velvet Mesquite Seedling Development in Three Southwestern Soils

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Seedlings of velvet mesquite (*Prosopis glandulosa* var. *velutina*) were grown in sandy loam, clay loam, and clay soils to 30 and 60 days of age. Top and root growth parameters were measured at those time intervals and top growth was measured at 10-day intervals over the study period. A significantly ($P=0.005$) higher root growth rate and root penetration was found for seedlings in sandy loam and clay loam soils over the initial 30-day growth period. At approximately this time, top growth became favored over root growth. As a result, the rate of root growth in sandy and clay loam soils was reduced by nearly 60% during the second 30-day period. Seedlings grown in clay soils tended to have shorter root systems but the roots were more fibrous compared to seedlings in the other soils.

Velvet mesquite (*Prosopis glandulosa* var. *velutina*) has a taproot and long lateral roots which occupy a large volume of soil (Simpson 1977). Successful establishment of honey mesquite (*Prosopis glandulosa* var. *glandulosa*), and presumably velvet mesquite, may be limited by local soil and ecological factors (Scifres and Brock 1969, 1971). The successful colonization of a site by honey mesquite has been further hypothesized to be dependent on the seedling's depth of root system development and successional status of the stand being invaded (Scifres and Brock 1972, Scifres et al. 1971). Successful invasion of arid sites by velvet mesquite, including riparian areas, may depend on an extensive root system. The objective of this study was to investigate root development of velvet mesquite seedlings as influenced by different soils common to the Sonoran Desert in central Arizona.

Methods

Three soils from central Arizona were collected and used as rooting media. Soils selected were a sandy loam, a clay loam, and a clay soil of Coolidge, Cantine, and Cashion series, respectively. The Coolidge soil was collected 4.8 km west and 6.4 north of Buckeye, Arizona. Vegetation was mixed desert shrub with velvet mesquite, ironwood (*Olneya tesota*), and green paloverde (*Cercidium microphyllum*). The Cashion soil was collected 3.2 km east and 1.6 km south of Buckeye, Arizona. The area previously supported mesquite bosques as a part of the flood plain vegetation near the Gila River. The Cantine soil was collected approximately 8 km south and 3.2 km east of Tempe, Arizona. The original vegetation of this area was desert shrub. The common woody trees were velvet mesquite and green paloverde.

All soils were collected from 0 to 25 cm depths. Approximately 200 liters of soil was taken from each site. Soil was passed through a 1-cm mesh sieve before filling the containers used to grow the seedlings. The soil was lightly tamped when filling containers to approximate soil consistency under field conditions. Soil textures from duplicate samples were measured by the hydrometer method (Day 1965). Soil bulk density was estimated using paraffin coated peds (Blake 1965).

Two of the soil series selected as rooting media were in the order Aridisols (Coolidge and Cantine) while the Cashion soil is an Entisol. The classification of the Coolidge soils is a coarse-loamy, mixed hyperthermic Typic Calciorthids. Cantine soils are fine, mixed hyperthermic Typic Haplargids, while Cashion soils are

clayey cover loamy, mixed, hyperthermic Typic Torrifluvents (Hartman 1977). Sand content for these soils ranged from approximately 15 to 56% (Table 1). Conversely, clay content was approximately 18 to 54%. Bulk density of the sandy loam and clay soil were similar while the clay loam soil had lower bulk density manifested by its structure. The clay loam had structure that was moderately subangular blocky while the sandy loam and clay soils tended to have massive structure.

The soil containers were plastic cylinders 15 cm in diameter and 100 cm in height with a volume of 17.7 liters. The cylinders were slit along one side and banded with wire before filling with soil. This configuration was used to facilitate root sampling.

The experiment was a completely randomized design and was conducted in a greenhouse. Eight cylinders of each of the three soils represented the experimental units. Four replicates were sampled at 30 days of seedling age with the remaining 4 examined at 60 days. Velvet mesquite seed coats were nicked with a scalpel to assure imbibition, and 4 seeds were planted per replicate. Seedlings were thinned to 2 plants per container after 2 days. After the first leaf of the seedling had expanded, approximately 1 week after planting, 1 seedling was removed leaving 1 seedling per container. Remaining seedlings provided uniformity in size and vigor.

The cylinders were watered prior to planting to bring the soils to field capacity. During the course of the experiment, the cylinders were hand watered daily to maintain moisture conditions for optimal seedling growth. No artificial light was provided, and greenhouse temperature was maintained at approximately $27 \pm 2^\circ\text{C}$ with evaporative air conditioners. These conditions provided an environment good for seedling growth and are similar to those used in studies with honey mesquite (Scifres and Brock 1969 and Meyer et al. 1973).

The experiment was repeated two times. The first portion covered 60 days and was conducted from 1 April through 1 June 1979. A second, identical test was performed from 10 September through 9 November 1979. Ten days after emergence and at 10 day intervals, plant height and the number of expanded leaves per seedling were recorded. Plant height was divided by plant age at each measurement interval to give an estimate of rate of growth in mm/day. At 30 days, four randomly selected replicates of each soil were sampled for root system development. The soil and root systems were exposed and roots washed free of soil using a fine mist water spray. The following measurements were collected:

1. Maximum root length (mm).
2. The number of secondary roots originating from the primary root.
3. Depth from soil surface to first lateral root (mm).
4. Root and shoot weights per seedling following oven drying at 80°C for 48 hours.
5. Rate of tap root growth (mm/day).
6. Shoot/root ratio by weight.

The procedure was repeated at 60 days with the 4 remaining plants in each soil.

There were no significant differences between the spring and fall experiments. Therefore, the data were pooled yielding 8 replicates per soil, seedling age combination. Pooled data were analyzed using one-way analysis of variance procedures developed for a microcomputer (G.L. Wysong, Arizona State University, Tempe). All statistical inferences were made at $\alpha = 0.05$ unless otherwise stated. Appropriate mean separation was made using Student-Newman-Kuels' test (Steel and Torrie 1960).

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Table 1. Some physical characteristics of three soils from Central Arizona used in seedling velvet mesquite root studies.

Series	Textural class	Mean Particle Size Distribution						Bulk density	SE
		Sand	SE ¹	Silt	SE	Clay	SE		
		%						g/cc	
Coolidge	Sandy loam	56.5	2.12	25.8	2.83	17.7	0.71	1.70	0.028
Cantine	Clay loam	36.5	0.98	25.2	0.45	38.2	1.41	1.34	0.007
Cashion	Clay	15.0	0.56	30.8	2.54	54.2	1.98	1.64	0.085

¹ = SE is the standard error of the mean.

Results and Discussion

Top Growth

Velvet mesquite seedling heights in clay loam soil were consistently greater at 30 and 60 days than seedling heights measured in clay and sandy loam soils (Fig. 1). After 60 days of growth, seedling heights in clay soils were smallest ($\bar{x}$ = 275 mm) and those in clay loam soils the tallest ($\bar{x}$ = 675 mm). Shoot growth rates at 30 days of age were 8, 4, and 3 mm/day for plants in clay loam, sandy loam, and clay soils, respectively. Shoot growth rates at 60 days averaged 10, 7, and 4.5 mm/day for seedlings in the clay loam, sandy loam and clay soils.

Fig. 1. Heights of seedling velvet mesquite plants observed in duplicate experiments and in 3 southwest desert soil types. Means with the same letter are not significantly different at $P=0.05$.

No significant ($P=0.10$) differences in the number of leaves per plant were found for seedling velvet mesquite except for the 60-day sampling period (Fig. 2). Shortly before this date, seedlings in the clay loam soil initiated secondary branching which accounted for

Fig. 2. Number of mature (expanded) leaves of seedling velvet mesquite plants in varying desert soil types. The mean with the asterisk (*) is significantly different at $P=0.05$.

the observed rapid increase in the number of leaves per plant.

Seedling shoot weight at 30 days of age was similar among the soils (Fig. 3). Seedlings in clay soil had the lowest shoot weights at both 30- and 60-day harvests. Seedlings grown in clay loam soil had significantly greater shoot weights (325%) than those grown in sandy loam soils and 427% greater weight than those in clay soil at 60 days.

Root Growth

Root weights of velvet mesquite seedlings at 30 days of age were greatest in the sandy loam soil, although not statistically significant (Fig. 3). The coefficient of variation (CV) for root weights for the

Table 2. Mean maximum root length and root growth rates for velvet mesquite seedlings at 30 and 60 days of age grown in soils of three textural classes.

Textural Class	Velvet Mesquite Seedling Age			
	30 days		60 days	
	Length (mm)	Growth rate (mm/day)	Length (mm)	Growth rate (mm/day)
Clay	250.0 b ¹	8.3 b	445.0 a	7.4 a
Clay loam	736.3 a	21.2 a	937.5 a	15.6 a
Sandy loam	728.5 a	24.3 a	732.5 a	12.2 a

¹ = Means in columns with the same letter are not significantly different at $P=0.05$.

Fig. 3. Shoot and root weights (ovendry) for seedling velvet mesquite plants at 30 and 60 days of plant age grown in 3 southwestern soils. Means for shoot or root weights followed by the same letter are not significantly different at $P=0.05$.

first 30 days was 50%. While mean root weights of velvet mesquite seedlings were very similar at 60 days, there was more variation among the replicates with a CV of 64% being found.

Shoot-ratios indicate the growth differences observed in this study among the soils. Velvet mesquite seedlings in clay loam soil had the greatest shoot-root ratio at both 30 and 60 days (5.99 and 6.02 respectively) indicating the greater seedling height and the number of expanded leaves as reported earlier. Shoot-root ratios of seedlings were 2.74 and 2.43 at 30 days in clay and sandy loam soils and were significantly different ($P<0.005$) compared to the clay loam seedlings. At 60 days of age, shoot-root ratios were 2.26 and 2.49 for clay and sandy loam soil seedlings and were significantly lower ($P<0.025$) from seedlings in clay loam soil.

Mean maximum root length was similar at 30 days for velvet mesquite seedlings in clay loam and sandy loam and least (250 mm) in clay soil (Table 2). At 60 days the mean seedling root length in clay loam soil was 2 times greater than root lengths for plants in clay. Variation was great among seedling roots in clay soils. The variation resulted from 2 cylinders containing clay soil where roots contacted the cylinder sides and apparently grew, with less resistance, along the pot-soil interface than roots in the matrix of the clay soil.

Early seedling root growth of velvet mesquite was observed in a laboratory study utilizing glass fronted root boxes (Brock and Hellerud, 1979 unpublished data). Three root boxes were filled with clay, clay loam, and silt loam soils and each box had 4 seedlings. The rate of primary root growth was observed daily for seedlings growing in moist soil. The average root growth rate for the first 10 days following germination was 14.1 mm/day. There were no statistically significant differences ($P=0.26$) in root growth rates at this early seedling age.

Root growth rate of velvet mesquite seedlings over the first 30 days was 24.3 mm/day for plants growing in the sandy loam soil which was similar to clay loam soil and significantly greater than clay soils (Table 2). After 60 days, seedlings in clay loam soils tended to have the greatest root growth rate but differences were not significant ($P=0.05$) from seedlings growing in clay or sandy soils. Root extension slowed with increasing seedling age. At approximately 30 days of plant age, top growth (Fig. 1 and 2)

increased, apparently at the expense of root extension. By this time, roots had penetrated to approximately 70 cm in the coarse sandy soil and the well-structured clay loam soil. Apparently growth activity in the seedling was being transferred from root to shoot. An adaptive advantage to seedlings in arid regions would be to initially accentuate root growth to increase the probability of maintaining contact with soil moisture before expending energy to produce shoot material.

Development of seedling velvet mesquite root systems was more extensive in the loam soils than in clay. While there was a statistically similar number of seedling velvet mesquite secondary roots observed at 30 days to be growing from the primary root, there were substantially more secondary roots in the coarser textured loam soils ($\bar{x}=66$) compared to clay soils ($\bar{x}=34$). At 60 days of age there were significantly more ($P<0.025$) secondary roots in the loam soils ($\bar{x}=112$) compared to the clay soil ($\bar{x}=55$).

The depth to the first lateral root was statistically similar among soils after 30 days. The shallowest depth at 30 days ($\bar{x}=14$ mm) was observed in clay loam soil. Depth of the first lateral root in the clay soil was 21 mm and 39 mm in sandy loam soil. At 60 days of age, seedlings in clay soils had the shallowest root system ($\bar{x}=6$ mm depth) while the sandy loam seedlings first lateral root was significantly deeper at a 16 mm ($P<0.025$). The depth to the first lateral root of seedlings in clay loam soils after 60 days was intermediate ($\bar{x}=11$ mm) to the other treatments.

Overall, the clay soil provided a rooting media that normally would be considered the least conducive to successful seedling root development. Seedlings growing in this soil had the shortest root system length, the slowest root growth rate, the fewest number of secondary roots junctioning from the primary root, but had root weights similar to other seedling root weights. From observations during sampling of seedling velvet mesquite root systems and by examination of data presented, the seedlings growing in the clay soil were found to have a more fibrous root system compared to those in the other soils. To demonstrate this observation, the number of secondary roots per unit of primary root was calculated. At 30 days the seedlings in the clay soil had 94% and 32% more secondary roots/unit primary root, compared to those in sandy loam and clay loam soils, respectively. Statistically these data were not significant ($P=0.39$). At 60 days of age, the number of secondary roots/unit primary root for all seedlings was within approximately 20%, with the sandy loam soil having the larger value. The strategy of a more fibrous root system observed for seedlings of velvet mesquite in clay soils during initial seedling establishment, however, has perhaps, ecological significance.

Conclusions

It was hypothesized that successful velvet mesquite seedling establishment was contingent on development of a deep root system. The ability for velvet mesquite seedlings to develop relatively deep root systems was found to be true for seedlings in soil which had less resistance to root penetration (sandy and well structured soils). In the clay soil, root elongation was apparently slowed by resistance imparted by the finer texture. To compensate for lack of rooting depth, the seedlings growing in clay soil may be displaying an adaptive strategy by producing a more fibrous root system that would encompass an equal or perhaps larger volume of soil upon which to draw moisture and nutrients. The root system of velvet mesquite seedlings develops initially (first 30 days) at the expense of top growth, which insures an increased probability of reaching water and nutrients for later growth processes.

The difference observed in velvet mesquite seedling root growth as influenced by soil textural classes may help explain the success of invading velvet mesquite on semiarid and arid rangelands. The ability of velvet mesquite seedlings to develop an extensive root system enhances its success as a competitor in desert ecosystems especially in riparian zones. The results of this study may also help

explain current distributions of velvet mesquite on various range sites.

Literature Cited

- Blake, G.R. 1965.** Particle density. In methods of soil analysis. Agron. Monogr. No. 9. Part 1. Amer. Soc. Agron., Ames, Iowa.
- Day, P.R. 1965.** Particle fractionation and particle size analysis. In: Methods of soil analysis. Agron. Monogr. No. 9. Part 1. Amer. Soc. Agron., Ames, Iowa.
- Hartman, G.W. 1977.** Soil survey of Maricopa County, Arizona: Central part. USDA, Soil Conservation Service and University of Arizona.
- Meyer, R.E., R.H. Haas, and C.W. Wendt. 1973.** Interaction of environmental variables on growth and development of honey mesquite, *Prosopis juliflora*. Bot. Gaz. 134:173-178.
- Scifres, C.J., and J.H. Brock. 1969.** Moisture-temperature interrelations in germination and early seedling development of mesquite. J. Range Manage. 22:334-337.

- Scifres, C.J., and J.H. Brock 1971.** Thermal regulation of water uptake by germinating honey mesquite seeds. J. Range Manage. 24:157-158.
- Scifres, C.J., and J.H. Brock. 1972.** Emergence of honey mesquite seedlings relative to planting depth and soil temperature. J. Range Manage. 25:217-219.
- Scifres, C.J., J.H. Brock, and R.R. Hahn. 1971.** Influence of secondary succession on honey mesquite invasion in North Texas. J. Range Manage. 24:206-210.
- Simpson, B.B. (ed.). 1977.** Mesquite: its biology in two desert ecosystems. US/IBP Synthesis Series No. 4. Dowden, Hutchinson and Ross, Inc. Stroudsburg, Pa.
- Steel, R.G.D., and J.H. Torrie. 1960.** Principles and procedures of statistics. McGraw Hill Book Co., Inc. New York, N.Y.