United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

Research Note
PNW-RN-496
July 1990

Soil Water Use by *Ceanothus velutinus* and Two Grasses

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Abstract

Seasonal trends of soil water content in plots of snowbrush *(Ceanothus velutinus* Dougl.), orchard grass *(Dactylis glomerata* L), and pinegrass *{Calamagrostis rubescens* Buckl.) and in bare plots were measured on a burned-over forest watershed in north-central Washington. A comparison of soil water contents at depths of 12, 24, 36, and 48 inches indicated that the grasses and snowbrush generally used similar amounts of soil water; although during midsummer, water content at 12 inches in -pinegrass plots was significantly lower than that in snowbrush plots, which indicated greater water use by pinegrass. From the soil surface to a depth of 24 inches, soil water content in snowbrush plots was similar to that in bare plots during most of the summer, thereby suggesting that snowbrush may not be a serious competitor for soil moisture during the initial establishment of conifer seedlings. Pinegrass probably has the greatest potential to be a more serious competitor for soil moisture with newly planted conifer seedlings than either orchard grass or snowbrush.

Keywords: Orchard grass, pinegrass, reforestation, site preparation.

Introduction

Snowbrush *(Ceanothus velutinus* Dougl.) is one of the most common shrubs naturally regenerating after fires in the Western United States. Seeds of snowbrush may persist in the soil for hundreds of years until heat stimulates them to germinate (Gratkowski 1962). The shrubs frequently form a continuous canopy and are considered a serious competitor for soil moisture and light with young conifers (Conard and Radosevich 1981, Conard and others 1985, Petersen and others 1988, Zavitkovski and others 1969). Grasses also can comprise a large part of the vegetative cover of burned-over or harvested areas in the Pacific Northwest. Pinegrass *(Calamagrostis rubescens* Buckl.), a native rhizomatous perennial grass, frequently exhibits vigorous regrowth after site disturbance; and an introduced species, orchard grass *(Dactylis glomerata* L), often is seeded to quickly establish a vegetative cover for erosion control. Orchard grass can form dense stands initially, but it is relatively short-lived compared to pinegrass, which tends to become more abundant with time. These species, with other shrubs, forbs, and grasses, often comprise the dominant water-consuming vegetation on burned-over watersheds until forest trees again occupy the area and become the major water users.

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In much of the interior West, availability of soil moisture is the main factor limiting survival and growth of conifers seedlings; thus water depletion by competing vegetation is a major concern of foresters. Earlier studies compared soil water use by snowbrush and adjacent areas covered by herbaceous vegetation (Conard and others 1985, Petersen 1980), but little is known about soil moisture use by snowbrush in comparison to specific grasses like pinegrass and orchard grass. Information on water use by these species is needed to assess their relative competitiveness for soil moisture when considering site preparation options and to gain an understanding of the role of these species in the hydrologic recovery of burned or harvested areas. This note describes the seasonal trend of soil water content at various depths in the soil profile for plots of snowbrush, pinegrass, and orchard grass and discusses the relation of soil water use by the species to site preparation and the establishment of conifer seedlings.

Methods

Plots were established in the Brennegan Creek and Preston Creek watersheds, tributaries of the Entiat River in north-central Washington. Elevation ranged from 3,281 to 3,937 feet. Exposure of the Brennegan Creek plots ranged from west to northwest, and exposure of the Preston Creek plots was southeast. Slope steepness ranged from 20 to 40 percent. Average annual precipitation at 3,281 feet is 22 inches per year and mean annual temperature is 44.3 °F (Helvey and others 1976). Summers normally are hot and dry with only about 13 percent of the precipitation occurring from June to September. Soils are coarse and relatively deep; they developed in ash and pumice over granite bedrock and are classified as Rampart sandy loams (Iritani 1965). Vegetation, since a severe forest fire in 1970, consists mostly of dense stands of snowbrush and scattered plants of pinegrass, orchard grass, hard fescue *(Festuca ovina* var. *duriuscula* (L.) Koch), bracken fern *{Pteridium aquilinum* (L.) Kuhn.), spreading dogbane *(Apocynum androsaemifolium* L), and fireweed *{Epilobium angustifolium).*

In 1976-77, four plots were established in Brennegan Creek and two in Preston Creek; these were in dense stands of snowbrush ranging from 30 to 48 inches in height. Each 60- by 60-foot plot was divided into four 30- by 30-foot subplots. In each plot, ceanothus was left intact on one subplot. The other three subplots were cleared of all vegetation to bare soil. Standing snags were removed to eliminate shading. The three bare subplots were trenched to a depth of 2-1/2 feet along sides bordering snowbrush to cut existing lateral root systems. Black polyethylene plastic (4 mil) was placed vertically in the trench, which was backfilled to minimize reentry of snowbrush roots into the cleared areas. In each plot, orchard grass seed was sown on one of the subplots at the rate of 20 pounds per acre. An adjacent cleared subplot was seeded with an equal amount of pinegrass seed. The remaining cleared subplot was left bare and was maintained by periodic weeding. The seeded subplots were fertilized with ammonium phosphate (16-20-0) at the rate of 48 pounds of N (nitrogen) per acre. Fertilization is important for establishment of grasses in this area (Klock and others 1975). Establishment of pinegrass was poor, however, so the following year we planted container seedlings (3.5-cubic inch Ray Leach cells) of pinegrass grown in a greenhouse. Distribution of the grasses after establishment was not uniform across subplots. On four of the six orchard grass subplots, grass coverage was estimated at 70 to 75 percent; on two subplots, coverage was 40 percent. Pinegrass cover on the same four sites ranged from 50 to 75 percent and on the other two subplots was 25 percent.

In 1978, three aluminum access tubes (1.5 inches inside diameter) were installed 60 inches deep in each subplot to permit measurement of soil water content with a neutron probe soil moisture meter. Tubes were at least 5 feet from the edges of the subplots to avoid shading and other edge effects on soil moisture. On the grass subplots, the tubes were placed next to established grass plants. Volumetric measurements of soil water were made at depths of 12, 24, 36, and 48 inches. We assumed that measurements of soil moisture involved a sphere of influence about 12 inches in diameter at each depth. Water content per foot of soil was calculated for each depth, and for the total soil profile from 6 to 54 inches. From 1978 to 1983, measurements of soil moisture were made periodically in spring, summer, and fall. In 1979 and 1980, snowbrush stands were slightly defoliated during an infestation of California tortoise shell moths {*Nymphalis californica* Boisduvae), and some winter damage occurred in shoots exposed above the snowpack. Data presented in this report were collected during 1983. By that time, snowbrush had fully recovered, and the grasses were well established and representative of grass-covered areas.

Data Analysis

Data for soil water content at four depths in the soil profile and 10 time periods were analyzed with analysis of variance using depth and time as repeated measures factors. The univariate analysis showed a strong time effect ($p<0.01$), a strong depth effect ($p<0.01$), and also a time-by-depth interaction ($p<0.01$). Owing to few replications, full multivariate tests of time and its interactions are not available. Because of the time-by-depth interaction, and the other interactions, soil water contents were compared at each depth and each time. Although chosen depths and times were arbitrary, the patterns of significance seem to have some consistency. Within each time and depth, Tukey's multiple comparisons (Dunn and Clark 1974) were used to determine which subplots had significantly different soil water contents at the 0.05 level. Because of the repeated measures design, these tests may be too liberal. Another problem is the small number of degrees of freedom. Because of these considerations, these water-use patterns probably should be investigated further.

Results and Discussion

Soil water content at all depths decreased from May to October in all subplots (fig. 1). A decline in soil moisture during the summer months is typical of eastern Washington because the area receives little rainfall during summer. The decline is the result of several factors, including evaporative water loss from the soil surface, plant water use, and deep drainage in the soil profile. Lowest soil water content on all subplots occurred at the 12-inch depth. Soil water content increased with depth, with the highest water content at 48 inches. At all depths, soil water content decreased most rapidly from May through August and then decreased slowly during September and October. The rapid decline in soil water content from May through August presumably reflected relatively high water use by plants and high rates of evaporative water loss during this period, compared to fall months when plant water use and evaporative losses were low in response to reduced evaporative demand.

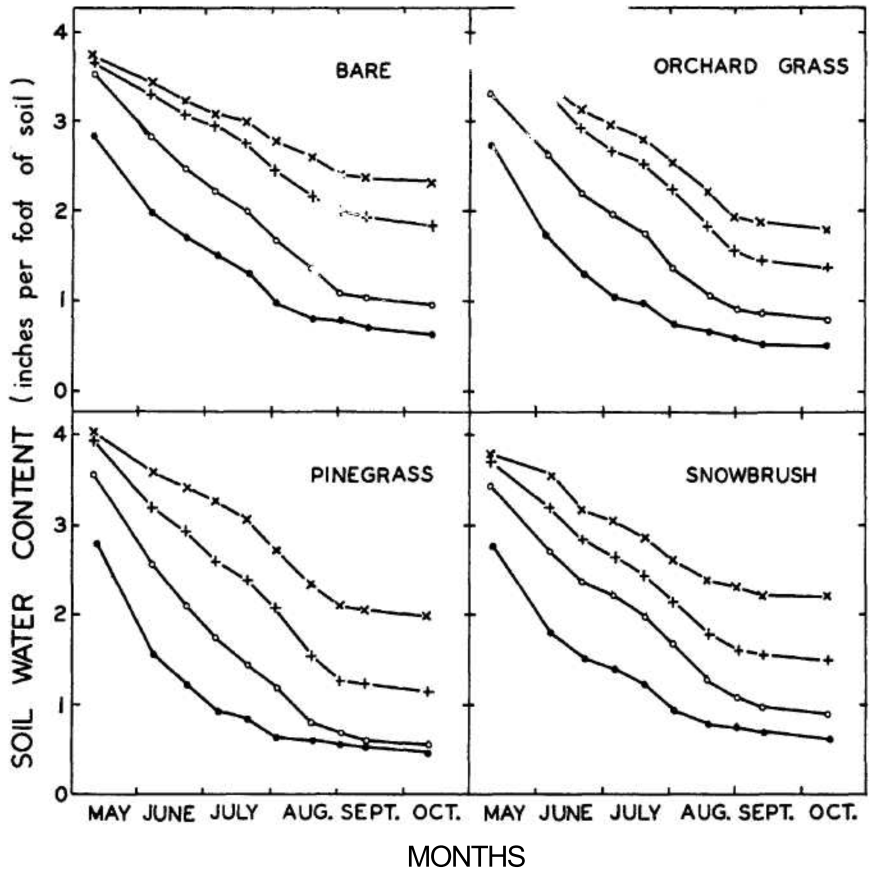

Figure 1—Seasonal trend of soil water content for bare, pinegrass, orchard grass, and snowbrush subplots at 12 (•), 24 (o), 36 (+), and 48 (X) inches in the soil profile.

A comparison of average soil water contents at four depths in the soil profile for the four treatments indicated that at least at certain times of the year, orchard grass and pinegrass reduce soil water content more than does snowbrush (fig. 2). At 12 and 24 inches, average water contents for the grass subplots remained below that for snowbrush subplots for most of the summer and fall; however, the variability of soil water content (from one area and plot to another) increased as depth increased and as soil water content decreased (time increasing). Tukey's multiple comparisons (0.05 level) showed statistical differences in mean soil water contents at 12 inches from June 6 to August 2 and at 24 inches in July (table 1). No other significant differences were found. In early June, B (bare) is different from P (pinegrass) at 12 inches. Otherwise, from late June through early August, B and S (snowbrush) are not different, S and O (orchard grass) are not different, and O and P are not different. At 24 inches, B and P are different in July. At 36 and 48 inches, no statistical differences were found due to variability in moisture contents from one area and plot to another Thus, the only significant difference between vegetation types was that between pinegrass and snowbrush at the 12-inch depth between June 21 and August 2. There were no statistical differences between vegetation types at 24 inches. Observation of the rooting depth of the grasses and snowbrush indicated that roots were restricted to

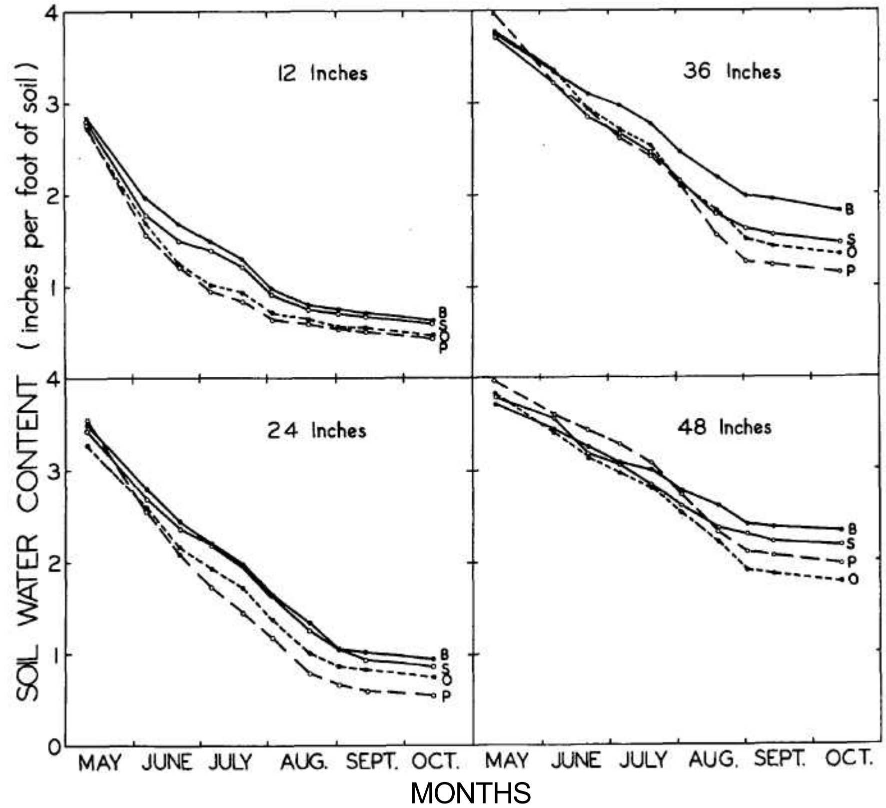

Figure 2—Seasonal trend of soil water content at four depths for bare (B), snowbrush (S), orchard grass (0), and pinegrass (P) subplots.

Table 1—Results of Tukey's multiple comparisons showing which treatments are significantly different for soil water contents at two soil depths during summer 1983, for bare subplots and for subplots containing snowbrush, orchard grass, and pinegrass

	Soil depth	
Date	12 inches	24 inches
June 6	B S O P[a b]	
June 21	B S O P	
July 5	B S O P	B S O P
July 19	B S O P	B S O P
August 2	B S O P	

[a] Bare (B), snowbrush (S), orchard grass (O), and pinegrass (P) subplots.
[b] Subplots sharing a common underline are not statistically different at the 0.05 level.

the top 30 inches of soil. No roots were observed in coarse pumice, commonly called "popcorn pumice," deeper than 30 inches; however, the lack of roots below 30 inches does not preclude the possibility of moisture moving upward to shallower depths in response to moisture gradients caused by water absorption by roots.

There was a considerable decline in soil water content on the bare subplots in the absence of plant water use. The general similarity in soil moisture decline for all treatments may be explained in part by drainage characteristics in these soils. Klock (1981), working in the same general area immediately after a severe forest fire, compared seasonal trends of soil moisture content on bare plots covered with plastic to moisture contents on adjacent bare uncovered plots. He found a considerable decline in soil moisture on both plots, even though water loss by evaporation was prevented on some plots by a layer of plastic covered with soil. Klock calculated a drainage rate for these soils of 0.56 mm per day, which for the 157 days involved in the present study, would represent a loss of soil water by drainage alone of 3.4 inches.

At depths of 12 and 24 inches, soil water contents in the snowbrush subplots were similar to or only slightly less than those for bare subplots for most of the summer. This finding is in general agreement with results reported by Youngberg (1965), who found that soil moisture is available for longer periods of time under snowbrush than in bare areas or under grass. The most likely explanation for the similarity in water contents in snowbrush and bare subplots in our study was that water loss by evaporation probably was relatively high from the exposed soil surface of the bare subplots. On the other hand, evaporative water loss from the soil surface in the snowbrush subplots probably was minimal because of shading, mulching of the soil surface by leaf litter, reduced soil temperature, increased humidity, and reduced air movement. Conard and Radosevich (1982) found a considerable decrease in evaporative demand under a shrub canopy, including snowbrush, compared to areas where shrubs had been removed. Little information is available on transpirational water loss per unit of foliar surface from snowbrush compared to associated species. The stomata of *Ceanothus velutinus* apparently can remain open at leaf water potentials down to -1.8 MPa and lower (Conard and Radosevich 1981). Also, Marshall and Waring (1984), who compared stomatal responses of snowbrush with several species of conifers and associated shrubs, found that snowbrush has the highest daytime stomatal conductance, and its conductance does not respond to change in vapor pressure deficit. These considerations suggest a high rate of water loss from ceanothus, but the effect of other factors, such as age of the stand, is not known.

Soil moisture and atmospheric conditions under snowbrush canopies suggest that snowbrush, by ameliorating stressful humidity and temperature conditions, may facilitate the initial establishment of conifer seedlings, particularly on arid sites. Youngberg (1965) reached a similar conclusion after finding higher soil moisture and lower soil temperatures under snowbrush compared to open areas. Scott (1970) concluded that snowbrush has a beneficial effect on the establishment and growth of Douglas-fir seedlings in western Oregon because of the favorable moisture, temperature, and nutritional conditions under ceanothus canopies. In a study of first-season survival and growth of Douglas-fir seedlings planted in northern Idaho shrubfields, Christianson and others (1984) found that seedling growth under shrubs was not significantly different from seedling growth in cleared strips. Also, Tappeiner and Helms (1971) report that the decreased radiation load and higher relative humidity under shrub canopies appeared to aid the establishment of conifer seedlings in *Ceanothus prostratus.* But there also is general agreement that after the establishment of conifers, snowbrush can be a serious competitor with conifer seedlings and young trees for soil moisture and light (Jaramillo 1988, Petersen and Newton 1982, Zavitkovski and others 1969). Recently, Petersen and others (1988) reported that competition for soil water by *Ceanothus velutinus* and associated forbs is a factor limiting stemwood production in 10-year-old Douglas-fir trees.

The seasonal change in total soil water content in the soil profile from 6 to 54 inches for the four treatments (fig. 3) was similar to the trends in soil water content shown in figure 2; that is, during summer and fall, soil water content on orchard grass and pinegrass subplots was less than that on snowbrush or bare subplots. Because of variability from one site and plot to another, there were no significant differences between vegetation types (although some differences existed at 12 and 24 inches, none existed at 36 and 48 inches.) If the difference between soil water contents on May 10 and October 13 in figure 3 is taken as the amount of water use during the season, water use by snowbrush was 8.8 inches and by orchard grass and pinegrass was 9.7 inches. Water loss from the bare areas was 8.1 inches. Seasonal water use, expressed as a percentage of decrease in soil water content, was 58.7, 62.8, 68.4, and 71.3 percent, respectively, for the bare, snowbrush, orchard grass, and pinegrass subplots. A factor not evaluated in the present study, but that would influence the degree of soil water depletion, was the number of grass plants per unit of area. Because soil moisture measurements in the grass subplots were taken between and adjacent to established grass plants, they probably reflected soil water use that would occur in areas with fairly abundant grass cover as compared with areas of sparse grass cover.

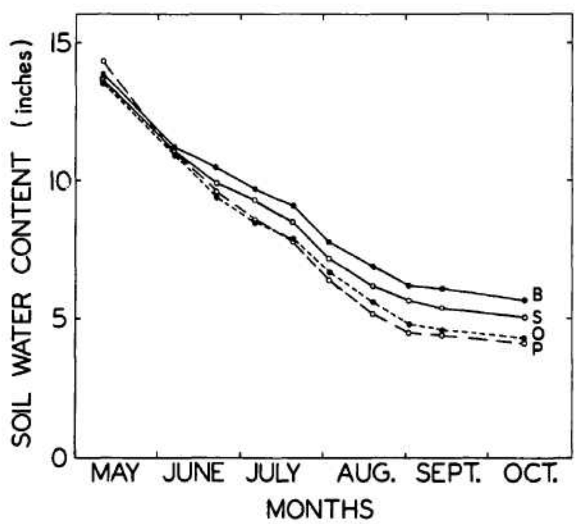

Figure 3—Total soil water content in the soil profile from 6 to 54 inches on bare (B), snowbrush (S), orchard grass (0), and pinegrass (P) subplots.

Conclusions

The results of this study indicated that under the given conditions, there were no major differences in soil water use by snowbrush, pinegrass, or orchard grass. In the middle of summer, pinegrass reduced soil water content at depths of 12 and 24 inches to lower levels than did snowbrush, but the difference was small—only 0.4 to 0.5 inch of water per foot of soil. Thus, on the basis of soil water use, the results do not strongly support the removal of any one of the three species over another to reduce competition for soil moisture during tree planting. Growth characteristics of pinegrass, such as early spring growth initiation, rhizomatous rooting, vigorous regrowth after disturbance, long-livedness, and its appreciable soil water use during midsummer, suggest that it probably has the potential to be the most serious competitor for soil moisture with newly planted conifer seedlings.

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