NOTES

Influence of artificial shade on water stress of containerized ponderosa pine seedlings[1]

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Artificially shaded and unshaded containerized *Pinus ponderosa* Laws. seedlings were planted in the Sacramento Mountains of southern New Mexico on July 29, 1975. Xylem pressure potential (P_{stem}) and relative water content (RWC) were measured four times per day from August 1 to 16, 1975. Shading had little effect on RWC but significantly increased P_{stem}; midafternoon (1530 hours, MDST) increase averaged 2 bars (1 bar $= 10^5$ Pa). During the study RWC ranged from 86 to 94% and P_{stem} ranged from -4 to -10 bars. At the end of September no mortality had occurred in either treatment.

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Le 29 juillet, 1975, nous plantâmes, dans la chaîne de montagnes Sacramento de la partie méridionale du Nouveau-Mexique, de jeunes plantes de Pinus ponderosa Laws., qui étaient ou ombragées artificiellement ou pas ombragées et en conteneurs. Le potentiel de pression du xylon (P_{stem}) et le contenu relatif d'eau (RWC) furent mesurés quatre fois par jour du 1 au 16 août, 1975. L'action d'ombrer eut peu d'effet sur le contenu relatif d'eau (RWC) mais augmenta d'une manière significative le potentiel de pression du xylon (P_{stem}). En plein aprèsmidi (15 h 30 dans le fuseau horaire Montagne, heure d'été) l'augmentation était de deux bars. Pendant cet examen le RWC varia de 86 à 94% et le P_{stem} (pression d'eau) varia de -4 à -10 bars (1 bar $= 10^5$ Pa). Fin septembre nous ne rencontrâmes aucune mortalité dans les deux traitements.

Introduction

Reforestation of *Pinus ponderosa* Laws. in the southwestern United States is often unsuccessful because of environmental moisture stress. Plant water stress results from an imbalance of water absorption and loss often resulting from transplanting and subsequent exposure to summer drought (Rietveld and Heidmann 1969; Schubert 1970).

Although ponderosa pine probably benefits less from summer shading than most other commercial species of the Southwest, studies have shown a definite beneficial effect on survival of seedlings (Schubert and Adams 1971). Reduced drought mortality by shading (Maguire 1955) probably stems from a reduction in transpiration by lowering needle surface temperature, thus decreasing the vapor pressure gradient to the atmosphere. Natural overhead shading also reduced frost heaving of ponderosa pine (Larson 1960).

The role of artificial shade in survival of containerized seedlings has not been determined. The purpose of this study was to relate artificial shading to water stress in containerized ponderosa pine seedlings planted in the Sacramento Mountains of southern New Mexico. This was evaluated by measuring relative water content (RWC) and xylem pres-

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sure potential (P_{stem}) (Ritchie and Hinckley 1975).

The seedling containers used were Ferdinand book planters, 2.5 × 2.0 × 10.0 cm (Spencer–Lemaire, Inc.). Containers were filled with a 4:4:1 by volume mixture of peat, vermiculite, and forest soil, and seeded in mid-April 1975. All containers were watered daily until emergence and thereafter three times per week. After 12 weeks in the greenhouse, the containers were moved outdoors to the planting site where they were acclimated for 4 more weeks. During acclimation the seedlings were watered once per week but not fertilized. The planting site is located in the ponderosa pine zone and was burned by wildfire in 1974. The site is at an elevation of 2300 m, has a north-facing aspect, and an 8% slope. The soil is a deep, well-drained clay loam classified as a Typic Argiboroll.

On July 29, 1975, 16 weeks after seeding, 460 seedlings 6–8 cm tall were hand planted singly on 50 × 50 cm scalps positioned on 1 × 1 m centers. Half of the seedlings (alternating rows of 10 seedlings) were shaded with 15 × 20 cm wood slabs oriented so that the seedlings were shaded from 1300 hours Mountain Daylight Savings Time (MDST) until sunset.

Relative water content and P_{stem} were measured at 700, 1100, 1530, and 1930 MDST from August 1 through August 16, 1975. All measurements were made on whole shoots severed at ground level and were replicated five times. Whole shoots were used because seedlings lacked secondary needles. P_{stem} was measured with a pressure chamber (Scholander *et al.* 1965) within 60 s after the stem was cut. These same shoots were then used to determine *RWC*, calculated as follows (Weatherley 1950):

$$[1] \quad RWC = \frac{\text{fresh weight} - \text{oven dry weight}}{\text{turgid weight} - \text{oven dry weight}} \times 100.$$

The use of whole seedlings instead of needles (Harms and McGregor 1962) for *RWC* determinations was examined in a separate study (Buchanan Fisher and Davault, unpublished) and it was found that: (1) whole shoots and secondary needles are saturated to 100% *RWC* after 8 h; (2) at P_{stem} values between −5 and −13 bars (1 bar = 10^5 Pa), there was no statistically significant difference between *RWC* of whole shoots and needles; (3) the same shoots could be used to determine P_{stem} and *RWC* measurements without introducing significant error.

All data were analyzed by three-way analysis of variance (Snedecor and Cochran 1967).

Results and Discussion

Data are presented for 5 rainless days (August 7, 8, 9, 10, and 16) during the study period. Soil water content in the top 10 cm of the unshaded plots decreased from 20% to 14% between August 7 and August 10, then increased to 19% on August 16 after a heavy rain. Soil water content in the top 10 cm of the shaded plots was more stable. It was between 17 and 18% on August 7–10, and 19% on August 16. Field capacity for this soil is typically about 22% and permanent wilting point about 11%.

The grand means (5 days, five times per day, five replications per time) of P_{stem} and *RWC* on the shaded plots were −6.6 bars and 89.8%, respectively. On the unshaded plots these values were −7.2 bars and 90.2%. The difference in *RWC* was not statistically significant, but the P_{stem} difference was significant ($p = 0.05$).

Shaded and unshaded seedlings had similar P_{stem} values in the morning hours, before the shades came into effect. In the afternoon P_{stem} of the unshaded seedlings (Fig. 1) was significantly decreased by 2 bars ($p = 0.05$). The influence of shade on P_{stem} became more pronounced as the soil water content decreased. On August 10 the difference at midafternoon was about 3 bars (Fig. 2). *RWC* generally varied directly with P_{stem} (Fig. 1).

Values of P_{stem} and *RWC* measured in this study ranged from −4 to −10 bars and 86 to 94%, respectively. In northern Arizona, Larson and Schubert (1969) determined *RWC* for ponderosa pine during a June drought. When *RWC* was above 90%, at the beginning of the drought, no mortality occurred. Pharis (1966) found that an *RWC* of 43% was lethal to ponderosa pine seedlings in the greenhouse. At the end of the present study 17 seedlings of each treatment were growing. One month later, at the

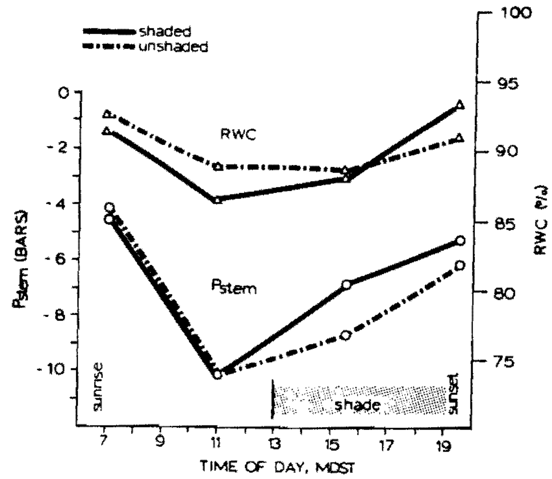

FIG. 1. Average diurnal variation in xylem pressure potential (P_{stem}) and relative water content (*RWC*) for shaded and unshaded ponderosa pine containerized seedlings during 5 days.

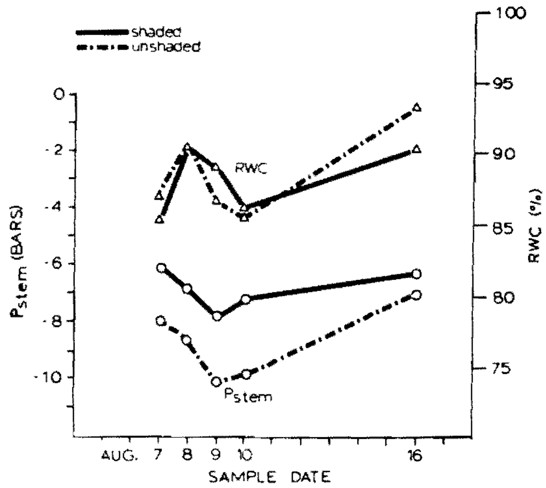

FIG. 2. Variation in xylem pressure potential (P_{stem}) and relative water content (*RWC*) at 1530 MDST (midafternoon) on 5 different days for shaded and unshaded ponderosa pine containerized seedlings.

end of September, no mortality had occurred in either treatment.

Within the range of pressure potentials measured in this study a 2–3 bar difference in P_{stem} could have a significant positive influence on growth of 1st-year seedlings. Photosynthesis of *Pinus taeda* seedlings stops at a needle water potential of −11 bars (Brix 1962). In addition, stomatal closure in ponderosa pine seedlings occurs at about 84% *RWC* (Lopushinsky 1969). Reduced cell division and elongation might also be significant at moderate moisture stress levels (Kramer 1969), and could strongly influence root growth. Seedling establishment is highly dependant upon deep and well-developed root systems, which increase resistance to frost heaving and second season drought (Larson 1967).

Normally artificial shade, as described here, may not be economically feasible for commercial planting of containerized seedlings. However, because of the apparent advantages of shading, ponderosa pine seedlings should be planted near logging debris or in natural shade. Cutting methods that provide shading overwood through the reproductive period should be favoured (Larson 1960) and logs, stumps, and brush used (Coffman 1975). Seedlings should be planted to allow effective shading during the midday (1000–1500 hours), but heavy overhead shade should be avoided (Pearson 1950).

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