Title: **Evaluating Pinyon Pine and Subalpine Fir Root Growth in a Gravel Bed Growing System**

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YEAR-END STATUS OF THE PROJECT

Experimental Technique:

The experiment, growing corkbark fir and pinyon pine seedlings in a gravel bed or field soil for one growing season before transplanting to the field, was started in April, 2004. A gravel bed measuring 10 ft. by 12 ft. by 1.2 ft. tall was made by lining a wooden frame with 4 mil plastic sheets. The bed was filled with a mixture of 60% pea gravel (3/8-inch minus), 30% Turface®, and 10% silica sand (by volume). A field bed 10 ft. by 12 ft. in size was also prepared. Corkbark fir (*Abies lasiocarpa arizonica*) 3-0 seedlings were received in late March, held in refrigerated storage, and planted on April 14 in the gravel bed or part of the field bed. The remaining fir seedlings were planted in the field bed on April 16. The pinyon pine 4-0 seedlings (*Pinus edulis*) were received on April 20 and planted on April 21 and 23 in the gravel or field beds. Five plants of each species for the two transplant months (September and October) were planted in four blocks. The original plan involved planting two rows of each species for each month, with one row destructively sampled and the other to be transplanted into the field. Therefore, a total of eighty plants were planted for each species in each type of planting bed (gravel vs. field soil). One extra row of experimental fir trees was planted in the field and gravel beds (so that 20 extra trees could be used in the experiment if needed). To minimize root damage when transplanting, guard rows of seedlings were planted between the rows of experimental plants. The gravel bed and field bed were fertilized with Scott's Osmocote® 15-9-12 at the labeled rate on May 21 and fertilized with Peter's (liquid) 30-10-10 at 150 mg/Liter N once a week starting on June 18 and ending on July 30.

Results to Date:

Both species of conifers, corkbark fir and pinyon pine, grew in the gravel bed, but large numbers of both species failed to survive the entire growing season in the gravel bed and field for different reasons. The corkbark fir seedlings were growing well until around the second week of July at which time a number of plants in the experiment (in both guard rows and experimental rows) appeared to be wilted or wilting. A few trees were brown, and their needles were dried out. Trees in field soil and the gravel bed seemed equally effected. Mortality data were taken on August 4, 2004. In the field soil, 15% of the experimental seedlings died (out of

the 100 seedlings planted), and 27% of the experimental plants died in the gravel bed (Table 1). More complete information on the percentages of seedlings that died due to root rot are found in Table 1. Fusarium root rot, in particular *F. oxysporum* and *F. proliferatum*, were the organisms causing the problems on corkbark fir roots. When using fir seedlings for the root harvesting or transplanting studies, any plants with roots that appeared to be diseased or weak were discarded rather than used in the experiment.

Table 1. Percentages of dead corkbark fir seedlings due to *Fusarium* root rot.

Planting Medium	Experimental Plants (%)	Guard Row Plants (%)	Total Losses in the Medium (%)
Field soil	15	35	50
Gravel bed	27	21	48

The pinyon pine seedlings survived transplanting poorly, most likely due to inadequate root regeneration. Many of the seedlings planted in either field soil or the gravel bed died. When data were taken on August 4, 2004, the percentage of surviving of pine seedlings in the gravel bed was over double that of pinyon pines growing in field soil. Forty two out of 180 (23.3%) experimental and guard row seedlings planted in the gravel bed were alive and growing on this date compared to 19 out of 180 seedlings (10.6%) in the field bed. Pinyon pine seedlings in the gravel bed clearly survived transplanting better than those planted in field soil.

Despite the numbers of seedlings lost to disease (fir) or poor transplant survival (pine), enough plants survived to complete the remainder of the proposed experiments, but fewer plants were available than originally desired. Enough fir seedlings grew well enough to harvest (destructively sample) plants and transplant others in September (on the 14th) and October (on the 12th). Only enough pinyon pine seedlings survived to harvest and transplant the plants in October, with plants destructively sampled on October 12 and others transplanted on October 21. Data on field transplant survival and subsequent field growth will be available after mid-September 2005.

Destructive harvesting of fir and pine seedlings clearly demonstrated that root systems of plants grown in the gravel bed were much larger than those grown in field soil (Tables 2 and 3). Growth of the fir seedlings was unaffected by the month the plants were harvested. ($P > 0.06$ for the growth parameters determined). Shoot heights and stem diameters of the fir seedlings were similar during both months, regardless of whether plants were grown in gravel or soil (Table 2). In contrast, fir seedlings grown in the gravel bed produced at least 30% more root dry weight and 74% more root volume than those planted in field soil. Differences in root growth were also easy to see visually (Figure 1).

Pinyon pine seedlings grown in the field or a gravel bed also had similar shoot growth but had different amounts of root growth in each medium (Table 3). Although shoot heights and stem diameters of surviving pine seedlings were similar for soil-grown and gravel-grown plants, seedlings in gravel produced at least 37% more root dry weight and 86% more root volume than those grown in soil. Differences in root growth were also easy to observe (Figure 2).

Table 2. Mean shoot and root growth of corkbark fir seedlings grown in a gravel bed or field soil and harvested in September or October 2004.

Month	Treatment	Mean Height (cm)	Mean Stem Diameter (mm)	Mean Shoot Dry Weight (g)	Mean Root Dry Weight (g)	Mean Root Volume (ml)
September	Gravel	27.0	9.2	14.7	8.4 a*	40.5 a
	Field	25.4	8.9	13.9	6.7 b	24.1 b
October	Gravel	25.2	8.7	14.2	9.4 a	42.0 a
	Field	27.2	8.6	15.2	6.9 b	23.2 b

* Means followed by different letters within a column indicate significant differences at the 1% level as determined by Least-Square means (n = 20).

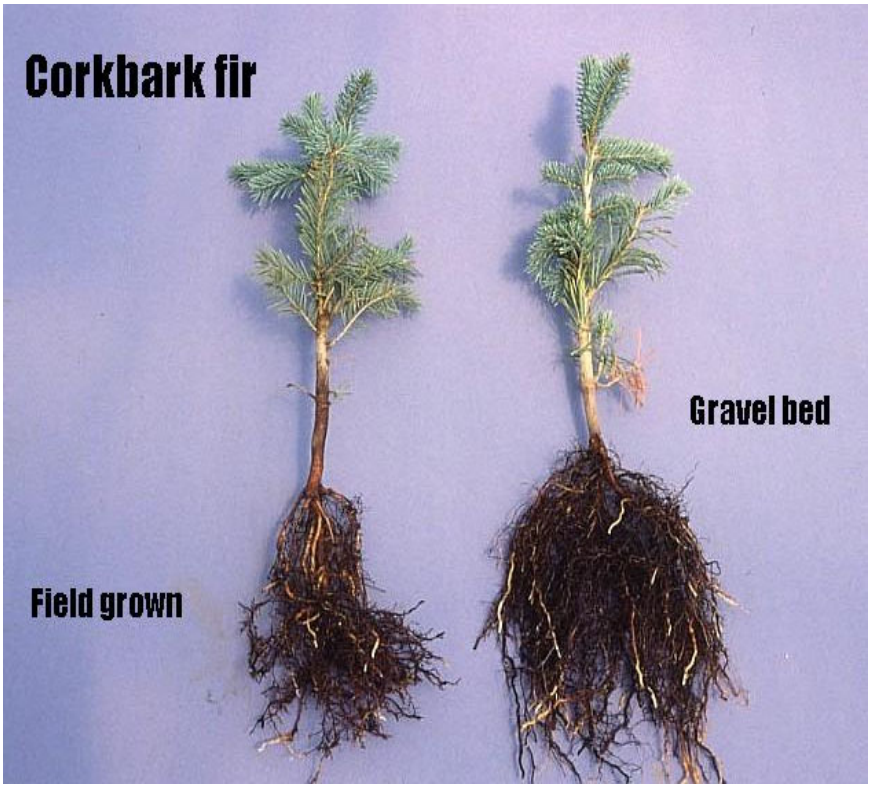

Figure 1.

Root systems on corkbark fir seedlings grown for 26 weeks in field soil (left) or a gravel bed (right) before lifting. Plants used for this picture represented the average root system of plants in the treatment.

Table 3. Mean shoot and root growth of pinyon pine seedlings grown in a gravel bed or field soil and harvested in October 2004.

Treatment	Mean Height (cm)	Mean Stem Diameter (mm)	Mean Shoot Dry Weight (g)	Mean Root Dry Weight (g)	Mean Root Volume (ml)
Gravel	43.4	9.8	30.6	9.5 a*	28.2 a
Field	43.6	9.8	29.1	6.9 b	15.1 b

* Means followed by different letters within a column indicate significant differences at the 1% level as determined by Least-Square means (n = 20 for gravel plants; n = 15 for soil plants).

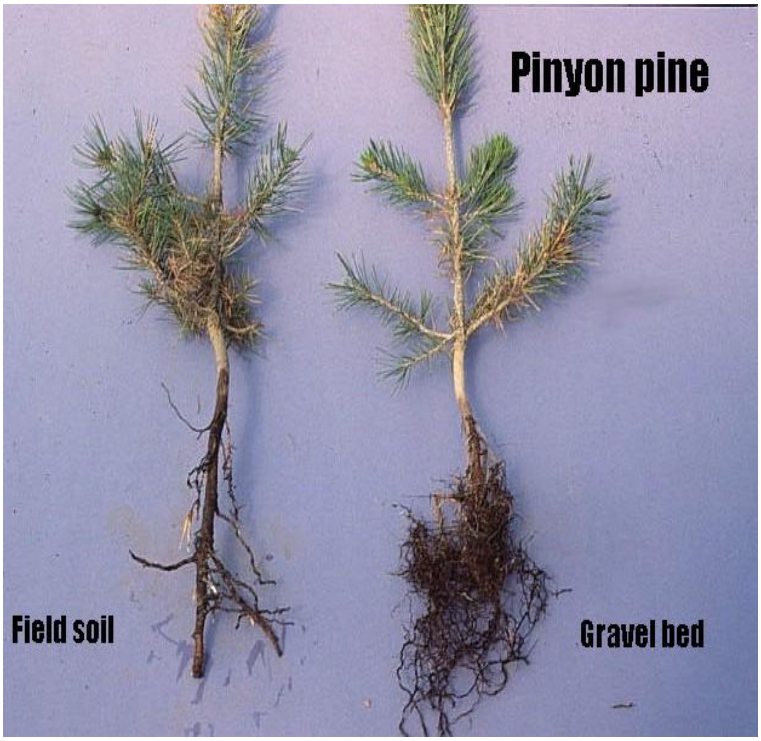

Figure 2.

Root systems on pinyon pine seedlings grown for 25 weeks in field soil (left) or a gravel bed (right) before lifting. Plants used for this picture represented the average root system of plants in the treatment.

Discussion:

Corkbark fir and pinyon pine seedlings tolerated the gravel bed environment, and these plants produced larger root systems than those grown in field soil (Tables 2 and 3; Figures 1 and 2). Even though some fir seedlings succumbed to Fusarium root rot enough plants survived and grew well enough to use in the experiment. Although corkbark fir can sometimes be difficult to transplant (Randy Poss, personal communication), the seedlings used in the study grew well in the field and gravel beds, but those in the gravel bed produced mores roots than those in soil. Despite the infection of many seedlings by Fusarium root rot, those plants that were disease free

grew well in the gravel bed. In contrast, severe losses pinyon pine seedlings during the study were due to poor transplant survival of this species. Seedlings that died in the field or gravel beds failed to form any new roots. For some reason, however, at least double the number of pine seedlings planted in the gravel bed survived transplanting compared to those grown in soil.

Several factors may be responsible for corkbark fir and pinyon pine seedlings producing larger root systems when grown in the grave bed compared to soil. First, the gravel mix had better aeration and drainage than field soil. Improved aeration and drainage in the gravel may have resulted in better or optimum moisture availability to the seedlings, enabling the plants to produce more roots. The gravel bed medium also was easier to move around, enabling plant roots to grow further in the medium than in field soil, thereby allowing the plants to produce larger root systems. For pinyon pine seedlings, the improved rhizosphere with better aeration, drainage, and moisture availability in the gravel bed most likely enabled the root systems to produce new roots, which in turn helped the plants to survive transplanting compared to soil-grown plants. What would be interesting to know is if growing pinyon pine seedlings in a container potting mix that is well aerated could yield similar results to the gravel bed.

Final Part of the Experiment:

The last part of this study involves determining how well gravel-grown or soil-grown plants transplant to the field. Two questions come to mind. First, will the larger root systems on gravel-grown plants enable the corkbark fir and pinyon pine seedlings to survive transplanting to the field better than those plants grown in soil? Second, will seedlings with larger root systems at transplanting time grow faster after one growing season in the field? To answer these questions, 15 gravel-grown and 15 soil-grown fir seedlings were transplanted to a field (soil) in September and October. In addition, 15 gravel-grown and 12 soil-grown pine seedlings were transplanted to a field in October only (due to low available numbers of pinyon pine plants). Plant survival, stem height, and stem diameter will be measured in early August 2005 to determine if gravel bed-grown seedlings transplant better and grow faster than those transplanted from a soil bed.

Significance to the Nursery Industry:

This study has demonstrated that two difficult-to-transplant species, corkbark fir and pinyon pine, can be grown in a gravel bed to produce larger root systems than if the plants had been planted into field soil. Despite disease problems encountered with corkbark fir, transplant survival was similar among seedlings planted field soil or the gravel bed. In contrast, at least double the number of pinyon pine seedlings survived transplanting if grown in the gravel bed compared to field soil. Improved aeration, drainage and moisture availability are most likely the reasons for improved transplant survival and larger root systems of pinyon pine seedlings grown in the gravel bed for one growing season. Still, 23% survival of pinyon pine seedlings grown in the gravel bed is too low for commercial viability. Perhaps root promoting chemicals applied to seedling root systems will improve root regeneration and ultimately transplant survival. Since a gravel bed is a non-conventional growth medium, perhaps a well-aerated potting mix made with softwood bark can be used to promote transplant survival and root system growth of pinyon pine seedlings. I have submitted a proposal to follow up on these potential improvements.