FIFTH YEAR TRANSPLANT SURVIVAL ON CONSTRUCTED TEST PLOTS, QUESTA MINE, QUESTA, NEW MEXICO[1]

Anne Wagner, Jeff Sanders, Bruce Buchanan, Edward Redente, Joshua Voss and Bryce Young[2]

Abstract: Chevron Mining Inc. established a revegetation test plot program to evaluate the potential cover depth, soil amendment, and planting treatments for reclamation of the Questa Mine rock piles. The Questa Mine is located near the Village of Questa, New Mexico at an elevation of approximately 2438 m. The test plot program consisted of constructing multiple test plots on 3 slope gradients: 3 horizontal units to 1 vertical unit (3h:1v slope gradient), 2h:1v slope gradient, and flat gradient (platform) test plots. Each test plot was constructed with 3 cover soil depth treatments over the existing rock pile material. These cover soil depth treatments included: no cover, 30 cm, and 90 cm of cover soil material. Soil amendment treatments varied between the sloped and flat gradient test plots. The sloped gradient test plots received treatments of forest soil mycorrhizal inoculant or no inoculant. The flat gradient test plots received treatments of phosphate fertilizer, forest soil mycorrhizal inoculant, or no amendment. After construction, each test plot was seeded, hydromulched, and planted with transplant tree and shrub seedlings. The transplanted tree seedlings consisted of 2 categories: nurse species and crop species. The nurse species consisted of fast establishing, short-lived species, which will shade and protect the crop species. The crop species consisted of multiple conifer species, which represent the post-mining land use plant community. The crop and shrub species were planted at a constant density, while the nurse species were planted at 2 different densities. Overall survival of all seedlings (2008) for platforms, 3h:1v, and 2h:1v slopes was 47%, 44%, and 46% respectively. Of all the treatments applied to the test plots, the one that consistently made a significant difference in survival was the depth of cover soil. The overall survival of all seedlings in 2008 for 0, 30, and 90 cm covers was 22%, 59%, and 58% respectively.

Additional Key Words: Revegetation, reforestation, high altitude reclamation, transplant establishment, soil amendments, inoculant, and cover soil depth.

---

[1] Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, ***Revitalizing the Environment: Proven Solutions and Innovative Approaches*** May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

[2] Anne Wagner, Chevron Mining Inc., Questa, NM 87556; Jeff Sanders, Chevron Mining Inc., Questa, NM 87556; Bruce Buchanan, Buchanan Consultants, Ltd., Farmington, NM 87499; Edward Redente, MWH Americas, Inc., Fort Collins, CO 80525; Joshua Voss and Bryce Young, Buchanan Consultants, Ltd., Farmington, NM 87499.

Proceedings America Society of Mining and Reclamation, 2009 pp 1483-1495
DOI: 10.21000/JASMR09011483
http://dx.doi.org/10.21000/JASMR09011483

INTRODUCTION

Chevron Mining Inc. (CMI) owns and operates the Questa Mine, which is located approximately 3 miles east of Questa, New Mexico at an elevation of approximately 2438 m. The post-mining land use for this site is forestry; therefore numerous studies have been conducted to investigate revegetation technologies and approaches. A study was initiated in 2003 to evaluate the effects of cover soil depth, soil amendments, and planting densities on tree and shrub seedling survival on rock piles. The rock piles were created from removal of overburden during open pit operations from 1965 to 1983. This paper presents the fifth-year seedling survival results from the study plots.

The reclamation standard at this site is a woody plant density of at least 791 stems/ha measured after a minimum of 12 years. This total must be comprised of at least two conifers at a density of 544 stems/ha and a mixture of four species of deciduous trees and shrubs at 247 stems/ha. It is anticipated that only a certain percentage of the seedlings planted will survive. Once the survival rates are known, then planting densities of seedlings can be calculated to meet or exceed the reclamation standard. This study provides survival data for 17 species of trees and shrubs on various treatments and provides CMI additional information for planning the appropriate planting densities and treatments needed to successfully reclaim the mine site and meet the post-mine land use.

METHODS AND MATERIALS

Test Plot Construction

Sites for the test plots were selected based on elevation, aspect, and access for construction. The sloped plots were constructed by regrading selected areas on the rock piles to the designed subgrade elevation and slope. Three slope gradients were used in the study: 3 horizontal units to 1 vertical unit (3h:1v) slope gradients, 2h:1v slope gradients, and flat gradients (platforms). Nine 3h:1v plots, six 2h:1v plots, and 5 platform plots were constructed for a total of 20 test plots. The 3h:1v plots are each 89.3 m x 53.6 m, the 2h:1v plots are each 65.5 m x 53.6 m, and the platform plots are each 45.7 m x 53.6 m.

Once constructed, the test plots were covered with 3 cover soil depth treatments: no cover (0 cm), 30 cm, and 90 cm. The cover soil material was excavated from near-pH-neutral apalite and black andesite rock fragments (< 20 cm diameter) from the Spring Gulch rock pile (Table 1).

The platform test plots received three soil amendment treatments: control (no soil amendments), forest soil mycorrhizal inoculant (1121 kg/ha), and fertilizer (67 kg P_2O_5/ha). The sloped test plots received 2 amendment treatments: control (no soil amendment) and mycorrhizal inoculant (1121 kg/ha), which was screened soil from a nearby, previously undisturbed site. The soil amendment treatments were incorporated into the cover soil treatments by ripping furrows 30.5 cm deep and 45.7 cm apart with a bulldozer. The treatments were ripped in one direction due to space restrictions and to minimize the possibility of contamination of the neighboring treatments (Golder 2004).

Table 1. Physio-chemical Properties for Spring Gulch Cover Soil (adapted from Golder, 2004).

			< 2 mm Fraction			Coarse	Organic			
	pH	EC dS/m	Sand % wt.	Silt % wt.	Clay % wt.	Fragments % wt.	Matter %	Nitrate ppm	Phosphorus ppm	Potassium ppm
Max	8.2	5.78	57	15	5	98	0.90	3.9	22.9	173
Min	7.1	0.32	77	27	18	53	0.04	<1	1.0	24
Mean	7.6	1.34	69	20	11	80	0.35	1.9	4.5	62

Between late October and early November 2003, the plots were planted with tree and shrub seedlings. The species were grouped into three seedling classes based on their desired reclamation purpose: 1) nurse species, 2) crop species, and 3) shrub species. The nurse species were chosen as fast-growing species, which would, overtime, provide shade and wind cover for the crop trees, and in some cases are nitrogen fixers. The crop species are conifers that are present in the mature forest surrounding the mine site. The shrub species provide understory growth and a wildlife food source in the final reclamation plant community (Golder, 2004). The common name, scientific name, and class of each species planted are presented in Table 2.

The nurse seedlings were planted at two densities: an A planting density (approximately 1625 seedlings/ha) and B planting density (approximately 3250 seedlings/ha). The crop seedlings were planted at approximately 805 seedlings/ha on all plots, and the shrubs were planted at approximately 520 seedlings/ha on all plots. The nurse trees on the platform test plots were planted using only the A planting density, while the sloped test plots were planted with both the A and B nurse seedling densities. On the sloped plots, each cover soil depth treatment was split in half along the length (down slope) of the test plot. One-half of the depth treatment was planted with the A planting density, while the other half was planted with the B planting density.

Table 2. Tree and Shrub Species Transplanted on Test Plots at the Questa Mine Site.

Class	Common Name	Scientific Name
Nurse	Narrowleaf cottonwood	*Populus angustifolia*
	New Mexico locust	*Robinia neomexicana*
	Quaking aspen	*Populus tremuloides*
Crop	Ponderosa pine	*Pinus ponderosa*
	Southwestern white pine	*Pinus strobiformis*
	Douglas-fir	*Pseudotsuga menzesi*
	Piñon pine	*Pinus edulis*
	Engelmann spruce	*Picea engelmanni*
	Limber pine	*Pinus flexilis*
Shrub	Big sagebrush	*Artemisia tridentata* ssp. *tridentata*
	Rubber rabbitbrush	*Ericameria nauseosa*
	Apache plume	*Fallugia paradoxa*
	Woods' rose	*Rosa woodsii*
	Mountain mahogany	*Cercocarpus montanus*
	Fourwing saltbush	*Atriplex canescens*
	Gambel oak	*Quercus gambelii*
	Scouler's willow	*Salix scouleriana*

Monitoring Parameters

Within each treatment the following monitoring parameters were recorded:

- Number of seedlings planted (measured)
- Number of seedlings alive (measured)
- Survival rate (calculated)

Platform Test Plots

A complete population count of all seedlings was collected for the 18 subplots (2 seedling density treatments, 3 soil amendment treatments, and 3 cover soil depth treatments) within each platform test plot. This count consisted of identifying and marking all planted seedlings with pin flags. These data were compared to notes recorded during planting to ensure that all planted seedlings were documented.

Sloped Test Plots

A sample count of the seedlings for the sloped plots was conducted using a circular sample plot with a 3.7-m radius (42.0 m^2). Each sloped test plot had 12 subplots (2 seedling density treatments, 2 soil amendment treatments, and 3 cover soil depth treatments). Prior to sampling, each subplot was divided into evenly spaced sections oriented along the length of the plot. The 3h:1v test plot subplots were divided into 5 sections, and the 2h:1v test plot subplots were divided into 4 sections. Three of the 5 sections from the 3h:1v subplots and 2 of the 4 sections from the 2h:1v subplots were randomly chosen for sampling. These same sections have remained as the permanent sample plots. The section center points were established on the subplot and recorded with a mapping-grade Trimble Pro-XL global positioning system receiver for future studies.

Data Analysis

Tree and shrub survival was calculated as the number of seedlings surviving divided by the number planted in a treatment. The mean survival for each treatment was calculated and then the treatments were compared using either an analysis of variance (ANOVA) or a t-test (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Platform Test Plots

A total of 3093 trees and shrubs were planted on the 5 platform test plots, and the total number surviving after 5 years was 1453, or 47.0%. Seedlings on the 30 (59.9%) and 90 cm cover depths (55.1%) had significantly greater survival than on the 0 cm cover (26.8%) ($p<0.01$), and there was no difference in survival between 30 and 90 cm cover depths. There was no difference between the mean survival rates of seedlings on the three soil amendments: control (45.8%), inoculant (47.7%), and fertilizer (48.4%) (Table 3).

Nurse Species. A total of 1645 nurse trees were planted on the 5 platform test plots, and the total number surviving after 5 years was 964, or 58.6%. Seedling survival on the 30 (73.2%) and 90 cm (70.8%) covers was significantly greater than 0 cm cover depth (32.0%) ($p<0.01$), and there was no difference in survival between 30 and 90 cm cover depths. There was no difference between the mean survival rates of seedlings on the 3 soil amendments: control (60.4%), inoculant (60.7%), and fertilizer (55.0%) (Table 3).

Table 3. Platform Test Plot Mean survival rates, Questa Mine, New Mexico, 2008.

Treatment	All species		Nurse species		Crop species		Shrub species	
	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD
Cover depth								
0 cm cover	26.8 a	27.1	32.0 a	35.8	24.2 a	16.2	16.4 a	21.4
30 cm cover	59.9 b	13.5	73.2 b	16.4	42.7 b	19.5	48.5 b	17.1
90 cm cover	55.1 b	10.3	70.8 b	12.4	33.4 ab	18.9	41.6 b	9.9
p-value	p<0.01		p<0.01		p=0.03		p<0.01	
Soil amendments								
Control	45.8 a	20.5	60.4 a	27.8	27.7 a	17.1	35.2 a	23.4
Inoculant	47.7 a	24.8	60.7 a	33.3	31.2 a	16.7	33.9 a	19.8
Fertilizer	48.4 a	25.9	55.0 a	30.8	41.5 a	22.5	37.5 a	22.8
p-value	p=0.95		p=0.85		p=0.13		p=0.90	

[1] Treatment means followed by the same letter are not significantly different

Crop Species. A total of 839 crop trees were planted on the 5 platform test plots, and the total number surviving after 5 years was 278, or 33.1%. There was no difference in mean survival between the 30 (42.7%) and 90 cm (33.4%) cover depths, nor was there a difference between the 0 (24.2%) and 90 cm cover depths; however, the survival on the 30 cm cover depth was greater than on the 0 cm cover (p=0.02). There was no difference between the mean survival rates of seedlings on the 3 soil amendments: control (27.7%), inoculant (31.2%), and fertilizer (41.5%) (Table 3).

Shrub Species. A total of 609 shrubs were planted on the 5 platform test plots, and the total number surviving after 5 years was 211, or 34.7%. Shrub seedling survival on the 30 (48.5%) and 90 cm (41.6%) cover depths was significantly greater than on the 0 cm cover (16.4%) (p<0.01), and there was no difference in seedling survival on the 30 and 90 cm cover depths. There was no difference between the mean survival rates of seedlings on the 3 soil amendments: control (35.2%), inoculant (33.9%), and fertilizer (37.5%) (Table 3).

The survival rate of the 17 seedling species on the platform plots varied widely. In general, most species had poor survival on the 0 cm cover and conversely, most did well on the 30 and 90 cm cover depths. All of the nurse species averaged better than 50% survival on the 30 and 90 cm cover depths, and similarly 2 crop species (southwestern white pine and limber pine) and 2 shrub

species (mountain mahogany and Woods' rose) averaged better than 50% survival. One crop species (piñon pine) and one shrub (fourwing saltbush) survived at less than 10% on all cover depths (Table 4).

Table 4. Survival Rates of Seedling Species by Cover Depth on the Platform Test Plots, Questa Mine, New Mexico, 2008.

				Survival by Cover Depth (%)		
Class	Species	Planted	Alive	0 cm	30 cm	90 cm
Nurse	Narrowleaf cottonwood	1077	617	31.7	72.0	68.1
	New Mexico locust	380	254	35.7	79.8	79.5
	Quaking aspen	188	101	35.9	65.0	60.9
Crop	Ponderosa pine	172	50	19.3	37.3	30.4
	Southwestern white pine	184	83	33.3	59.4	42.1
	Piñon pine	138	8	8.5	4.3	4.5
	Limber pine	192	97	35.4	62.5	54.0
	Englemann spruce	106	27	21.6	36.4	19.4
	Douglas-fir	47	13	0.0	50.0	42.9
Shrub	Big sagebrush	78	11	7.7	25.0	8.3
	Fourwing saltbush	61	0	0.0	0.0	0.0
	Mountain mahogany	79	51	34.6	77.8	80.8
	Rubber rabbitbrush	76	21	23.1	34.8	25.9
	Apache plume	74	21	7.1	45.8	36.4
	Gambel oak	57	18	20.0	35.0	41.2
	Woods' rose	77	56	40.7	88.5	91.7
	Scouler's willow	107	33	13.5	47.1	33.3

3h:1v Sloped Test Plots. A total of 3917 trees and shrubs were planted on the nine 3h:1v sloped test plots, and the total number surviving after 5 years was 1781, or 45.5%. Seedlings on the 30 (56.8%) and 90 cm (53.3%) cover depths had significantly greater survival than on the 0 cm cover (22.6%) ($p<0.01$), and there was no difference in seedling survival on the 30 and 90 cm covers. There was no difference in the mean survival rates of seedlings on inoculant (45.3%) and no-inoculant (43.0%) plots. There was no difference in the mean survival rates of seedlings at planting densities A (44.5%) and B (43.8%) (Table 5).

Table 5. 3h:1v Sloped Test Plot Mean Survival Rates, Questa Mine, New Mexico, 2008.

Treatment	All species		Nurse species		Crop species		Shrub species	
	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD
Cover depth								
0 cm cover	22.6 a	28.0	25.0 a	32.2	20.4 a	31.5	16.0 a	32.8
30 cm cover	56.8 b	19.7	67.0 b	27.5	34.7 b	33	45.8 b	39.6
90 cm cover	53.3 b	21.0	63.0 b	26	36.2 b	31.3	35.3 b	37.8
p-value	p<0.01		p<0.01		p<0.01		p<0.01	
Soil amendments								
No inoculant	43.0 a	26.8	50.7 a	33.4	27.2 a	31.9	34.5 a	39.8
Inoculant	45.3 a	28.8	52.6 a	35.4	33.7 b	33.1	31.2 a	37.8
p-value	p=0.23		p=0.31		p=0.04		p=0.25	
Planting Density								
A Planting	44.5 a	26.1	52.8 a	33.2	30.7 a	32.5	39.2 a	40.3
B Planting	43.8 a	29.4	50.5 a	35.5	30.2 a	32.8	27.0 b	36.5
p-value	p=0.40		p=0.27		p=0.44		p<0.01	

[1] Treatment means followed by the same letter are not significantly different

Nurse Species. A total of 2486 nurse trees were planted on the nine 3h:1v sloped test plots, and the total number surviving after 5 years was 1313, or 52.8%. Seedlings on the 30 (67.0%) and 90 cm (63.0%) cover depths had significantly greater survival than on the 0 cm cover (25.0%) ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. There was no difference in the mean survival rates of seedlings on the inoculant (52.6%) and no inoculant (50.7%) plots. There was no difference in the mean survival rates of seedlings at planting densities A (52.8%) and B (50.5%) (Table 5).

Crop Species. A total of 926 crop trees were planted on the nine 3h:1v sloped test plots, and the total number surviving after 5 years was 290, or 31.3%. Seedlings on the 30 (34.7%) and 90 cm (36.2%) cover depths had significantly greater survival than on the 0 cm (20.4%) ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. The mean survival rate of seedlings on plots with inoculant (33.7%) was significantly greater than plots with no inoculant (27.2%) ($p=0.04$). There was no difference in the mean survival rates of seedlings at planting densities A (30.7%) and B (30.2%) ($p=0.44$) (Table 5).

Shrub Species. A total of 505 shrubs were planted on the nine 3h:1v sloped test plots, and the total number surviving after 5 years was 178, or 35.3%. Seedlings on the 30 (45.8%) and 90 cm (35.3%) cover depths had significantly greater survival than on the 0 cm cover depth (16.0%) ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. There was no difference in the mean survival rates of seedlings between inoculant (31.2%) and no-inoculant (34.5%) plots. The mean survival rate of seedlings on plots with planting density A (39.2%) was significantly greater than plots with planting density B (27.0%) ($p<0.01$) (Table 5).

The survival rate of the 17 seedling species on the 3h:1v sloped plots varied widely. In general, most species had poor survival on the 0 cm cover depth and conversely, most did well on the 30 and 90 cm cover depths. All of the nurse species averaged better than 50% survival on the 30 and 90 cm cover depths, and similarly 1 crop species (limber pine) and 2 shrub species (mountain mahogany and Woods' rose) averaged better than 50% survival. One crop species (piñon pine) had survival of less than 10% on the 0 cm and 90 cm cover depths and survival of only 10.6% on the 30 cm cover depth. Two shrubs (big sagebrush and fourwing saltbush) had survival of less than 10% on all 3-cover depths. Rubber rabbitbrush had survival of less than 10% on the 0 cm and 90 cm cover depths and only 12.0% on the 30 cm cover depth. Gambel oak and Scouler's willow each had only 1 seedling planted (which subsequently died), so their survival is 0% (Table 6).

2h:1v Sloped Test Plots. A total of 1734 trees and shrubs were planted on the six 2h:1v sloped test plots, and the total number surviving after 5 years was 833, or 48.0%. Seedlings on the 30 (58.8%) and 90 cm (58.4%) cover depths had significantly greater survival than on the 0 cm (21.9%) cover ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. The mean survival rate of seedlings on plots with inoculant (50.9%) was significantly greater than plots with no inoculant (41.7%) ($p=0.03$). There was no difference in the mean survival rates of seedlings at planting densities A (46.0%) and B (46.6%) (Table 7).

Table 6. Survival Rates of Planted Seedling Species on the 3h:1v Sloped Test Plots, Questa Mine, New Mexico, 2008.

				Survival by Cover Depth (%)		
Class	Species	Planted	Alive	0 cm	30 cm	90 cm
Nurse	Narrowleaf cottonwood	1637	783	21.4	63.2	57.1
	New Mexico locust	580	391	29.4	83.2	85.5
	Quaking aspen	269	139	20.7	64.4	68.4
Crop	Ponderosa pine	256	68	15.1	30.9	31.5
	Southwestern white pine	200	74	29.7	38.7	41.9
	Piñon pine	141	8	4.5	10.6	2.0
	Limber pine	147	98	35.6	75.5	84.9
	Englemann spruce	118	26	5.6	37.1	23.4
	Douglas-fir	64	16	11.1	30.8	30.0
Shrub	Big sagebrush	83	1	4.8	0.0	0.0
	Fourwing saltbush	12	0	0.0	0.0	0.0
	Mountain mahogany	121	58	21.6	67.4	51.2
	Rubber rabbitbrush	89	8	7.4	12.0	8.1
	Apache plume	87	29	4.0	51.9	40.0
	Gambel oak	1	0	N/A	0.0	N/A
	Woods' rose	111	82	33.3	97.5	93.8
	Scouler's willow	1	0	N/A	0.0	N/A

Nurse Species. A total of 1094 nurse trees were planted on the six 2h:1v sloped test plots, and the total number surviving after 5 years was 596, or 54.5%. Seedlings on the 30 (67.6%) and 90 cm (67.0%) cover depths had significantly greater survival than on the 0 cm (23.6%) cover ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. The mean survival rate of seedlings on plots with inoculant (57.8%) was significantly greater than plots with no inoculant (47.5 %) ($p=0.04$). There was no difference in the mean survival rates of seedlings at planting densities A (53.2%) and B (52.1%) (Table 7).

Crop Species. A total of 407 crop trees were planted on the six 2h:1v sloped test plots, and the total number surviving after 5 years was 145, or 35.6%. Seedlings on the 30 (41.7%) and 90 cm (38.4%) cover depths had significantly greater survival than on the 0 cm (23.6%) cover ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. There was no difference in the mean survival rates of seedlings between inoculant (35.5%) and no-inoculant

plots (30.7%). There was no difference in the mean survival rates of seedlings at planting densities A (33.6%) and B (32.7%) (Table 7).

Table 7. 2h:1v Sloped Test Plot Mean Survival Rates, Questa Mine, New Mexico, 2008.

Treatment	All species		Nurse species		Crop species		Shrub species	
	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD	Mean[1]	SD
Cover depth								
0 cm cover	21.9 a	27.4	23.6 a	32.1	19.3 a	28.5	13.2 a	28.0
30 cm cover	58.8 b	18.4	67.6 b	22.7	41.7 b	34.5	51.3 b	39.5
90 cm cover	58.4 b	20.8	67.0 b	28.6	38.4 b	37.0	54.3 b	38.3
p-value	p<0.01		p<0.01		p<0.01		p<0.01	
Soil amendments								
No inoculant	41.7 a	28.2	47.5 a	34.0	30.7 a	34.5	34.0 a	39.5
Inoculant	50.9 b	28.0	57.8 b	34.9	35.5 a	35.0	45.9 a	40.0
p-value	p=0.03		p=0.04		p=0.21		p=0.06	
Planting Density								
A Planting	46.0 a	29.9	53.2 a	37.4	33.6 a	36.7	41.9 a	39.7
B Planting	46.6 a	27.0	52.1 a	32.1	32.7 a	32.9	36.9 a	40.6
p-value	p=0.55		p=0.42		p=0.44		p=0.25	

[1] Treatment means followed by the same letter are not significantly different

Shrub Species. A total of 233 shrubs were planted on the six 2h:1v sloped test plots, and the total number surviving after 5 years was 92, or 39.5%. Seedlings on the 30 (51.3%) and 90 cm (54.3%) cover depths had significantly greater survival than on the 0 cm (13.2%) cover ($p<0.01$), and there was no difference in survival on the 30 and 90 cm cover depths. The mean survival rate of seedlings on plots with inoculant (45.9%) was significantly greater than plots with no inoculant (34.0%). The mean survival rate of seedlings on plots with planting density A (41.9%) was significantly greater than plots with planting density B (36.9%) (Table 7).

The survival rate of the 14 seedling species on the 2h:1v sloped plots varied widely. In general, most species had poor survival on the 0 cm cover and conversely, most did well on the 30 and 90 cm cover depths. Two of the nurse species (narrowleaf cottonwood and New Mexico locust) averaged better than 50% survival on the 30 and 90 cm cover depths, and similarly 1 crop

species (limber pine) and 3 shrub species (mountain mahogany, apache plume, and Woods' rose) averaged better than 50% survival. Piñon pine had survival of less than 10% on the 0 cm and 30 cm cover depths only 11.5% on the 90 cm cover. Three shrubs (big sagebrush, fourwing saltbush, and rubber rabbitbrush) had less than 10% survival on all cover depths. Englemann spruce, Gambel oak, and Scouler's willow were not planted on the 2h:1v sloped plots (Table 8).

Table 8. Survival Rates of Planted Seedling Species on the 2h:1v Sloped Test Plots, Questa Mine, New Mexico, 2008.

				Survival by Cover Depth (%)		
Class	Species	Planted	Alive	0 cm	30 cm	90 cm
Nurse	Narrowleaf cottonwood	723	401	28.5	69.6	65.3
	New Mexico locust	257	153	34.7	67.4	72.0
	Quaking aspen	114	42	13.9	52.5	42.1
Crop	Ponderosa pine	130	46	25.5	43.2	40.5
	Southwestern white pine	121	46	13.9	43.6	52.2
	Piñon pine	78	4	4.8	0.0	11.5
	Limber pine	77	48	52.4	72.4	59.3
	Englemann spruce	0	0	N/A	N/A	N/A
	Douglas-fir	1	1	N/A	100.0	N/A
	Big sagebrush	42	2	0.0	6.7	10.0
	Fourwing saltbush	3	0	0.0	N/A	0.0
Shrub	Mountain mahogany	47	29	36.8	84.6	73.3
	Rubber rabbitbrush	54	2	0.0	6.3	7.1
	Apache plume	34	19	18.2	80.0	62.5
	Gambel oak	0	0	N/A	N/A	N/A
	Woods' rose	53	40	23.1	88.9	95.5
	Scouler's willow	0	0	N/A	N/A	N/A

CONCLUSIONS

Without exception, there was a significant difference between survival on the 0, 30, and 90 cm cover depth treatments. In nearly all cases, the survival on the 0 cm cover was significantly lower than on the 30 and 90 cm cover depths, and in nearly all cases, the survival on 30 and 90 cm cover depths were not significantly different. All classes of seedlings showed higher survival on the test plots with cover material than without.

There was no difference in seedling survival between the control and the soil amendment treatments on the platform plots, suggesting that the fertilizer and inoculant had no effect on survival. In contrast, the inoculant on the sloped plots did increase survival in some cases. On the 3h:1v plots, the crop species survived better with an inoculant, and on the 2h:1v slopes the nurse species survived better with an inoculant. In all but one case, there was no difference in survival between the A and B planting densities.

The data gathered on the survival rates of the species in this study and on which treatments significantly improve survival will be important for CMI for reclamation planning. These data will allow CMI to determine which species to plant, the appropriate planting densities for those species, and the treatments (i.e., cover soil application) that will be needed to successfully meet the site's reclamation standard.

REFERENCES

Golder Associates. 2004. 2003 Test Plot Construction Summary Report. Prepared for Molycorp, Inc.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical Methods. Iowa State University Press. 593 pp.