The Influence Of Seed Source And Stock Size On First-Year Performance Of Direct Transplanted Conifer Seedlings[1]

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Abstract

The ability of an organism to survive and grow in an environment is partly controlled by the organism's genotype. The influence of genotype on seedling survival and the large amount of genetic variability within forest tree species has, in part, led the U.S.D.A.-Forest Service, in cooperation with many state forest agencies, to develop seed zones. Seed zone delineation is an attempt to prevent using seedlings from unfit or non-adapted seed sources on a planting project. A current approach in reforestation involves matching planting stock type to site conditions and developing a planting stock with attributes best suited to the site. This system is often referred to as a target seedling system. One target parameter often used is the overall seedling size. The influence of seedling size on reforestation and afforestation success has been well documented. The objectives of this study were to examine the influence of seed source or genotype, and stock size on transplant success of seedlings transplanted directly into overburden piles at the Molycorp Mine in northern New Mexico. Four sources of ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), two northern New Mexico and two southern New Mexico seed sources were evaluated. Seedlings from each seed source were produced in three different container sizes, 16.4 cm^3, 115 cm^3 and 164 cm^3 containers to generate three stock sizes. Two planting sites were used at the mine. The overall study design was a randomized complete block design within an overall split plot design with planting sites being main plots. First year survival and covering of seedlings by overburden movement on the rock pile slopes were recorded. Data were analyzed using categorical model analysis with treatment comparisons utilizing a Bonferroni adjustment to reduce the likelihood of making a Type I error. Overall, survival was low (<35%) with the smallest stock sizes having the lowest survival. Smaller seedlings had greater losses (39%) due to covering than did the mid- and large-size seedlings, 29 and 32%, respectively. Seed source did not influence survival or covering responses.

Additional Key Words: overburden, genetics, seedling size.

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Introduction

The ability for an organism to survive and grow in an environment is partly controlled by the organism's genotype. In terrestrial plant species, including forest tree species, there exists well-documented variation in the genetic make up of members in the population (Zobel and Talbert 1984). Two widely accepted rules governing tree seed movement which apply to this study are: "*Do not move high-elevation or high-latitude sources to low elevations or low latitudes, or the reverse*" and "*Do not plant trees originating on basic soils on acid soils or vice versa*" (both from Zobel and Talbert 1984). These two rules are based on the assumption that adaptation to these two environmental conditions, growing season length and timing, and edaphic conditions are under strong genetic control. The influence of genotype on seedling survival and the large amount of genetic variability within forest tree species has, in part, led the U.S.D.A.-Forest Service, in cooperation with many state forest agencies, to develop seed zones (Harrington et al. 1996a, 1996b). Seed zone delineations are an attempt to prevent the use of seedlings from unfit or non-adapted seed sources in a planting project. Therefore, use of plant material from a given zone on projects within the same zone, should lead to improved success of reforestation efforts. However, in many tree species, including ponderosa pine, the large interval between seed crops may necessitate seedlings from seed outside the area of the planting be used.

A current approach in reforestation involves matching planting stock type to site conditions. This system is often referred to as a target seedling system (Rose et al. 1990). Target attributes are developed based on physiological and/or morphological parameters intrinsic to the seedling, such as root to shoot ratio, seedling size, root growth potential or dormancy intensity. One target parameter often used is the overall seedling size. The influence of seedling size on reforestation and afforestation success has been well documented in the reforestation field (readers are referred to Mexal and Landis 1990 and articles cited therein). One simple way to manipulate seedling size when using container grown stock is by changing container size.

The Questa Molybdenum mine is currently operated as an underground block cave mine and the site is located in the Taos Range of the Sangre de Cristo Mountains, part of the Southern Rocky Mountain physiographic province. The mine is located within an area of high topographic relief, entirely on the south facing slopes along the north side of the Red River Valley. Elevations at the site range from approximately 2518 m to 3300 m. Deeply incised, steep-sided valleys dissect the mine site and surrounding area. The climate is semi-arid with mild summers and cold winters. Precipitation is common throughout the year, with the driest month typically being January and the wettest being August. Long-term average temperature at Red River is 4.2^{o} C according to the National Climate Data Center 1961-1990 records. Distribution of precipitation is variable and varies with elevation but is estimated to average 406 mm at the lower elevations and increases by about 12.7 mm for every 330 m in elevation.

The open-pit mining period occurred between 1964 and 1983. During open pit operations, the mine rock associated with development of the pit was placed in a series of mine rock piles in the vicinity of the open pit. Approximately 328 million tons of mine rock was placed in a series of piles that are tiered against the mountain slopes in the upper reaches of several canyons. Construction of the piles followed standard mining practices at the time. The piles were constructed in lifts created by end dumping over the pile crests. This method of construction results in pile slopes being at their angle of repose between berms or benches. The sequence of pile lift construction was generally from the top down. Bench surfaces were compacted by heavy equipment and trucks.

Objectives

The objectives of this study were: 1) to evaluate the effect of seed source on the survival of ponderosa pine seedlings; and, 2) to evaluate the effect of container size on the survival of ponderosa pine seedlings planted on waste rock piles at the Molycorp, Inc. Questa mine site in north-central New Mexico.

Materials and Methods

This study utilized seedlings generated from four ponderosa pine seed sources from New Mexico. One seed source was from the U.S.D.A. Forest Service seed zone in which the mine is located (U.S.D.A. seed zone 710; (Carson National Forest, northeastern Rio Arriba and north western Taos Counties, New Mexico;); and one from an adjacent seed zone to the west of this seed zone, U.S.D.A. seed zone 620 (Carson National Forest, north-central Rio Arriba County, New Mexico). The other two sources were from more southern seed zones (U.S.D.A. seed zones 170; Gila National Forest, west-central Catron County, New Mexico) and 840 (Lincoln National Forest, Lincoln County, New Mexico).

Seedlings from each of the four seed sources tested were produced in growing containers of three sizes: 16.4 cm^3, 115 cm^3, and 164 cm^3. The 16.4 cm^3 container has a cavity depth of 10.4 cm and cavity top width of 1.6 cm. The 115 cm^3 container has a cavity depth of 12.0 cm and cavity top width of 2.5 cm. The 164 cm^3 container has a cavity depth of 21.0 cm and cavity top width of 2.5 cm. Seedlings were propagated from seed in a greenhouse under a modified greenhouse production regime in the respective treatment containers filled with a 2:1:1 (v:v:v) peat:perlite:vermiculite growing media. General greenhouse conditions included a 16-hour photoperiod (ambient light plus supplemental light from high pressure sodium vapor lamps suspended above the seedlings); day temperatures ranging from 20 to 27^{o}C, night temperatures ranging from 19 to 23 ^{o}C. Seedlings were irrigated as needed. Nutrients were provided by two fertilizer treatments. A resin-coated, slow release fertilizer (Osmocote, 14-14-14, 3-4 month) was incorporated into the media at a rate of 4 kg/ m^3. Secondly, seedlings were fertilized twice weekly with a liquid fertilizer (Peter's 20-20-20 Peat Lite Special) mixed to deliver 100 ppm total N (Harrington 1996c). Four weeks prior to planting, seedlings were moved from the greenhouse to a shade house and received no further liquid fertilizers. This was done to allow the seedlings to acclimate to ambient conditions. Seedlings had set a terminal bud before they were shipped to the planting site.

The seedlings were planted from September 13 to 16, 1993. Planting holes were prepared using a planting bar for the 115 cm^3 and 164 cm^3 sizes and sharpshooter shovel for the 16.4 cm^3 size. Seed source and container size treatments were randomly allocated to each member of the planting crew. This randomization process was repeated for each planting block and was done to remove planter variance from the study. Seedlings received no supplemental irrigation after planting.

The first planting site was approximately 30 meters up the face of the lower front mine rock pile, called the Sulphur Gulch rock pile. This site was quite variable with several rills and a significant amount of large cobble on the surface. The overburden material at this site had a paste pH of greater than 6.0 and a paste TDS of 260 mg/L (SRK 1995). Most of the waste rock was gray in color and in some locations a finer textured substrata was evident. The second planting site was located at the base of the third (from the bottom) bench on the same rock pile. This site was only mildly sloped and had very little large rock. The overburden material at this site had a paste pH of 2.7 and a paste TDS of 1380 mg/L (SRK 1995). The lower, furthest east blocks, were in a highly compacted area. The waste rock at this site was brown to yellow in color.

The treatment design was a factorial design of seed source (four levels), and container size (three levels) and resulted in a total of twelve treatment combinations. The outplanting design was a split plot design with the two main plots being the two planting sites. Each planting site contained six randomized complete blocks. Due to the large planting area involved, blocking was done to account for site variability impacts on survival. Each treatment was represented in each block by a 10-tree row plot.

The response unit was the average survival or presence of overburden covering of the 10-tree row plot of each treatment within each block. Questions of primary interest were examining intrinsic stock attributes of genotype or seed source and seedling size based on container size. Portions of the planting blocks were covered by rock materials moving on the slopes. This was particularly evident at the first planting site. A seedling was considered covered when sufficient materials had been deposited to cover the cotyledon scar on the stem.

Categorical statistical analysis was conducted on the two dichotomous response variables, survival and covering. For each of the response variables a categorical analysis of variance was conducted using the CATMOD procedure in SAS (SAS Institute, 1990) with generalized least squares as the technique for obtaining estimates and concomitant statistics. Test statistics are asymptotic chi-square tests and test hypothesis of equal proportions of surviving (or covered) for the factors: Site; Block within Site; Seed Source; Container Size; Source by Size interactions; Site by Source Interaction; Site by Size interaction; and Site by Source by Size interaction. Null hypotheses were rejected at the significance level of alpha = 0.05. When a chi-square test for a main effect was rejected, asymptotic pairwise Z statistics and their observed significance levels were calculated to test that pairs of levels of the main effect factor were the same. To control the comparison-wise Type I error rate a Bonferroni adjustment was used. This adjustment is more conservative and only will declare differences if the observed significance level is less than 0.05 divided by the number of pairwise comparisons (i.e. 0.05/3 = 0.0166).

Results and Discussion

The planting date coincided with the first frost date. Overall, precipitation during the study period was above average (**see Table 1**). Study-wide survival was low, averaging slightly over 30%. Seed source or provenance did not influence first-year survival even though average survival ranged from 18 to 31% by seed source (**see Table 2 and 3**). However, assessing an exotic seed source's fitness for a site may take more than one year to determine (Zobel and Talbert 1984). This is due, in part, to annual variation in climatic attributes such as early or late frosts. Both the onset of terminal elongation and growth cessation and hardening are linked to environmental signals, primarily chilling units and photoperiod respectively (Kozlowski and Pallardy 1997). For example, seedlings that have satisfied their chilling hour accumulation and initiated growth early in the growing season may be susceptible to late frosts.

The two larger stock sizes, 115 cm^3 and 164 cm^3, had better survival relative to the smaller stock size evaluated (**see Tables 2 and 4**). The relationship of transplant (seedling) size and early survival has been examined extensively in the reforestation field. Published reports on the influence of stock size on survival vary in response to this effect ranging from no effect (Patterson 1991, Maiers 1997) to improved survival of larger stock (Amidon et al. 1981, Endean and Hocking 1972, Helgerson et al. 1989, Rose et al. 1991, Maiers 1997). The influence of site limitations can play an important role in this relationship. In a traditional reforestation situation, larger stock may have an advantage if site preparation activities were insufficient to control the competing vegetation (Helgerson et al. 1992, Maiers 1997, Maiers and Harrington 1999). If competing vegetation is adequately controlled, the advantage of the larger stock may be negated (Maiers and Harrington 1999). In this study, the larger seedlings may have been more suited to the site, in that they were less susceptible to losses due to covering (**see Tables 5 and 6**), and possibly better able to access deeper soil moisture. Seedling shoot heights for seedlings produced in the 16.4 cm^3 containers were between 8 and 10 cm whereas seedling shoot heights ranged from 13 to 18 cm in the larger two containers. Seedlings produced in the larger containers also had larger root collar diameters (caliper; 2.2 mm) than the seedlings produced in the smaller containers (1.6 mm). Both of these features, shoot height and caliper may impart greater resistance or tolerance to covering. In subsequent studies on this site, both on benches and pile faces, losses due to covering have been appreciably less (Harrington et al. 2000, Harrington and Dreesen unpublished data). These subsequent studies have relied on the 164 cm^3 and larger planting stock that may explain the reduction in covering losses.

Table 1: Average monthly precipitation for Red River, New Mexico and the monthly precipitation for the 12 months spanning this study

Month	Average Monthly Precipitation (mm)	1993/1994 Monthly Precipitation (mm)
August (93)	80.8	160.8
September	42.2	30.7

Table 1: Average monthly precipitation for Red River, New Mexico and the monthly precipitation for the 12 months spanning this study

Month	Average Monthly Precipitation (mm)	1993/1994 Monthly Precipitation (mm)
October	37.6	32.5
November	32.3	44.5
December	29.5	20.6
January (94)	26.9	22.9
February	28.4	41.4
March	42.9	72.9
April	40.1	99.8
May	46.0	75.7
June	35.6	34.5
July	66.5	42.7
August	80.8	109.0

Table 2: Categorical analysis of variance table for survival response for ponderosa pine seedlings grown in different size containers planted on overburden at the Molycorp, Inc. Mine in north-central New Mexico

Source	df	Chi- Square	Observed Probability
Intercept	1	52.27	0.0000
Site	1	3.00	0.0834
Block (Site)	9*	43.24	0.0000
Source	3	3.98	0.2632
Size	2	32.60	0.0000
Source*Size	6	3.38	0.7597
Site*Source	3	0.82	0.8437
Site*Size	2	0.32	0.8505
Site*Source*Size	6	3.04	0.8041
Residual	99	70.40	0.9868

* Block (Site) contains one or more redundant or restricted parameters.

Table 3: The influence of seed source on ponderosa pine seedling survival planted on overburden piles at the Molycorp Inc. Questa Mine. (Means are not significantly different at $\alpha = 0.05$).

Seed Source (Seed Zone)	Mean Survival Percentage ($\pm$ S.E.)
710	22.1 ± 2.8
620	30.8 ± 3.1
170	17.7 ± 2.6
840	25.0 ± 2.9

Table 4: The influence of stock size on ponderosa pine seedling survival planted on overburden piles at the Molycorp Inc. Questa Mine. (Means followed by the same letter are not significantly different at $\alpha = 0.05$).

Stock Size (cm^3)	Mean Survival Percentage ($\pm$ S.E.)
16.4	5.6 $\pm$ 1.4 a
115.0	31.5 $\pm$ 2.6 b
164.0	32.6 $\pm$ 2.7 b

Table 5: Categorical analysis of variance table for covering response for ponderosa pine seedlings grown in different size containers planted on overburden at the Molycorp, Inc. Mine in north-central New Mexico.

Source	df	Chi- Square	Observed Probability
Intercept	1	58.17	0.0000
Site	1	29.29	0.0000
Block (Site)	9*	105.45	0.0000
Source	3	1.40	0.7054
Size	2	11.13	0.0038
Source*Size	6	5.29	0.5072
Site*Source	3	1.50	0.6816
Site*Size	2	4.03	0.1334
Site*Source* Size	6	3.94	0.6852
Residual	99	63.54	0.9979

* - Block (Site) contains one or more redundant or restricted parameters.

Table 6: The influence of stock size on ponderosa pine covering planted on overburden piles at the Molycorp Inc. Questa Mine site. (Means followed by the same letter are not significantly different at $\alpha = 0.05$).

Stock Size (cm^3)	Mean Survival Percentage ($\pm$ S.E.)
16.4	39.3 $\pm$ 2.3 a
115.0	29.3 $\pm$ 2.2 b
165.0	31.6 $\pm$ 2.2 b

Planting site also influenced the covering response observed in this study (**see Table 5**). Planting site 1, located in the middle of the face of the rock pile had greater losses attributed to covering (42 $\pm$ 1.8%) than did the other, flatter planting site (22 $\pm$ 1.7%). While not monitored as part of this study, it appears some of the material deposited on the seedlings came from two primary processes, surface movement and equipment activities on the pile faces above the planting sites. Surface movement refers to the downward movement of gravel sized and smaller materials due to climatic forces, most likely during heavy rain events. It was observed that other work being performed above the planting site resulted in larger materials being dislodged and rolling down the pile faces. While not measured, it was evident that some of the covering losses observed were due to materials larger than the gravel sized particles that are not associated with erosional surface movement. The larger two seedlings sizes had shoot attributes, taller and more robust stems, which may have allowed them to withstand some particle deposition more so than the seedlings produced in the smaller container.

Conclusions

Movement of surface rock materials on this site, regardless of the origin, necessitates the use of planting stock of sufficient size to tolerate this movement or it requires measures be taken to reduce the movement of material. The results of this study indicate that larger stock sizes, greater than 115 cm^3, will be required for direct planting of seedlings on this site under current conditions. A balance that must be achieved will be between a seedling that has adequate shoot height and sturdiness to withstand the surface particle movements that can occur on this site, while still remaining small enough to plant economically. Additionally, early results indicate that stock produced with seed from sources near the mine site and further south in the state can survive when planted directly into the overburden. However, the recommendation of using the two southerly seed sources evaluated in this study at this site must be preliminary, in that the climate from only one growing season was evaluated. First-year survival is an early measure in terms of provenance evaluation in trees but subsequent evaluations of the materials surviving after one-year will either support or negate this claim.

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