

Water Relations of Two Subspecies of Big Sagebrush on Sand Dunes in Southeastern Idaho.

Abstract

Distributions of two subspecies of big sagebrush (*Artemisia tridentata* Nutt. subspecies *tridentata* and *A. tridentata* Nutt. subspecies *wyomingensis*) are associated with a soil texture gradient at sand dunes in southeastern Idaho. The two subspecies co-occur at the middle of the gradient on dune margins. The present study compared plant and soil water potentials among dune tops, dune margins, and adjacent slacks. We tested the hypothesis that there were no differences in these measured variables among the three locations on the dune landscape. Soil water potentials on the dune margins were significantly less negative than those on the adjacent slacks. Soil water potentials on the dune tops were not significantly different from those on the dune margins or the slacks. Predawn and midday plant water potentials of subspecies *tridentata* on the dune tops and both subspecies on the dune margins were significantly less negative than those of subspecies *wyomingensis* on the slacks. There was no difference in plant water potential between the two subspecies growing together on the dune margins. Plant water potentials of the two subspecies were significantly different when soil water potentials associated with each subspecies were also significantly different, even though subspecies *tridentata* plants were larger than subspecies *wyomingensis* plants.

Introduction

Inland sand dunes in arid and semiarid regions of North America have relatively moist soil environments compared to adjacent, fine textured soils (Barnes and Harrison 1982, Bowers 1982, Chadwick and Dalke 1965, Kirkpatrick and Hutchinson 1980, Pavlik 1980, Tevis 1958). Coarse textured sands have more macropores, which allow water from precipitation to infiltrate with little runoff or evaporation. Fine textured soils with high water holding capacities have surface layers that become saturated, resulting in surface evaporation and runoff. Thus, more water from precipitation is available to plants in the sandy soil on dunes than in adjacent, fine textured soils (Barnes and Harrison 1982, Bowers 1982, Pavlik 1980).

Distributions of two subspecies of big sagebrush at the Idaho National Engineering Laboratory (INEL) in southeastern Idaho are associated with a gradient in soil texture (Shumar 1983). Basin big sagebrush (*Artemisia tridentata* Nutt. subspecies *tridentata*; Beetle 1960) occurs on sandy areas and sand dunes and Wyoming big sagebrush (*Artemisia tridentata* Nutt. subspecies *wyomingensis*; Beetle and Young 1965) occurs on adjacent, fine textured soils. However, the subspecies co-occur along the dune margins, which are areas with shallow sand accumulation at the middle of the soil texture gradient.

Barker and McKell (1983) examined the water relations of the two sagebrush subspecies in contiguous stands, but on different soils. They found significantly lower soil and plant water potentials associated with Wyoming big sagebrush. However, Miller *et al.* (1982) found that soil and plant water relations of basin big sagebrush and Wyoming big sagebrush on separate sites were not significantly different. The presence of pure and mixed stands of the subspecies along the soil texture gradient at the INEL provided the opportunity to resolve the question of whether the two sagebrush subspecies have similar water relations when growing on the same soil or have some genetically determined difference that precludes similar water relations.

The present study compared plant and soil water potentials among dune tops, dune margins, and slacks (area between dunes with silt loam soil and no loose sand). The null hypotheses tested were: 1) soil water potentials are the same among the three areas of the sand dune environment, 2) plant water potentials are the same between basin big sagebrush plants on the dune tops and Wyoming big sagebrush plants on the slacks, and 3) plant water potentials are the same for both subspecies when they are growing together on the dune margins.

Methods and Materials

Plant and soil water potentials were measured at linear-type, stabilized sand dunes (*cf.* McKee 1982) during the summer of 1982. Three replicate transects were established, each extending from the top of a dune to the adjacent slack. Precipitation and other meteorological characteristics were assumed to be equal for all three transects at any particular time because these transects were within 250 m of each other.

Screen-caged thermocouple psychrometers (J. R. D. Merrill Co., Logan, Utah) were placed in the soil at the dune top, dune margin, and the slack at each transect. Because of a limited supply, one psychrometer was placed at one depth at each location on the dune landscape. This depth was subjectively determined by estimating the zone of maximum water accumulation in each case based on soil characteristics. At the slacks, the psychrometers were placed at a depth of 45 cm, which corresponded to the depth of an indurated layer of clay and calcium. We surmised that little available water would be found below this layer. At the margins, psychrometers were placed between 50 and 60 cm, which is the approximate depth of the interface between the sand and the underlying loess. We assumed that water would accumulate at these interfaces between different soil textures (Brady 1974, p. 186). Examination of the soil profile showed the highest density of roots in the same region. Psychrometers were placed approximately 75 cm deep at the dune tops. This depth was determined to be the average depth of roots by digging a trench and examining the root distribution.

Psychrometers were measured at midmorning on the following dates: 12 June, 27 June, 16 July, 30 July, 14 August, 4 September, and 5 October. The procedures and computer program of Brown and Bartos (1982) were used to determine soil water potential from psychrometer microvolt output.

Plant water potential was measured before dawn on the same dates psychrometer readings were taken, at midday on those dates except for 5 October, and diurnally at 2-hr intervals on 12 June and 16 July. Plant water potential was measured with a pressure bomb (Waring and Cleary 1967) on sagebrush branches clipped from the sunlit portion at the top of the crown. At each transect, four plants were selected for water potential measurements; a basin big sagebrush

plant at the dune top, a Wyoming big sagebrush plant at the slack, and one plant of each subspecies at the dune margin. Plants were randomly selected within a 5 m radius of each soil psychrometer. The same plants were used for predawn, midday, and diurnal measurements for the duration of the experiment. Because there were three transects, the sampling regime provided three measurements of plant water potential for each landscape position and subspecies. Estimates of between plant variance were measured on adjacent plants at approximately the same time in a previous study (95 percent confidence intervals were ± 0.5 Mpa for basin big sagebrush and ± 0.2 Mpa for Wyoming big sagebrush).

Soil water potential was analyzed with a two-way analysis of variance, with date as a random factor and position on the dune landscape (*i.e.* dune tops, dune margins, and slacks) as a fixed factor. Predawn and midday plant water potentials were analyzed by three-way analysis of variance, with date as a random factor and landscape position and subspecies as fixed factors. The alpha level was set at 0.05 for all tests. If the analyses of variance indicated significant differences among landscape positions or subspecies, then the Student-Newman-Keuls (SNK) multiple range test was used to determine which landscape positions or subspecies were significantly different from the others.

Results

The two-way analysis of variance of soil water potential indicated that the main effects, date and landscape position, were both significant. A subsequent SNK showed that the margins had significantly less negative water potentials than the slacks (Figure 1). Soil water potential at the dune tops was not significantly different from that of the margins or the slacks. Figure 1 shows that soil water potential on the dune tops was less negative than that of the margins in June, but dropped rapidly to a level similar to that of the slacks by the end of July.

Significant main effects in the three-way analysis of variance showed that predawn and midday plant water potentials were significantly different among dates, landscape positions, and subspecies. A significant two-way interaction between landscape positions and subspecies and a subsequent SNK analysis indicated that predawn

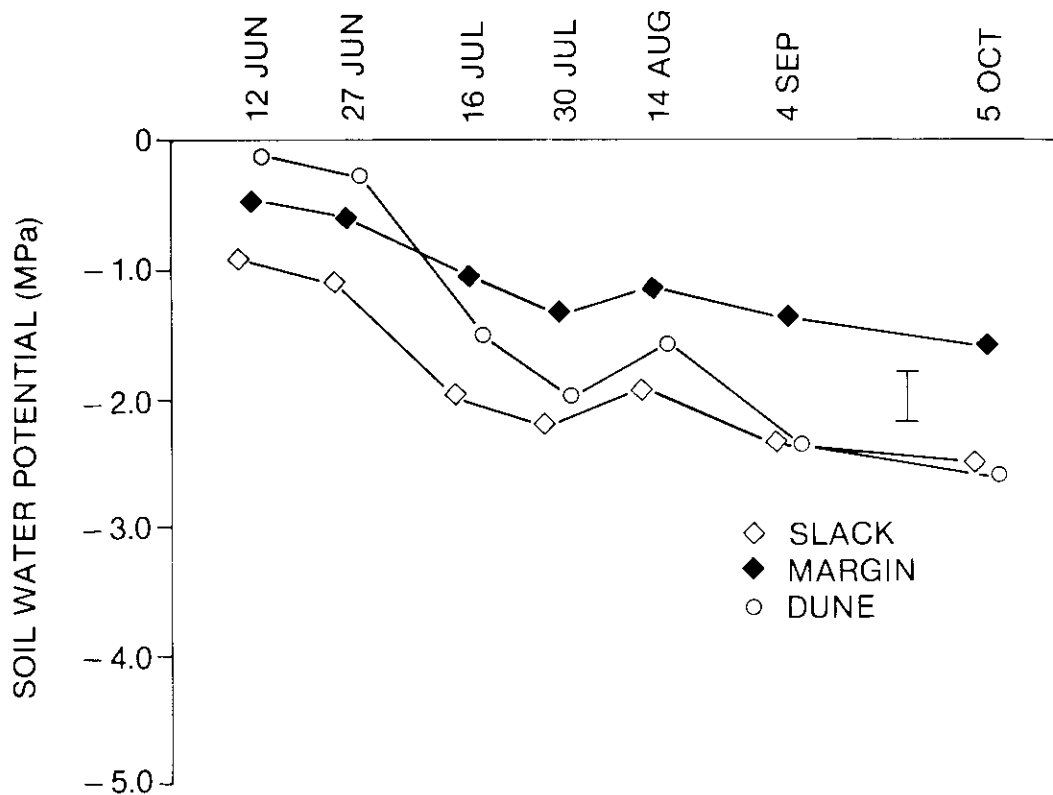


Figure 1. Average soil water potential at the slacks, dune margins and dune tops (labeled slack, margin and dune respectively) measured on seven dates in 1982. Values for the margins are significantly ($P < 0.05$) less negative than those of the other two landscape positions. Standard error bar is shown on the figure between 4 September and 5 October values.

water potential of Wyoming big sagebrush at the slacks was significantly more negative than predawn water potentials of big sagebrush at the dune tops and both subspecies at the margins (Figure 2). Predawn plant water potentials were not significantly different among the two subspecies at the margin and basin big sagebrush at the dune tops (Figure 2). Midday plant water potentials showed the same differences as predawn plant water potentials. Midday water potential of Wyoming big sagebrush at the slacks was significantly more negative than midday water potentials of basin big sagebrush at the dune tops and both subspecies at the margins (Figure 2).

The magnitudes of the difference between mean predawn and mean midday water potential were similar among landscape positions and subspecies on most dates. These daily differences ranged from a low of 0.3 MPa change in June to a maximum change of 1.4 MPa in August. Diurnal fluctuations in plant water potential for plants at the three landscape positions on 12 June and 16 July are presented in Figure 3. Diurnal patterns were similar for all plants on the slacks, margins, and dune tops. Water potentials of Wyoming big sagebrush plants at the slacks were consistently more negative than that of plants at the other two locations. Plant heights averaged 1.38 m and 0.81 m for basin big sagebrush and Wyoming big sagebrush respectively (Figure 3).

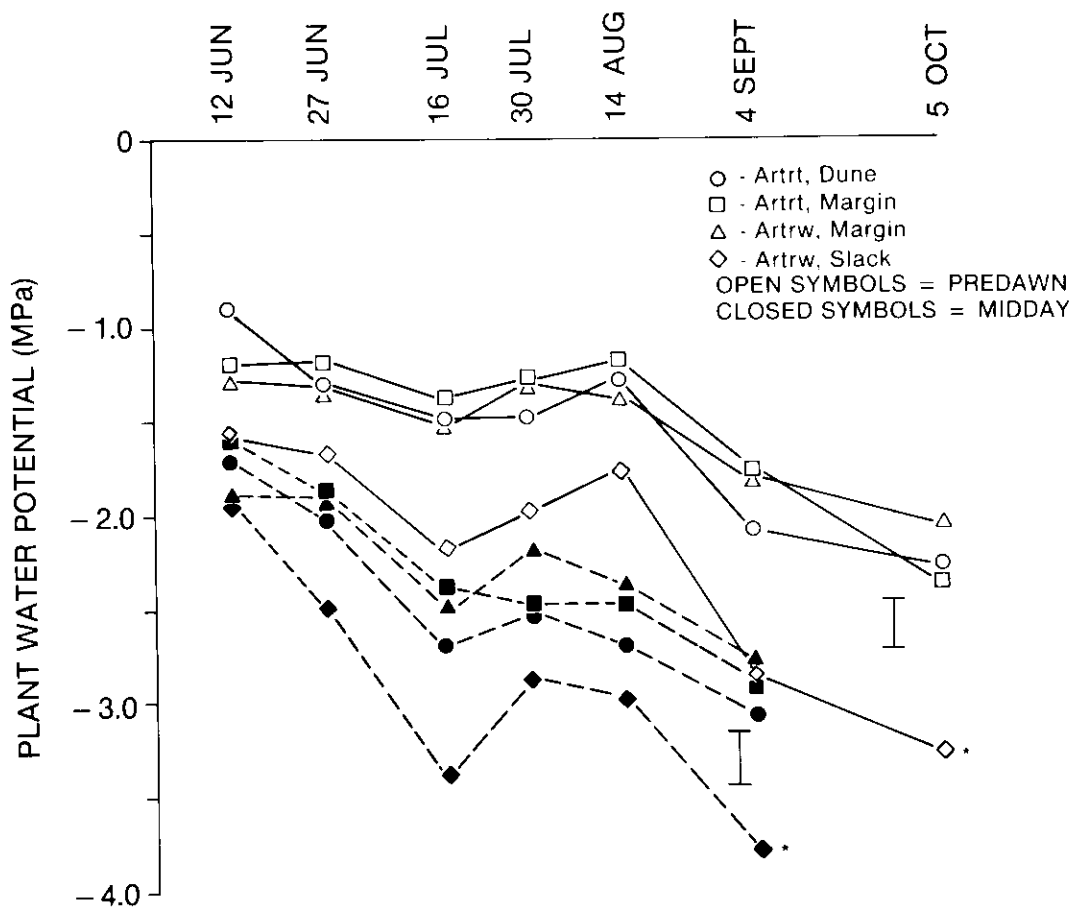


Figure 2. Predawn and midday plant water potential for basin big sagebrush (Artrt) on the dune, Wyoming big sagebrush (Artrw) on the slack, and both subspecies on the margin (see figure inset). Water potentials (both predawn and midday) for Wyoming big sagebrush on the slack (*) are significantly ($P < 0.05$) more negative than those of basin big sagebrush on the dune and both subspecies on the margin. Standard error bars for predawn and midday values are depicted on the figure.

Discussion

Plant water potentials of the subspecies were different only when soil water potentials associated with each subspecies were also significantly different. Plant water potentials of the two subspecies did not differ from each other when plants were growing on the same soil (*i.e.*, dune margins, Figure 2). Both predawn and midday water potentials of Wyoming big sagebrush on the slacks were considerably lower than those of basin big sagebrush on the dune tops and both

subspecies on the margins (Figure 2). Soil water potentials were also lower on the slacks than on the margins (Figure 1). Despite genetically controlled differences in root and shoot size between the two subspecies, they do not appear to respond differentially to soil water availability.

The results of Miller *et al.* (1982) and Barker and McKell (1983) also suggest that predawn plant water potentials of both sagebrush subspecies were similarly affected by soil water potentials. Miller *et al.* (1982) and our results indicate that the magnitude of the fluctuation be-

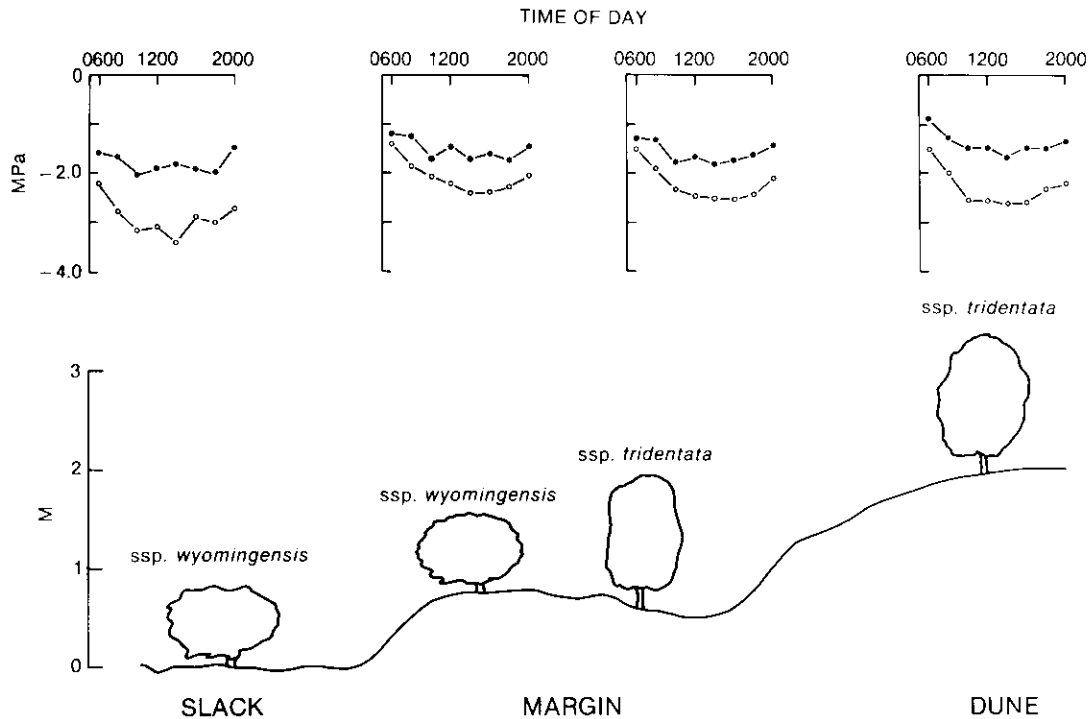


Figure 3. Diurnal curves of plant water potential taken on 12 June (closed circles) and 16 July (open circles). Curves correspond with the respective sagebrush subspecies and their location as depicted for the dune study area in the lower portion of the figure. Plants and dune landscape are scaled to average heights (m).

tween predawn and midday water potentials was about the same for the two sagebrush subspecies on any one date, which suggests that these midday values were affected by the evaporative demands of the day and the predawn value. The predawn value reflects soil water availability. Barker and McKell (1983) found differences in plant water potential between these two subspecies on three of six dates. Soil water potential under the respective subspecies were also significantly different on those dates.

Miller *et al.* (1982) found no differences in either predawn or midday water potentials between basin big sagebrush on one site and Wyoming big sagebrush on a second. The authors indicate that the deeper soils supporting basin big sagebrush held more water than the shallow soils supporting Wyoming big sagebrush. They attributed the similarity in plant water potentials of the two subspecies to higher "transpiration potentials" of basin big sagebrush because of its

greater leaf area. Thus, although more water was available to basin big sagebrush, its leaf water potentials were similar to those of Wyoming big sagebrush because of higher transpiration. Our results indicate that basin big and Wyoming big sagebrush had similar water potentials despite differences in size of the plants on the dune margin. We suspect that basin big sagebrush plants would have a larger root volume in addition to a greater leaf area. Thus, the root/shoot ratios may have been similar between the subspecies, resulting in equal plant water potentials so long as soil water content in the root zones and transpiration resistances were equal between the two stands. Barker and McKell (1983) found no differences in transpiration resistances between these two subspecies.

Predawn plant water potentials were not different between the dune tops and the margins, suggesting that more water was available below the depth where the psychrometers were located at the dune tops. Psychrometers at the dune tops

were placed at a depth of 75 cm, even though sand depth was as much as 200 cm. Although a high density of roots is found above 70 cm, big sagebrush plants commonly have roots that extend to 180 cm (Sturges 1977). We suspect that psychrometers at the dune tops were not deep enough to detect maximum water availability; had they been placed deeper, soil water potentials would probably have been similar between the margins and dune tops.

Increases in soil and plant water potentials during August were probably the result of precipitation inputs. From 16 July to 30 July, soil water potentials decreased (Figure 1) but plant water potentials increased (Figure 2). This apparent discrepancy may have been due to precipitation that wet the upper horizons of the soil in contact with plant roots but did not infiltrate down to the level of the psychrometers. Alternatively, the higher plant water potentials on 30 July as compared to 16 July also may have resulted from the loss of ephemeral leaves that generally occurs in July (Deput and Caldwell 1973). Abrupt reductions in shoot/root ratios occur in other desert plants to the benefit of the plant's water status (Etherington 1982).

Diurnal patterns of water potentials for big sagebrush in this study were similar to those of Deput and Caldwell (1973), Everett *et al.* (1977), and Campbell and Harris (1977). Minimum water potentials were -3.9 MPa for Wyoming big sagebrush and -3.5 MPa for basin big sagebrush, and were similar to minimum values reported by Deput and Caldwell (1973) and Miller *et al.* (1983). Although Branson *et al.* (1976) and Everett *et al.* (1977) obtained minimum values considerably lower than ours, Campbell and Harris (1977) obtained values similar to ours during a wet year and values similar to those of Branson *et al.* (1976) and Everett *et al.* (1977) during a

dry year. These results provide additional support to our hypothesis that plant water potential of the two subspecies is directly affected by soil water potential.

Higher moisture availability in dune sand as opposed to finer textured soils is in agreement with the work of other investigators (Barnes and Harrison 1982, Bowers 1982, Chadwick and Dalke 1965, Kirkpatrick and Hutchinson 1980, Pavlik 1980, Tevis 1958). Pavlik (1980) and Barnes and Harrison (1982) also reported higher water potentials of plants on sand dunes as compared to plants on adjacent non-dune substrates.

Conclusions

The dune margins were more mesic than the slacks. The phenomenon of moisture retention in the stabilized sand dunes at the INEL is similar to that reported for other inland sand dunes in the arid and semiarid regions of the American West. Water potential of basin big sagebrush plants at the dune tops and plants of both subspecies at the margins were significantly less negative than that of Wyoming big sagebrush plants at the slacks. There was no difference in plant water potential between the two subspecies growing together on the margins. The subspecies differ in size but apparently do not differ physiologically with respect to water potential.

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