Title: **Using Shade to Improve Transplant Survival of Pinyon Pine And Subalpine Fir Seedlings**

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FINAL STATUS OF THE PROJECT

Abstract:

Pinyon pine (*Pinus edulis*) and subalpine fir (*Abies lasiocarpa*) seedlings are native species that can be difficult to transplant, but shading young plants may improve their survival. The objective of this study was to determine the effects of a light treatment and type of growth medium on the survival and growth of these seedlings. Plug seedlings (2-0) of both species were the only plants available for this study. Seedlings were planted in 10 ft. by 12 ft. gravel beds or soil beds. Two blocks of plants were then grown in full sun or 55% shade. The experiment began in late May and ended in early October. All plug seedlings of pinyon pine grown in gravel survived, whereas 92% or 77% of the plants in full sun or 55% shade, respectively, survived. More than 95% of the subalpine fir grown in shaded conditions in gravel or soil survived transplanting, but half of the seedlings planted in full sun in soil died. A significant interaction between light treatment and type of growth medium affected mean shoot height increases and root volumes of fir seedlings. Pinyon pine seedlings grew the most in full sun with these plants having at least 17% larger mean stem diameters, 32% heavier mean shoot dry weights and 36% heavier mean root dry weights compared to those of plants grown under 55% shade. The gravel beds improved only mean shoot dry weights of fir seedlings and mean root volumes of pine seedlings compared to those of plants grown in soil. Overall, this study demonstrated that plug seedlings of pinyon pine can be transplanted successfully into soil, and shading can further improve their survival and the survival of plug-grown subalpine fir seedlings.

Materials and Methods:

In this experiment, pinyon pine (*Pinus edulis*) and subalpine fir (*Abies lasiocarpa*) seedlings were grown in gravel beds or field soil. Plug seedlings (2-0) of both species were the only plants available and were used in the study. The size of the gravel beds and the soil plots were 10 ft. by 12 ft. Pinyon pine seedlings were planted in a gravel bed filled with a mixture of 60% pea gravel (3/8-inch minus), 30% Turface®, and 10% silica sand (by volume). Fir seedlings were planted in a gravel bed that contained 80% pea gravel, 10% Turface®, and 10% sand. Field soil was prepared by tilling the soil 30 cm deep, adding 20 ft^3 of Eko® compost, and tilling in the compost to a depth of 30 cm. All seedlings were randomly assigned to a growth medium (gravel

or soil) and light treatment (shade or sun) and were planted in the field or gravel beds by April 28. After the seedlings were established for about 5 weeks, specific blocks of plants were covered with 55% shade cloth. All plants were fertilized with Peters® 30-10-10 fertilizer at 150 ppm N on June 23, July 7, and July 21. In addition, all plants were fertilized with controlled-release fertilizer 15-9-12 on July 13.

Seedlings were arranged in complete blocks within the gravel and soil beds, but the shade treatments were used only on the northern blocks in each bed to prevent unintended shading of full sun plants. Forty-eight (48) seedlings were used in two blocks for each full sun and shade treatment (24 seedlings per block) in the gravel bed and field soil for a total of 192 seedlings of pinyon pine and 192 subalpine fir seedlings. Extra seedlings were used as guard rows to separate the blocks of experimental seedlings. A low-volume irrigation system outfitted with spray stakes was used to water all containers. Seedlings in the gravel beds were irrigated twice a day, whereas those in soil were watered as needed, usually once a week.

All seedlings used in this experiment were harvested by October 12. Plant roots were washed free of gravel or soil and any potting mix (from the seedling plugs) after the plants were gently removed from the gravel or soil. The 2006 terminal leader growth of the seedlings and mean stem diameters were measured. Root volume was measure next by determining the amount of water displaced by the root system upon immersion in a graduated cylinder. The plants were then cut at the root-stem crown after being measured, and roots and shoots were dried separately to determine their dry weights.

Statistical analyses of the data included using analysis of variance on the plant growth data. The overall probability needed to show significant treatment effects had to be at or below the 5% level ($P \leq 0.05$) when completing the various statistical analyses. Mean separation tests were completed only if the statistical model was significant. In other words, the shade treatments or type of growth medium used (gravel or soil), or both affected the type of plant growth being analyzed. Least Square means were used to determine treatment differences at the 5% level.

Results and Discussion:

Most of the pine and fir seedlings grew during the summer, but plants in 55% shade survived the best. Pinyon pine seedlings survived the transplanting well, most likely because plug plants were used rather than bareroot seedlings (as used in previous years). All pinyon pine seedlings (100%) in the gravel bed survived and grew a small amount. In soil, however, 77% of the pinyon pines grown in full sun survived, but 92% of the shaded seedlings survived. Perhaps the moisture holding capacity of the soil caused some problems for the pinyon pine seedlings. Another possible explanation for the survival differences between the sun and shade seedlings is that the shade reduced plant temperatures and reduced stress, allowing shaded seedlings to establish better. The fir seedlings definitely survived transplanting better if grown in the 55% shade treatment. Needle color was a dark green on shaded fir seedlings, whereas needles on plants in full sun were a lighter green, regardless if the plants were grown in gravel or soil. Both the gravel bed and field soil dried out one time, and the fir seedlings in full sun suffered foliar damage. A few plants also died. Seedlings in the shade, however, lacked any damage from the dried soil or gravel episode. Shaded fir seedlings in both beds survived at similar levels; all

gravel-grown, shaded fir plants (100%) survived, and 96% of the soil-grown, shaded fir plants survived. In contrast, 79% of the gravel-grown fir seedlings in full sun survived, whereas only 50% of the soil-grown seedlings in full sun survived. Based on these results, shading subalpine fir seedlings improved seedling survival, regardless of the growth medium (gravel or soil).

Shoot height growth, shoot dry weight and root volume of subalpine fir seedlings were affected by light treatment and type of growing medium, whereas mean stem diameters ($P = 0.232$) and root dry weights ($P = 0.3402$) were unaffected by these treatments. A significant interaction between light treatment and growth medium affected shoot height increases and root volume (Table 1). Leaders on fir seedlings grown in shade in the gravel bed grew an average of 54% taller than those on plants grown under 55% shade in soil. The shade treatment may have caused the fir seedlings to stretch more compared to plants in full sun. Mean root volumes of fir seedlings grown in full sun in the field were at least 68% larger than those of plants grown in full sun in gravel. Mean root volumes of fir seedlings grown in full sun in the field were also at least 17% larger than those of plants grown in the shade, regardless of whether the plants were grown in soil or gravel (Table 1). Since root dry weight was unaffected by the various combinations of treatments, we were surprised that root volumes would differ significantly among the various treatment combinations. The reason for the low root volumes of plants grown in full sun in gravel is unknown. Perhaps the gravel drying out once damaged plant roots and caused a decrease in mean root volume for seedlings growing in full sun. Finally, mean shoot dry weight was significantly affected only by the type of growth medium ($P = 0.0301$). Seedlings grown in gravel produced at least 24% more shoot dry weight than those planted in soil (compare 10.7 g versus 8.6 g, respectively), regardless of the light treatment they received.

Table 1. Effects of light treatment and type of growth medium combinations on mean shoot height increases and root volumes of subalpine fir seedlings.

Treatment combination	Mean shoot height increase (cm)	Mean root volume (cm^3)
Shade + field	4.6 a[z]	11.9 b
Shade + gravel	7.1 b	11.8 b
Sun + field	6.3 ab	14.0 c
Sun + gravel	6.4 b	8.3 a

[z] Means within a column followed by different letters are significantly different as determined by Least Square means at the 5% level (n = 46, 48, 24, and 38 for the four treatment combinations, respectively).

Mean stem diameter, mean root volume, mean shoot dry weight and mean root dry weight of pinyon pine seedlings were affected by either light treatment or soil type, whereas mean shoot height increases were affected by a specific combination of the treatments. For example, a significant interaction ($P = 0.0422$) between light treatment and type of growth medium resulted leader growth of pine seedlings grown in full sun in soil being at least 38% taller than plants receiving any other combination of treatments. This difference in growth, however, was only 1 cm (about 0.4 inches) taller, so its biological significance was probably minor. Mean stem diameters as well as shoot and root dry weights of pine seedlings were affected only by light

treatment, with plants grown in full sun producing more growth (Table 2). Mean stem diameters, mean shoot dry weights and mean root dry weights of pine seedlings grown in full sun were 17.6%, 32.2% and 36.4% higher , respectively, than those of plants grown under 55% shade. Finally, root volumes of pine seedlings grown in gravel were on average at least 47% larger ($P < 0.0001$) than those on seedlings grown in soil regardless of the light treatment they received (data not shown).

Table 2. Effects of 55% shade and full sun on mean stem diameters as well as shoot and root dry weights of pinyon pine seedlings.

Light treatment	Mean stem diameter (mm)	Mean shoot dry weight (g)	Mean root dry weight (g)
55% shade	5.1 a	6.2 a	2.2 a
Full sun	6.0 b	8.2 b	3.0 b

[z] Means within a column followed by different letters are significantly different as determined by Least Square means at the 5% level (n = 92 and 85 for the two light treatments, respectively).

In this study, growing subalpine fir and pinyon pine seedlings in 55% shade promoted transplant survival, although plants grown in full sun grew the most if they survived. Fir seedlings planted in the sun had the lowest survival percentages, and fewer of those planted in soil survived compared to those grown in gravel even though both beds dried out once during the growing season. Similarly, the only pinyon pine seedlings that died were those that were grown in soil in full sun. The combination of full sunlight and soil apparently stressed the seedlings more than those grown in gravel and resulted in lower survival rates for both species of seedlings. Sunlight was important, however, since plants that survived transplanting grew the most in full sun, particularly pinyon pine seedlings (Table 2). Even when a specific combination of light and growth medium (the interactions) significantly affected plant growth, plants grown in full sun produced more growth than shaded plants (Table 1). The exception to this observation was shaded fir seedlings in gravel grew taller than shaded seedlings in soil (Table 1).

The type of growth medium (gravel versus soil) affected survival, as mentioned above, but it had only minor effects on fir and pine seedling growth. Only shoot dry weights of fir plants and root volumes of pine seedlings were significantly affected by growth medium. In both cases, plants grown in gravel produced more growth than those grown in soil, regardless of the light treatment the seedlings received. The larger root volumes of pinyon pine seedlings grown in gravel may have been due to keeping the root system more intact compared to root systems removed from soil. Plants grown in the gravel beds were easily removed at harvest and so most likely more of their roots were retained compared plants harvest from soil. We are unsure why shoot dry weights of fir plants grown in gravel were heavier. Perhaps growing conditions in the gravel were better for the fir plants than in the soil. This suggestion is supported by the statistical analysis that showed - in addition to the interaction (see above) - growth medium also affected fir seedling heights ($P = 0.0318$), with the leaders on gravel-grown plants growing 1.3 cm (one-half inch) taller than those on seedlings grown in soil.

Significance to the Nursery Industry:

This study demonstrated that plug seedlings of pinyon pine, a difficult-to-transplant species, could be grown in field soil since over 75% of the seedlings survived transplanting, regardless of whether the plants were grown in full sun or 55% shade. Growing plug seedlings of pinyon pine in 55% shade may help initial survival, but plants grown in full sun grew more than those in shade. Perhaps a compromise treatment can be used whereby plug pinyon pine seedlings are grown for the first several months, perhaps through July, under 55% shade. Shade cloth can then be removed to allow the plants to receive full sunlight as they continue to develop going into the fall. Even though plug seedlings transplanted quite well into soil, more research on improving root regeneration by bareroot pinyon pine seedlings is needed since 2-0 plug plants cost at least four times more than bareroot plants. To make purchasing pinyon pine seedlings more economically viable for specimen nursery growers, root regeneration will have to be improved for bareroot plants, which should also improve transplant survival.

The gravel helped improve survival rates of subalpine fir seedlings, but plants grown in soil survived quite well if they were grown in 55% shade. Perhaps subalpine fir seedlings should also be grown under a regime that includes shading the plants for the first several months and then growing them in full sun to permit optimum plant development as the plants are exposed to cooler temperatures. Using an initial shade treatment to reduce seedling stress should improve transplant survival.