ROOTING DEPTH OF 3 YEAR OLD SEEDLINGS INTO OVERBURDEN PILES AT A HIGH ELEVATION HARD ROCK MINE[1]

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Abstract: A series of tree survival test plots were established to examine tree survival rates on high elevation overburden piles. The removal of one of these plots, to allow further mining of the underlying material, created the opportunity to evaluate the rooting success of the tree species. It was hypothesized that roots would not be able to penetrate the overburden due to the chemical properties and compaction of the material. After 3 years there was no difference in rooting depth for the trees given different topdressing depths. All of the species exhibited the ability to root beyond the topdressing and follow water into the overburden.

Additional Key Words: reforestation, high altitude reclamation

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Introduction

In 2003, test plots were constructed at the Molycorp Mine in Questa, NM to evaluate various treatments affecting the survival of important tree and shrub species. The test plots included platforms (flat areas), 3:1 slopes and 2:1 slopes and were planted with species to be used in the reclamation of overburden piles at the mine. Treatments on each platform plot included 0, 30.5, and 91.4 cm of cover material application and both drill and hydro seeding methods. Each plot was ripped or chiseled to a depth of approximately 30.5 cm before planting.

The seedlings planted in late 2003 were evaluated in the middle of the growing seasons (July) of 2004, 2005, and 2006. Seedlings were evaluated by 3 groups of interest: 1) nurse trees (aspen, cottonwood and locust), 2) crop trees (various conifers) and 3) shrubs (various shrubs). Little is known about the ability of these plants to develop sufficient root systems to penetrate beyond the cover material into the overburden piles. Ashby (1997) found that on a reclaimed surface coal mine, above-ground tree height was increased by alleviating soil compaction with ripping to a depth of 1.2 m. However he did not examine the growth of the roots themselves. Thompson et al. (1987) found that penetrometer resistance and bulk density were both reliable predictors of the ability (or the inability) of roots to reach a given soil depth.

Methods

Site Selection

The first study site sampled was the platform plot B-10, which is located on the south edge of the mine. The site is the top of an overburden pile that was scheduled to be excavated in winter 2006. Previously collected data indicated that the B-10 plot had lower tree survival rates than the other platform plots (29.8% compared to 49.8% overall). The majority of the base rock pile material is chemically suitable for trees and shrubs, so was not expected to chemically restrict root growth.

To gain information about the rooting of trees on steep slopes (approximately 1.3:1 or 37˚) over a longer time period, a second site was chosen on the south-facing top of the adjacent outslope. The trees and shrubs in this area were planted approximately 10 years before this study.

Plant Selection and Data Collection

For the B-10 plot, a sample of plants to be excavated was chosen by convenience and by perceived exemplary characteristics for each species. Where non-exemplary individuals were located in close proximity to the excavated individuals, in some cases these were also excavated. This "targeted" sample selection prevents the interpretation of these results beyond an exploratory study of a convenience sample of plant individuals. Qualitative observations during the selection and excavation of these individual plants indicated that although the samples selected were exemplary above ground, they did not appear significantly different below ground than the less exemplary individuals.

A trackhoe was used to dig pits in the vicinity of the targeted plants. Great care was taken to ensure that none of the root mass was disturbed by the machinery. After a pit was dug, hand tools were used to remove the material around the target plant's roots. When possible, additional plants were excavated in the vicinity of the target plant. The data recorded for each specimen included species name, above-ground height, and deepest depth of rooting. Photographs were

taken of each individual to demonstrate the depth and path of the roots. A few videos were also taken to explain the root movement given the subsurface material composition and structure.

Trees excavated at the outslope of the overburden pile slope were removed and documented in a similar manner to those in the B-10 plot. When available, the trackhoe removed a "bench" below the target plants, and the remaining material was removed with hand tools. When the trackhoe was unavailable, the tree or shrub was excavated entirely with hand tools. The data recorded for each specimen included species name, above-ground height, and deepest depth of rooting. Due to the steep nature of the slope, the rooting depth was measured in one of two ways. Where roots ran perpendicularly to the slope, the deepest rooting depth was directly measured (D_d). Where roots ran parallel to the slope, the length of the root along the slope was measured and recorded, and the theoretical depth (D_t) was estimated by measuring the vertical distance traveled by the root. Where roots ran parallel to the slope, the depth from the surface (D_s) did not exceed 30.5 cm.

Statistical Analysis

Analysis of variance (ANOVA) and unpaired t-tests were conducted to determine if the different species classes and treatments had a statistically significant effect on the rooting depth.

Results

B-10 Plot

Forty samples representing 14 different species were excavated from the B-10 plot. Without controlling for species class or cover treatment, the plants had an overall mean above-ground height of 23.4 cm (SD = 11.7) and a mean rooting depth of 47.0 cm (SD = 23.4). Summary statistics for these plants appear in Tables 1 and 2. The depth of rooting varied based on the species class (crop, nurse, and shrub) (Table 1) and on the cover treatment (Table 2).

Table 1. Species class means for the B-10 plot.

Species class		Above-ground height (cm)	Below-ground depth (cm)
Crop	Mean	26.7	36.1
	SD	9.9	12.4
Nurse	Mean	23.4	50.3
	SD	12.4	29.0
Shrub	Mean	21.1	55.9
	SD	12.4	25.7

Table 2. B-10 sample means by cover depth.

		Above-ground height (cm)	Below-ground depth (cm)
0" Cover	Mean	15.7	54.6
	SD	7.9	24.9
1" Cover	Mean	30.7	51.1
	SD	13.5	33.5
3" Cover	Mean	24.6	39.6
	SD	10.2	11.4

Results from the t-tests performed on these data indicated that only the shrub species had significantly different mean rooting depths from the crop species ($p = 0.01$) (Table 3). These t-tests also showed that the 0 and 30.5 cm covers had significantly different rooting depths than the 3' cover treatment ($p = 0.03$ and $p = 0.07$ respectively). No statistically significant difference existed between the above-ground heights based on the species classes. When the cover treatments were considered, the 0 cm cover had significantly lower above-ground heights than the 30.5 and 91.4 cm covers ($p < 0.01$ and $p < 0.01$ respectively), but there was no difference between the 30.5 and 91.4 cm covers (Table 3).

Table 3. Results of t-tests for the B-10 plot.

Rooting depth	t	df	p- value
Crop vs nurse	1.6686	22	0.1094
Crop vs shrub	2.6926	28	0.0118
Nurse vs shrub	0.5049	22	0.6186
0 vs 30.5 cm cover	0.3029	20	0.7651
0 vs 91.4 cm cover	2.2545	28	0.0322
30.5 vs 91.4 cm cover	1.8751	26	0.0721

Above-ground height	t	df	p- value
Crop vs nurse	0.7041	22	0.4888
Crop vs shrub	1.3534	28	0.1867
Nurse vs shrub	0.4417	22	0.6630
0 vs 30.5 cm cover	3.233	20	0.0042
0 vs 91.4 cm cover	2.5466	28	0.0017
30.5 vs 91.4 cm cover	1.3536	26	0.1875

ANOVA results indicated that above-ground height, cover depth, and species class were significantly related to the rooting depth ($R^2 = 0.87$) (Table 4). When the above-ground height

was excluded from the ANOVA, the cover depth remained statistically significant and the species class fell from statistical significance ($p = 0.15$, $R^2 = 0.84$) (Table 5).

Table 4. ANOVA results for the B-10 plots.

Dependent variable - rooting depth					
Source	SS	df	MS	F	Prob > F
Model	14435.6339	6	2405.939	36.09	0.0000
above-ground height	456.4170	1	456.417	6.85	0.0133
cover	482.9643	3	160.988	2.41	0.0841
species class	404.5490	2	202.274	3.03	0.0617
Residual	2199.8662	33	66.663		
Total	16635.5000	39	426.551		
n	39				
Root MSE	8.1647				
R-squared	0.8678				
adjusted R-squared	0.8437				

Table 5. ANOVA results for the B-10 plots.

Dependent variable - rooting depth					
Source	SS	df	MS	F	Prob > F
Model	13979.2169	5	2795.843	35.79	0.0000
cover	3176.7557	3	1058.919	13.55	0.0000
species class	318.5710	2	159.286	2.04	0.1458
Residual	2656.2832	34	78.126		
Total	16635.5000	39	426.551		
n	39				
Root MSE	8.8389				
R-squared	0.8403				
adjusted R-squared	0.8168				

Qualitative observations from the extraction of the B-10 samples indicated that the roots could penetrate the unripped subsurface material. Often the roots followed the subsurface layer horizontally until they hit a coarse fragment or other obstruction that allowed for downward water movement. The roots tended to follow these water channels through the compacted layer.

Overburden

Twelve samples representing 7 different species were excavated from the top of the outslope of the overburden pile (Table 6). Two of the root samples were destroyed in the process of excavation. The overall above-ground height and rooting depth of the remaining 10 complete samples were 42.2 cm (SD = 31.5) and 86.6 cm (SD = 43.7) respectively. The majority of the species extracted (70%) fell into the crop species category. These had a mean height of 42.7 cm (SD = 37.1) above ground and a depth of 94.7 cm (SD = 48.5) below ground. There was only 1 nurse species, and it had an above-ground height of 38.1 cm and a below-ground depth of 91.4 cm. The two shrubs extracted had an above-ground mean height of 41.9 cm (SD = 26.9) and a below-ground mean depth of 55.9 cm (SD = 28.7).

Table 6. Sample data for the outslope.

Name	Above-ground height (cm)	Below-ground depth (cm)
Populus angustifolia	124.5	182.9
Pinus ponderosa	33.0	61.0
Artemisia frigida	22.9	35.6
Pseudotsuga menziesii	19.1	50.8
Pinus ponderosa	38.1	139.7
Robinia neomexicana	38.1	91.4
Pseudotsuga menziesii	17.8	71.1
Cercocarpus montanus	61.0	76.2
Pinus edulis	27.9	71.1
Pinus ponderosa	38.1	84.6
Mean	42.2	86.6
Standard Deviation	31.5	43.7

Pearson's correlation coefficient for these data was r = 0.82. ANOVA results suggested that both the species class and the above-ground height were significantly related to the rooting depth (Table 7). Even with a limited number of samples (10) and only a few specimens of each species, these results proved to be significant ($p < 0.01$, $R^2 = 0.96$).

Conclusion

Rooting of the tree and shrub species did not appear to be limited by the subsurface conditions of the B-10 and overburden root excavation sites. Qualitative observations of individual plants indicated that although they were exemplary above ground, they were not observationally different below ground from individuals that appeared less exemplary above ground.

Quantitative analysis revealed that cover depth was significantly associated with rooting depth: the samples from the 30.5 cm cover had significantly different rooting depths from the 0 and 91.4 cm cover treatments. Inferences about the other treatments and the species classes

(crop, nurse, and shrub) were restricted by our recognition of the limitations of the sample selection process and the conditions of the site.

Table 7. ANOVA results for the outslope.

Dependent variable - height above ground					
Source	SS	df	MS	F	Prob > F
Model	13768.7605	4	3442.190	38.80	0.0002
class	1159.0046	3	386.335	4.36	0.0595
Above-ground height	1773.1891	1	1773.189	19.99	0.0042
Residual	532.2395	6	88.707		
Total	14301.0000	10	1430.100		
n	10				
Root MSE	9.4184				
R-squared	0.9628				
adjusted R-squared	0.9380				

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