Root growth of *Artemisia tridentata*

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Abstract

We designed a greenhouse study to test the following 2 hypotheses: (1) root growth of Wyoming big sagebrush *(Artemisia tridentata* ssp. *wyomingensis)* exceeds that of basin big sagebrush *(A.t.* ssp. *tridentata)* and mountain big sagebrush *(A.t.* ssp. *vaseyana)* during the first 10 to 40 days after planting, and (2) root length of basin big sagebrush exceeds that of mountain big sagebrush, and root length of mountain big sagebrush exceeds that of Wyoming big sagebrush, at the end of a 174-day growing period. For the first 10 days, Wyoming big sagebrush root growth significantly (p=0.05) exceeded that of basin and mountain big sagebrush. At 20 and 30 days, Wyoming and basin big sagebrush were not significantly different, but both significantly exceeded mountain big sagebrush. At 40 days, basin big sagebrush root growth significantly exceeded that of Wyoming big sagebrush, which significantly exceeded mountain big sagebrush. Basin and Wyoming big sagebrush root lengths at 174 days were not significantly different, but both significantly exceeded mountain big sagebrush. Significant differences in root lengths at 174 days occurred among accessions. We concluded that Wyoming big sagebrush can survive on xeric sites where basin and mountain big sagebrush cannot because of smaller aboveground parts and rapid and long root growth.

Key Words: basin big sagebrush, Wyoming big sagebrush, mountain big sagebrush, root growth, site adaptability

Often 2 major big sagebrush *(Artemisia tridentata)* components occur on contiguous populations sites on foothills and valley floors in the drier zones of big sagebrush habitats of the Western United States (Barker and McKell 1983, Barker et al. 1983). An example of this double component is along U.S. Highway 189 between Kemmerer, Wyoming, and the junction of U.S. Highway 189 and Interstate 80. One component is a broad expanse of big sagebrush flats occupied by short-stunted (45 cm) big sagebrush plants *(A.t.* ssp. *wyomingensis).* Breaking up this monotonous landscape of dwarf big sagebrush plants are ribbons and patches of large big sagebrush plants, some 2 m or more in height. These larger plants occupy sites that concentrate water—drainages for the ribbon effects and swales for the patch effects. It is reasonable to believe that the taller plants are taller simply due to the effect of more water. This is partially true. When seedings of tall and short plants are grown together in a wetter but common environment, the same height relationship is maintained. Genetic factors determine stature, and the larger plants need more water to support their growth (Harniss and McDonough 1975, Welch and McArthur 1979, Winward 1980, McArthur and Welch 1982, Barker and McKell 1983, Barker et al. 1983, Welch 1983, Winward 1983, Welch and McArthur 1986).

Plant stature differences have been documented among 3 subspecies of big sagebrush: basin big sagebrush *(A.t.* ssp. *tridentata),* Wyoming big sagebrush *(A.t.* ssp. *wyomingensis),* and mountain big sagebrush *(A.t.* ssp. *vaseyana)* (Harniss and McDonough 1975, Winward and Tisdale 1977, Winward 1980, McArthur and Welch 1982, Barker and McKell 1983, Barker et al. 1983, Winward 1983, Welch and McArthur 1986). Documentation concerning root growth differences is limited to field studies of Fernandez and Caldwell (1975) and Sturges and Trlica (1978). We designed a greenhouse study to determine root growth and root length of 3 subspecies of big sagebrush. The hypotheses tested were: (1) root growth of Wyoming big sagebrush exceeds basin and mountain big sagebrush the first 10 to 40 days after planting, and (2) root length of basin big sagebrush exceeds mountain big sagebrush, which would exceed Wyoming big sagebrush at the end of the 174-day growing period. The rationale behind these hypotheses centers around the different habitats occupied by the subspecies (West et al. 1978, Winward 1983).

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Materials and Methods

This study was conducted in 2 parts. Part 1 was concerned with root growth during the first 40 days from planting, and part 2 with root length 174 days from planting. Both parts used the same 14 accessions of *Artemisia tridentata:* 4 accessions were Wyoming big sagebrush, 5 were basin big sagebrush, and 5 were mountain big sagebrush (Table 1).

Table 1. Acquisition sites for seed collections of 14 accessions of *Artemisia tridentata* used in this study.

Subspecies	Accessions	County and state
tridentata	Gordon Creek	Carbon, Utah
	Clear Creek Canyon	Sevier, Utah
	Loa	Wayne, Utah
	Dove Creek	Dolores, Colorado
	Kemmerer	Lincoln, Wyoming
vaseyana	Summit	Iron, Utah
	Hobble Creek	Utah, Utah
	Pinto Canyon	Washington, Utah
	Clear Creek Canyon	Sevier, Utah
	Sardine Canyon	Cache, Utah
wyomingensis	Trough Springs	Humboldt, Nevada
	Kemmerer	Lincoln, Wyoming
	Gordon Creek	Carbon, Utah
	Mayfield	Sanpete, Utah

The growth medium for both parts was prepared by mixing dry 4 parts of screened (6 mm by 6 mm) peat moss, 3 parts of expanded horticultural vermiculite, 3 parts of a dry fine sandy loam soil, and 2 parts number 3 silica sand blasting grit. Added to each 0.9 m^3 of mixture was a fertilizer supplement consisting of 600 g of dolomite limestone, 600 g of agricultural limestone (rock dust), 340 g of agricultural gypsum, 110 g of calcium nitrate, 110 g of osmocote, 90 g of tri-phosphate, 15 g of frittered trace elements, and 5 g of sesquestrene iron-138. The growing medium was mixed in a concrete mixer. Enough water was added during the mixing phase so that the medium would remain in a ball after being squeezed by hand. After mixing, the medium was heated to 76.7° C for 30 minutes with aerated steam. This treatment eliminates most soil-borne plant pathogens yet leaves most of the beneficial microrganisms (Nelson 1984). Next, the growing medium was placed in the containers designed for both parts of this study.

Part One: Seedling Root Growth at 10, 20, 30, and 40 Days

Containers for this part of the study were made out of 7.6-cm (inside diameter) polyvinyl chloride pipe. Depth of the containers was 50.8 cm. All containers were filled to 1 cm of the top with growth medium. Each accession was represented by 4 containers. Fifteen seeds were sown into the containers and covered about 2 mm deep with number 3 silica sand blasting grit. Containers were placed at random on a greenhouse bench. Greenhouse day (12 hours) temperature were set at 20° C. Night temperatures (12 hours) were set at 10° C. Day length was extended by means of artificial light for 12-hour days. Surface moisture was maintained by using a fogger once a day for 10 days. After 10 days no watering was needed.

At 10-day intervals from planting, a container for each of the 14 accessions was chosen at random to be used to determine root growth. This measure was then determined 10, 20, 30, and 40 days after planting. After the set of 14 containers for a given period was selected, growth medium was carefully soaked and washed away from the plants. Root length was measured to the nearest millimeter from 10 randomly chosen plants growing in a container. The time required for 10 plants per container to emerge was recorded.

Data were statistically analyzed by use of the Statistical Analysis Systems Anova program—randomized complete-block design (SAS Institute 1982). For significant *F* tests Student-Newman-Kuels multiple range tests at the 5% level were used to detect significance among treatment means. Treatments were subspecies; 10-day intervals were blocks. Containers were experimental units and plants were subsamples.

Part Two: Seedling Root Length at 174 Days

Containers for this part of the study were constructed of 9 mm plywood impregnated with copper-napthenate (Nelson 1984). Container size was 45.7 by 45.7 by 125.0 cm. Thermocouple psychrometers were placed at 25.4 and 50.8 cm and used to measure soil moisture and temperature on a weekly basis. Growth medium was placed within 1.0 cm of the top of the containers. Containers were sown 5 January 1983, with 5 seeds per accession, and the seeds were covered about 2 mm deep with number 3 silica sand blasting grit. Each accession was represented by 5 containers randomly placed in the greenhouse. Surface moisture was maintained by using a fogger until 3 or 4 seeds had germinated. After 20 days, plants in each container were thinned to 1 plant. The plant closest to the center of the container was kept. Greenhouse conditions were the same as described for part one.

Sagebrush plants were allowed to grow for 174 days. Then the crowns were detached from the roots at the culture medium surface. Crownless roots were gently washed with tap water to remove culture medium. After washing, the lengths of roots were measured in millimeters. (The choosing of the 174-day growing period had no scientific basis other than we felt that after this time we ran a high risk of having certain accession roots coming in contact with the bottom of the pots.)

Data were statistically analyzed by use of the Statistical Analysis Systems Anova program—completely random design (SAS Institute 1982). Treatments were either subspecies or accessions. Individual plant containers were experimental units.

Student-Newman-Kuels multiple range tests at the 5% level were used to detect significance among treatment means.

Results and Discussion

Part One: Seedling Root Growth at 10, 20, 30, and 40 Days

Root growth during the first 40 days is given in Table 2. At 10 days, Wyoming big sagebrush root lengths were significantly (p=0.05) longer than basin and mountain big sagebrush. Basin big sagebrush roots were significantly longer than mountain big sagebrush. Wyoming big sagebrush seeds germinated and emerged most rapidly, followed by basin and mountain big sagebrush. The Trough Springs accession of Wyoming big sagebrush had 10 seedlings growing 2 days after planting, whereas all other accessions required at least 4 days and one 8 days to produce 10 seedlings. This quick start helps to explain the longer roots of Wyoming big sagebrush.

Table 2. Emergence and seedling root lengths (10, 20, 30, 40 days after planting) of big sagebrush *(Artemisia tridentata)* subspecies-greenhouse environment.[a]

Subpecies	Emergence of 10 seedlings	Root length Day 10	Day 20	Day 30	Day 40
	Days	----------mm	----------		
A.t. ssp. *wyomingensis*	4	58a	158a	290a	413a
A.t. ssp. *tridentata*	5	47b	145a	304a	455a
A.t. ssp. *vaseyana*	6	30c	105b	211b	358b

[a]Means sharing the same letter within columns are not significantly different (p=0.05).

At 20 and 30 days, there was no significant difference between root lengths of Wyoming and basin big sagebrush. Both Wyoming and basin big sagebrush roots were significantly longer than mountain big sagebrush.

At 40 days, basin big sagebrush roots were significantly longer than Wyoming big sagebrush. Wyoming big sagebrush roots were significantly longer than mountain big sagebrush.

The data in Table 2 partially support our hypothesis that root growth of Wyoming big sagebrush exceeds that of basin and mountain big sagebrush during the first 10 to 40 days after planting. Wyoming big sagebrush root length did exceed mountain big sagebrush throughout the 40 days. However, Wyoming big sagebrush exceeded basin big sagebrush only for the first 10 days, was equal to basin big sagebrush for 20 or 30 days, and was exceeded by basin big sagebrush at 40 days.

At the end of 40 days, Wyoming big sagebrush was within 4 cm of 5.7 cm soil depth associated with Wyoming big sagebrush sites (McArthur and Plummer 1978, McArthur 1979, Winward 1983). It appears that Wyoming big sagebrush in 45 to 50 days after germination can draw water from the entire available soil profile. Actual field time may vary from this study depending on soil and other environmental conditions.

Part Two: Seedling Root Length at 174 Days

On a subspecies basis, basin and Wyoming big sagebrush grew roots significantly (p=0.05) longer than mountain big sagebrush,

Table 3. Root length of subspecies and accessions of big sagebrush seedlings *(Artemisia tridentata)* after 174 growing days (greenhouse environment).[a]

Subspecies	Root length mm
tridentata	926[a]
wyomingensis	876[a]
vaseyana	680[b]
Accessions	
Kemmerer (t)[b]	1032[a]
Gordon Creek (t)	1008[a]
Kemmerer (w)	982[ab]
Clear Creek (t)	966[ab]
Dove Creek (t)	890[bc]
Trough Springs (w)	886[bc]
Gordon Creek (w)	826[cd]
Mayfield (w)	808[cde]
Loa (t)	782[cdef]
Summit (v)	718[defg]
Sardine (v)	712[efg]
Pinto Canyon (v)	682[fg]
Hobble Creek (v)	660[g]
Clear Creek Canyon (v)	626[g]

[a]Means sharing the same letter are not significantly different (p=0.05).
[b]t = *Artemisia tridentata* ssp. *tridentata*
w = *Artemisia tridentata* ssp. *wyomingensis*
v = *Artemisia tridentata* ssp. *vaseyana*

but not from each other (Table 3). Moisture was never limiting during this phase of the study. Water potential for the first 161 days ranged from -3.2 to -6.5 bars, for the 168th day -3.5 to -8.5 bars, and for the 174th day -3.5 to -11.2 bars. From the last measurements of part one (40 days), basin big sagebrush doubled its root length, Wyoming slightly more than doubled its root length, and mountain big sagebrush slightly less than doubled its root length.

While the data support our hypothesis that root length of basin big sagebrush exceeds mountain big sagebrush in a 174-day growing period, we didn't expect Wyoming big sagebrush root length to exceed mountain big sagebrush nor to be nonsignificantly less than basin big sagebrush. This is based on our belief that the more xeric and shallow soils (West et al. 1978, Winward 1983) found in the Wyoming big sagebrush habitats would apply evolutionary pressure for rapid root growth and perhaps quicker germination, but not necessarily for long roots. Part one supported the rapid root growth and quicker germination idea. Wyoming big sagebrush plants (above ground) were significantly (p=0.05) smaller both in height and weight than were the basin and mountain big sagebrush plants (unpublished data on file, Shrub Sciences Laboratory), but produced roots longer than those of mountain big sagebrush after 174 growing days.

It appears that Wyoming big sagebrush has evolved so that top growth is under genetic conrol to produce smaller aboveground parts—a strategy that would conserve water while assigning energy into rapid and long root growth. These 2 characteristics, and probably others, allow Wyoming big sagebrush to survive on xeric sites where basin and mountain big sagebrush cannot.

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