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Seed Upgrade in *Alnus Tenuifolia*[1]

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Abstract

Little is known about the propagation of thinleaf alder (*Alnus tenuifolia*). This species, native to New Mexico, has potential applications in rehabilitation of disturbed lands, riparian restoration and possibly landscaping. An efficient and economical method for propagation is needed. Thinleaf alder produces prolific amounts of small seed with typically low viability. These characteristics make propagation by seed problematic. Problems encountered with seed propagation might be solved by refining or upgrading the seed (seed upgrade). The I.D.S. method, developed by Milan Simak (1983) for conifer seeds, was evaluated for its effectiveness in refining thinleaf alder seed. I.D.S. involves imbibing the seeds, partially re-drying to leave a residue of moisture, and separating by a density method. The viable seeds should retain moisture while the non-viable should not, thus creating a density differential between viable and non-viable seeds. Thinleaf alder seed was subjected to simple density separation by the specific gravity method, using petroleum ether, with and without I.D.S. treatment. The I.D.S. method used was effective in eliminating empty seed of thinleaf alder; however, seed source influenced the effectiveness of the technique. Further research is necessary to determine the optimum duration of the “drying” time in the I.D.S. techniques.

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Introduction

New Mexico has two species of alder, Arizona alder (*Alnus oblongifolia* Torr.) which is found in the mountains of southwest New Mexico (Martin and Hutchins 1980, Vines 1960), and thinleaf alder (*Alnus tenuifolia* Nutt.), designated by Carter (1997) as *Alnus incana* ssp. *tenuifolia* Nutt, found in the northern and western mountains (Martin and Hutchins 1980, Vines 1960). Until recently, existence of these species has been of interest mainly from a botanical standpoint. However, with increasing land-use in the western United States, these trees may have a further purpose in the revegetation of degraded riparian areas, and as "oasis" plants for those interested in native landscapes (Phillips 1995).

Efficient propagation of nursery stock from seed requires extensive knowledge of the germination requirements and cultural methods needed for the particular species. Little is known about the propagation requirements for thinleaf alder. This deficit is due, in part, to a lack of demand for this species in the past. Extensive work has been done on the propagation of other species within *Alnus*, specifically those species of commercial value to the timber industry such as red alder (*A. rubra* Bong.). Information generated from propagation studies on these species has elucidated some universal seed characteristics and germination requirements for members of *Alnus*. Seeds are characteristically very small and light, and may have a winged integument to aid in wind dispersal. Average seed density for *A. tenuifolia* averages about 1488 seeds per gram (Vines 1960). Seed quality and germination capacity are often very low, as it is difficult to separate sound from empty seeds when size and weight are so low (Brinkman 1974, Schopmeyer 1974). Within species, germination requirements may differ with provenance (Fowler and Dwight 1964, Wilcox 1968) or even within a provenance (Bjorkbom et al. 1965, Schopmeyer 1974).

Methods to upgrade seed quality (separate viable from non-viable seeds) have been developed for different species. Conventional seed separation techniques are based on density, such as air column or liquid separation, or by size and shape, such as with screens. Separation of viable and non-viable seeds is extremely problematic with very light, winged seeds like those of alder. Air separation techniques may not be practical for winged, lightweight seed. Flotation techniques often employ lighter-than-water solvents, but some of these substances may have adverse effects on seed viability (Barnett 1971, McLemore 1965). Wide scale use of some solvents is not considered desirable because of health and safety concerns.

A method of seed refinement/upgrade originally developed by Milan Simak; called the I.D.S. method (Incubation, Drying, and Separation) shows promise for separating live and dead seeds (cited in Bonner 1984, Downie and Wang 1992, Simak 1983, Sweeney et al. 1991). Seeds are imbibed for several hours, then incubated at cool temperatures (15^{o}C) for several hours in 100% relative humidity. Seeds are then "dried" for several hours at 35% relative humidity at cool temperatures (timing and relative humidity must be adjusted for the particular species). During the drying period, dead seeds will lose most of the water previously imbibed, while live seeds should retain most of their imbibed water. This differential moisture content would make separation by flotation and other density separation methods potentially feasible. Similar methods of conditioning have been shown to improve seed quality in lettuce, tomato, and onion (Hill et al. 1989). It has also been shown that drying of stratified seeds for storage or for separation from stratification medium need not result in loss of viability (Danielson and Tanaka 1978, Schopmeyer 1974).

The purpose of this study is to determine the effectiveness of the I.D.S. seed refinement technique and other separation procedures in increasing the percentage of live seeds in thinleaf alder seed lots. Secondly, this study examined the within-species variability of different seed lots in their response to I.D.S. and seed separation treatments.

Methods and Materials

Seed Sources

Alder strobiles were collected in October and November of 1998 in Catron County, New Mexico, near the towns of Luna and Reserve, in the Cottonwood Canyon Campground and in the Head of the Ditch Campground; and in Taos County, New Mexico, in the Red River Canyon near the Molycorp molybdenum mine (Table 1). Strobiles were kept cool and allowed to dry for several weeks. Seeds were separated from the opening strobiles by rubbing on a coarse screen.

Table 1: Seed Source Locations and Elevations

Species	Source	Lot No.	Baseline % Fill	Description	Elevation (meters)	Latitude Longitude
Thinleaf Alder	Luna	NA	23.4	Head of the Ditch CG	2134	N 33º 49' W 108˚ 59'
	Reserve	NA	26.8	Cottonwood Canyon	1829	N 33º 37' W 108º 55'
	RRC-1	98108	0.8	Red River Canyon	2469	N 36º 41' W 105º 29'
	RRC-2	98109	0.9	Red River Canyon	2469	N 36º 41' W 105º 29'

All seed sources were evaluated for percentage of filled seeds by means of dissection performed under a dissecting microscope at 30X magnification (Berry and Torrey 1985). Alder species baseline percentage of filled seeds was estimated using 25 samples of 100 seeds pooled into one percentage response for each seed source. Baseline percentage fill (Table 1) is the estimate of the percentage of filled seed in the entire seed collection for each source.

Separation Media

Ethanol and water were not particularly effective in separation of thinleaf alder seeds, either using I.D.S. methods or when separating dry seed. It was necessary to choose a fluid with a lower specific gravity than ethanol (S.G.=0.79) in order to separate filled and empty seeds with very low densities. Falleri and Pacella (1997) found that low-density London plane tree (*Platanus* x *acerifolia* [Ait.] Willd.) seeds could not be separated using water as the separation medium due to the very small density differences between sound and empty seeds, and chose petroleum ether as a separation medium. Petroleum ether was chosen for the separation of thinleaf alder seeds because of its low specific gravity (S.G.=0.60), its relative stability, low reactivity, and rating as a slight health risk. Contact with skin may cause dryness and irritation, but no chronic systematic effects have been reported with industrial use (Mallinckrodt Baker, Inc. 1997a).

Seed Refinement Treatments

Separation treatments examined included density separation of dry seed samples in petroleum ether (the control), and imbibed seed samples treated with the I.D.S. method at 0, 1, 18, and 24 hour drying times, followed by density separation in petroleum ether (Table 2). Seeds were imbibed for 24 hours by submersion in a 10-gallon glass aquarium filled with distilled water and equipped with an aeration pump and filter. Seeds were packaged in filter papers, then the packages were enclosed in wire cages (purchased tea balls were used for this purpose) weighted with marbles to keep them submerged. At the end of the imbibition period, seeds were removed from the cages, thoroughly blotted, and placed on clean filter paper. The drying incubation was performed in a closed chamber with a constant humidity obtained by the use of $CaCl_26H_2O$ salt in a saturated solution prepared by adding 5000g $CaCl_26H_2O$ to 3.0 liters of distilled water (Slavik 1974, Young 1967). Imbibed seeds were placed on filter paper and suspended on a screen above the calcium chloride solution. Humidity was monitored using a hygrometer, and held steady at 50% in the presence of the wet seeds and filter paper.

Table 2. Alder Preparation Protocols for Seed Refinement

Preparation Protocol	Imbibition Time (Hours)	Drying Time (Hours)
1- (Control)	0	0
2	24	0
3	24	1
4	24	18
5	24	24

At the end of the appropriate drying incubation, the seeds were placed in petroleum ether and briefly and vigorously stirred to separate seeds adhering to one another. Floating seeds were removed from the surface of the petroleum ether by means of a small net and/or a spatula, placed on clean moistened filter paper and placed in a labeled plastic bag to await counting. The sinking seeds were strained through the net and packaged in a similar manner. Five repetitions were performed for each of the five treatments using 100 seeds per repetition. Percentage of filled seeds contained in each was determined by means of dissection tests performed on the floating and sinking fractions, using a scalpel and a dissecting microscope with 30X magnification.

In addition, the percentage recovery of filled seeds from the sinking fraction was calculated based on the total number of filled seeds present in that particular repetition:

$$\frac{\text{\# of filled seeds in the sinking fraction}}{\text{\# of filled seeds in the sinking fraction + \# of filled seeds in the floating fraction}} \text{ X 100=percentage recovery}$$

Data Analysis

Percentage of filled seeds present in the sinking fractions (percentage fill), and proportion of filled seeds recovered from the total filled seeds available in the sample (percentage recovery) were response variables, and the preparation protocols and seed sources as independent variables. Data was analyzed by using categorical data modeling analysis as found in the SAS statistical program. The PROC CATMOD procedure can perform analysis and give "analysis of variance" in the general sense that it analyzes the response functions, fits linear models to functions of response frequencies, and partitions the variation among those functions into various sources (SAS Institute 1989).

All of the response variables considered had a binomial type of probability distribution (seed filled or not filled, seed germinated or not germinated). All treatments of both experiments were analyzed using the PROC CATMOD procedure to examine the general model, as well as planned comparisons using contrast statements where appropriate. The PROC MEANS procedure was used to calculate marginal percentages (main effect and interaction combinations), along with standard errors. Pairwise Z-tests were used to separate percentages in those effects which were determined to be significant by categorical modeling at the observed significance level, alpha = 0.05; this method of percentage separation is analogous to Fisher's LSD for separating means.

The categorical modeling procedure used two models, one for the percentage of filled seeds attained in the sinking and floating fractions, and one for the percentage of filled seeds recovered from those available in the baseline sample. The treatment structure for both of these seed refinement studies was a 5 X 2 X 4 factorial (preparation protocol by separation fraction by seed source).

The reader is referred to Jones (2000) for a more descriptive explanation of the categorical models used in this study.

Results

Preparation protocol, seed source, and the separation fraction had significant (alpha=0.05) effect on the percentage fill (Table 3). The effect of separation fraction was influenced by both source and preparation protocol.

Protocols 1, 4, and 5, the control and 24 hour imbibition followed by either 18 or 24 hours drying, respectively, all had greater than 80% filled seed in the sinking fraction (Table 2 and Figure 1). Twenty-four hour imbibition alone or in conjunction with 1 hour of drying both had lower percentages of filled seeds in the sinking fraction (less than 35%). Protocol 4, the 24-hour imbibition, followed by 18 hours of drying and density separation in petroleum ether, was chosen as the separation method for the germination requirement study.

Table 3: Analysis of Variance Table for Thinleaf Alder Percentage of Filled Seeds as Influenced by Preparation Protocol, Separation Fraction, and Seed Source–Factorial Analysis

Source	DF	Chi-Square	Observed Significance Level
Intercept	1	116.63	0.0000
Seed Source	3	173.67	0.0000
Preparation Protocol	4	44.90	0.0000
Separation Fraction	1	88.29	0.0000
Source*Prep	12	5.41	0.9427
Source*Fraction	3	9.71	0.0212
Prep*Fraction	4	9.86	0.0429
Source*Prep*Fraction	11	7.14	0.7878

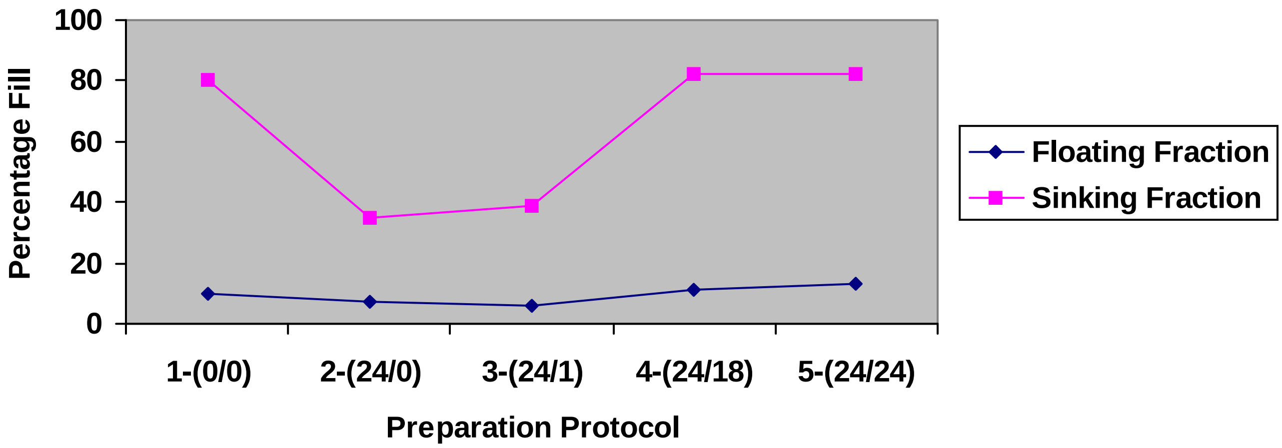

Figure 1: Alder percentage fill as influence by preparation protocol and separation fraction. Error bars represent +- one standard error. Bars that are not visible are smaller than the symbol used to represent the percentage. (Protocols are described in Table 2).

The proportion of filled seed in the sinking and floating fractions was also influenced by seed source. Percentage of filled seeds in the sinking fraction ranged from 4.44% for the Red River Canyon #1 source to over 86% for the Luna source (Table 4). Percentage of filled seeds in the floating fraction ranged from less than 1% to just over 12%, while the baseline percentage of filled seeds in the seed sources ranged from less than 1% to over 26%. The separation process improved percentage fill in the sinking fraction compared to the percentage fill in the floating fraction by about seven-fold for the Luna and Reserve seed sources, ten-fold for the Red River Canyon #1 source, and almost fifteen-fold for the Red River Canyon #2 source. Separation improved the percentage of filled seeds in the sinking fraction compared to the unseparated seed source by almost four-fold for the Luna source, almost two-fold for the Reserve source, almost six-fold for the Red River Canyon #1 source, and ten-fold for the Red River Canyon #2 source.

Table 4: Thinleaf Alder Percentage of Filled Seeds in the Fractions as Influenced by Source and Compared to Baseline % Fill Uninfluenced by Preparation Protocol

Seed Source	Baseline % Fill	% Fill - * Sinking Fraction	S.E.	% Fill - * Floating Fraction	S.E.	*N*
Luna	23.4	86.34c	1.80	12.65d	0.72	4000
Reserve	26.8	46.44b	1.39	6.31c	0.70	4000
RRC-1	0.8	4.44a	1.31	0.44a	0.14	4000
RRC-2	0.9	9.09a	3.28	0.62a	0.15	4000

*Percentages followed by the same letter are not significantly different at a=0.05.

Floating separation fractions had a much lower percentage of filled seeds (4.64%) than sinking fractions (47.11%) (Table 5). Percentage of filled seeds was consistently low in the floating fraction but varied with the preparation protocol in the sinking fraction (Figure 1).

Table 5: Thinleaf Alder Percentage of Filled Seeds as Influenced by Separation Fraction

Separation Fraction	% Fill *	S.E.	*n*
Floating Fraction	4.63a	0.23	8030
Sinking Fraction	47.11b	1.12	1970

*Percentages followed by the same letter are not significantly different at a=0.05.

Seed source and preparation protocol both influenced the percentage of filled seeds recovered (Table 6). In contrast to the percentage of filled seeds in the sinking fraction (Figure 1), the percentage of seeds recovered was improved by 24 hours imbibition alone or with one hour drying at 50% humidity (Table 7). These two treatments had in excess of 80% recovery whereas the other three separation treatments all averaged less than 67% recovery.

Percentage recovery as influenced by source varied from approximately 32% for the Red River Canyon #2 collection to over 88% for the Reserve seed source (Table 8). The Red River Canyon #1 and Luna sources both had percentage recoveries slightly greater than 50%.

Table 6: Analysis of Variance Table for Thinleaf Alder Percentage of Filled Seeds Recovered in the Sinking and Floating Fractions as Influenced by Preparation Protocol and Seed Source–Factorial Analysis

Source	DF	Chi-Square	Observed Significance Level
Intercept	1	6.94	0.0084
Seed Source	3	110.55	0.0000
Preparation Protocol	4	23.71	0.0001
Source*Prep	12	17.15	0.1439

Table 7: Thinleaf Alder Percentage of Filled Seeds Recovered in the Sinking Fraction as Influenced by Preparation Protocol

Protocol (Soak/Dry)	% Recovery *	S.E.	*n*
1 - 0/0	64.47a	2.90	273
2 - 24/0	80.94b	2.36	278
3 - 24/1	82.25b	2.30	276
4 - 24/18	66.67a	3.12	228
5 - 24/24	60.41a	3.12	245

*Percentages followed by the same letter are not significantly different at a=0.05.

Table 8: Thinleaf Alder Percentage of Filled Seeds Recovered In the Sinking Fraction as Influenced by Seed Source

Seed Source	%Recovery *	S.E.	*n*
Luna	53.92b	2.06	586
Reserve	88.52c	1.23	671
RRC-1	52.38ab	10.90	21
RRC-2	31.82a	9.93	22

*Percentages followed by the same letter are not significantly different at a=0.05.

Discussion

Traditionally seed refinement has been thought of as enhancing the number of potentially viable seeds (filled seeds) in a seed lot. Previously published studies have used total germination as the measure of seed refinement efficacy. In this study the number of filled seeds in the sinking fraction was used. The I.D.S. treatments imposed did not improve the number of filled seeds in the sinking fraction in comparison with ordinary gravity separation. In two of the alder I.D.S. treatment levels, 24-hour soak with either no drying time or one hour of drying time actually reduced the percentage of filled seeds in the sinking fraction. The two remaining alder I.D.S. treatments had considerably longer drying times and resulted in percentages of filled seeds in the sinking fraction similar to those of the non-imbibed control treated by gravity separation. The influence of drying time on the efficacy of the I.D.S. treatment has been seen in other species (Falleri and Pacella 1997, Sweeney et al. 1991). In a study of London plane tree, researchers found that as drying time increased from 7.5 hours to 24 hours observed germination percentage was greater than control (Falleri and Pacella 1997). At drying times less than 7.5 hours, observed germination was comparable to unseparated controls. In the same study, only seed receiving 24 hours of drying as part of an I.D.S. treatment had greater germination than non-treated seed separated in petroleum ether.

The response of the alder seed to I.D.S indicates there may be potential for I.D.S. as a seed refinement tool, using longer imbibition and drying times. The difference in times from the 1-hour to the 18-hour drying is considerable and corresponds to a significant difference in the percentage of filled seeds in the sinking fraction. The shorter drying times may have been of insufficient duration to allow the unfilled seed to lose sufficient moisture and hence these seeds ended up in the sinking fraction. In contrast, the 18- and 24-hour drying times may have allowed the imbibed unfilled seeds to lose the majority of the water imbibed, and resulted in percentages of filled seeds in the sinking fraction similar to those seen in the non-imbibed controls.

While all thinleaf alder sources had improved percentages of filled seeds in the sinking fractions, there appear to be differences between sources in response to seed refinement. This difference was most pronounced when comparing the Reserve and Luna seed lots. The Luna seed lot had over a three-fold improvement in the percentage of filled seeds in the sinking fraction compared to the percentage of filled seeds in the initial seed lot (23.4%). In contrast, seeds from the Reserve seed source had a similar initial percentage of filled seeds (26.8%) but the percentage of filled seeds in the sinking fraction was slightly less than twice this amount (46.4%). Differences of seed source in response to similar seed refinement techniques (I.D.S.) has been observed in other studies (Donald 1985, Downie and Wang 1992). Downie and Wang (1992) found that the I.D.S. treatment improved germination percentage regardless of the initial seed lot germination capacity in three conifer species, lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), Jack pine (*P. banksiana* Lamb.), and white spruce (*Picea glauca* [Moench] Voss). The authors of that study did not compare responses between seed sources. While not tested in this study, there may have been differences in the rate of moisture loss between the Luna and Reserve sources during the drying portion of the I.D.S. regimes imposed in this study. More detailed studies examining source differences in the rate of moisture loss would be beneficial.

The above discussion focuses primarily on reducing the number of empty or non-viable seeds in a seed lot. During seed refinement some viable seed is also lost in the floating fraction (Downie and Wang 1992, Falleri and Pacella 1997, Sweeney et al. 1991). In cases where there is more than adequate seed supply, the loss of viable seed in the floating fraction is not a problem. In those cases where the amount of available viable seed is limited and losses of viable seed needs to be minimized, other criteria can be used to determine the most effective seed refinement technique. Such was the case in this study.

The percentage of filled seeds recovered in the sinking fraction provides a measure of how efficient the refinement technique is at reducing the number of filled (potentially viable) seeds lost in the floating fraction. In the current study involving alder, those protocols with low percentages of filled seeds in the sinking fraction had a high percentage of filled seeds recovered (Figure 2). In the case of alder, the high recovery of filled seeds was inversely related to the I.D.S. treatment's ability to remove non-viable seed. A similar trend was observed in another study in an attempt to upgrade germinated cabbage seeds using density gradients. As percentage recovery increased, the percentage of germinated seeds decreased because of the increased recovery of non-germinated seeds (Taylor and Kenny 1985). The technique employed to determine which seed refinement protocol to use in the germination studies was to multiply the percentage of filled seeds in the sinking fraction by the percentage of filled seeds recovered. This value addresses both the protocol's ability to remove non-viable seeds as well as its ability to reduce the loss of potentially viable seeds.

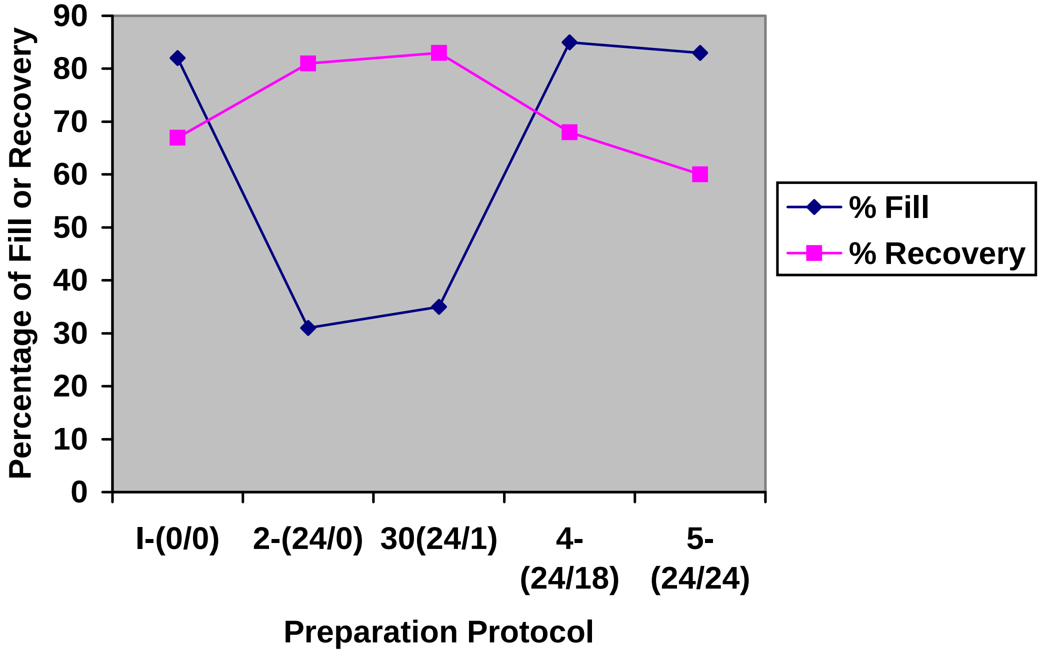

Figure 2: Alder percentage Fill and percentage recovery of the sinking fraction as influenced by preparation protocol. Error Bars represent +/- one standard error. (Protocols described in Table 2).

Depending on a grower's constraints, either greenhouse space or seed supply, the evaluation of a seed refinement technique could be based on one of three criteria discussed above: percentage of filled seeds in the sinking fraction, percentage of filled seeds recovered, or the product generated by multiplying these two values as was done in this case. In cases where seed supply is a greater constraint, selection of seed refinement technique may be based solely on the percentage of filled seeds recovered. This seed refinement technique may not be as efficient in removing unfilled seeds, but loss of filled seeds would be minimized. In the case where growing space is the greater constraint, the percentage of filled seeds in the sinking fraction would be the criteria used for seed refinement technique selection. If both greenhouse space and seed supply is limited, then the product of the two may be used to determine the appropriate protocol. The use of this information in conjunction with spreadsheet-based seed sowing programs allows nursery managers to select the best seed refinement technique for their nursery (Harrington and Glass 1997, Wenny 1993).

The particular separation medium found to be most effective would vary with species. Large and dense seeds may often be effectively separated using water as the medium (Simak 1983). This is known as the specific gravity method of separation when used on untreated seeds. In very small seeds where the density gradient between empty, dead, and filled live seeds is not great, water may not be effective, and it is more advantageous to adjust the specific gravity of the separation medium, rather than trying to make fine adjustments in the density gradient of the seeds to be separated (Downie and Wang 1992).

Literature Cited

Barnett, James P. 1971. Flotation in ethanol reduces storability of southern pine seeds. *Forest Science* 17(1):50-51.

Berry, Alison M. and John G. Torrey. 1985. Seed Germination, seedling inoculation and establishment of *Alnus* spp. in containers in greenhouse trials. *Plant and Soil* 87:161-173.

Bjorkbom, John C., D. A. Marquis, and F. E. Cunningham. 1965. The variability of paper birch seed production, dispersal, and germination. USFS Research Paper NE-41. Washington: GPO.

Bonner, F.T. 1984. New forests from better seeds: The role of seed physiology. In *Seedling Physiology and Reforestation Success*, eds. Mary L. Duryea and Gregory N. Brown, 37-60. Dordrecht: Martinus Nijhoff/Dr.W. Junk Pub.

Brinkman, Kenneth A. 1974. *Betula* L. Birch. In *Seeds of Woody Plants in the United States,* USDA Agricultural Handbook 450*,* ed. C. S. Schopmeyer, 252-257. Washington: GPO.

Carter, Jack L. 1997. *Trees and Shrubs of New Mexico*. Boulder: Mimbres Publishing. pp. 400-402.

Danielson, H. Rodger and Yasuomi Tanaka. 1978. Drying and storing stratified ponderosa pine and douglas-fir seeds. *Forest Science* 24(1):11-16.

Donald, D. G. M. 1985. The separation of full dead seed from live seed in *Pinus elliottii*. In *Proceedings of the International Symposium on Nursery Management Practices for the Southern Pines*, Montgomery, AL, August 4-9, 1985. ed. David B. South, 83-88. Auburn, AL: Auburn University.

Downie, Bruce and Ben S. P. Wang. 1992. Upgrading germinability and vigor of jack pine, lodgepole pine, and white spruce by the IDS technique. *Can. J. For. Res.* 22(8):1124-1131.

Falleri, Elisabetta and Rosetta Pacella. 1997. Applying the IDS method to remove empty seeds in *Platanus* x *acerifolia*. *Can. J. For. Res.* 27:1311-1315.

Fowler, D. P. and T. W. Dwight. 1964. Provenance differences in the stratification requirements of white pine. *Can. Journ. of Botany* 42:669-675.

Harrington, J. T. and P. A. Glass. 1997. Determining the number of seeds to sow per cell: An application of the geometric distributions. *Tree Planters' Notes* 8:28-34.

Hill, H. J., A. G. Taylor, and T. -G. Min. 1989. Density separation of imbibed and primed vegetable seeds. *J. Amer. Soc. Hort. Sci.* 114(4):661-665.

Jones, Cindy L. 2000. Seed upgrade and germination strategies for *Alnus tenuifolia* and *Betula occidentalis*. Master's Thesis. New Mexico State University 107 pp.

Mallinckrodt Baker, Inc. 1997. Material Safety Data Sheet Petroleum Ether. MSDS Number: P1696. Phillipsburg, NJ: Mallinckrodt Baker, Inc.

Martin, W. C. and C. R. Hutchins. 1980. *A Flora of New Mexico.* Vaduz: J. Cramer, A.R. Gantner Verlag K. G. pp.510-514.

McLemore, B. F. 1965. Pentane flotation for separating full and empty longleaf pine seeds. *Forest Science* 11(2):242-243.

Phillips, Judith. 1995. *Plants for Natural Gardens.* Santa Fe: Museum of New Mexico Press. pp.108-109.

SAS Institute Inc. 1989. *SAS/STAT User's Guide, Version 6,* Fourth Edition, Volume 1. Cary, NC: SAS Institute, Inc.

Schopmeyer, C. S. 1974. *Alnus* B. Ehrh. In *Seeds of Woody Plants in the United States,* USDA Agricultural Handbook 450, ed. C. S. Schopmeyer, 19-40, 126-135, 140-152, 206-211. Washington: GPO.

Simak, Milan. 1983. A new method for improvement of the quality of *Pinus contorta* seeds. In *Lodgepole pine: regeneration and management*, ed. Mayo Murray, 39- 41. USDA For. Serv. Gen. Tech. Rep. PNW-157.

Slavik, Bohdan. 1974. Water exchange between plant and atmosphere. Chapter 5 of *Methods of Studying Plant Water Relations*. Prague: Academia Publishing House of the Czechoslovak Academy of Sciences.

Sweeney, J. D., Y. A. El-Kassaby, D. W. Taylor, D. G. W. Edwards, and G. E. Miller. 1991. Applying the IDS method to remove seeds infested with the seed chalcid, *Megastigmus spermotrophus* Wachtl, in douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco. *New Forests* 5:327-334.

Taylor, A. G. and T. J. Kenny. 1985. Improvement of germinated seed quality by density separation. *J. Amer. Soc. Hort. Sci.* 110(3):347-349.

Vines, Robert A. 1960. *Trees, Shrubs, and Woody Vines of the Southwest.* Austin: University of Texas Press. pp.139-142.

Wenny,D.L. 1993. Calculating filled and empty cells based on number of seeds sown per cell: A microcomputer application. *Tree Planters' Notes* 44:49-52.

Wilcox, James R. 1968. Sweetgum seed stratification requirements related to winter climate at seed source. *Forest Science* 14:16-19.

Young, J. F. 1967. Humidity control in the laboratory using salt solutions - a review. *J. Applied Chem.* 17:241-245.

Preliminary Evaluation on Adventitious Rooting Hardwood Stem Cuttings of *Symphoricarpos oreophilus*, *Ribes cereum*, and *Cercocarpus montanus* from throughout New Mexico[5]

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Project Number: NMPMC-P-9803-CR

Abstract

Current trends in restoration, reclamation and revegetation are focusing on using local sources of indigenous plants including woody shrubs. However, for many native shrubs propagation techniques are not well researched, resulting in increased production costs for those species. Further, propagation literature is often based on studies with a limited number of sources. This investigation was undertaken to evaluate the suitability of rooting of dormant hardwood cuttings of *Symphoricarpos oreophilus, Ribes cereum*, and *Cercocarpus montanus* as a means of plant propagation. Exogenous hormone application dosage and timing of collection were evaluated for seven sources of each species. Sources were selected to represent a range of latitudes from the southern part of the state to the northern part of the state. At the northern-most latitude, Molycorp, Inc. mine near Questa, NM, collections were made at three elevations ranging from 8,200 feet to 9,800 feet. Several rooting response variables were measured. *Ribes cereum* and *Cercocarpus montanus* had overall poor rooting in this investigation. Only the *Symphoricarpos oreophilus* had appreciable rooting. Exogenous hormone dosage, timing of collection and source of cuttings all influenced the rooting response. Late winter/early spring cuttings had the highest rooting percentages across all sources with the exception of the most northerly, highest elevation source. IBA/NAA applications from 250 to 1,000 ppm improved the percentage of cuttings rooting. There was considerable variation in rooting among the sources evaluated with the more northerly sources, from the Sandia Mountains northward, having overall the greatest percentage of cuttings rooting.

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Introduction

In the southwestern U.S., mine reclamation activities have increased in scope as new government regulations take effect. Natural invasion and succession occurs slowly on most mine sites (Monsen 1983), and as a result, planting nursery-grown materials is necessary to speed up the time scale of revegetation. Species chosen for initial plantings must be adapted to the local climate as well as other site conditions such as moisture availability and edaphic features. This has lead many revegetation specialists to use species native to areas immediately surrounding the disturbance. However, for many native shrub propagation techniques are not well researched, resulting in increased production costs for those species (Dreesen and Harrington 1997). In addition, propagation literature is often based on studies involving few seed lots or cutting sources, failing to take into account ecotypic variability. As a result the recommended protocols may not be suitable for all sources of a species.

In New Mexico three native shrub species capable of growing on disturbed sites are being studied as candidate species for reclamation. Mountain snowberry (*Symphoricarpos oreophilus*) is a many-branched upright shrub growing to between 1 and 1.5 meters tall occurring throughout montane regions of western North America from British Columbia to Montana, south to California, New Mexico, and northern Mexico at elevations of 1200 to 3200 meters (McMurray 1986). Seasonal growth is characterized by rapidly elongating basal sprouts in the early spring (George and McKell 1978) followed by sparse growth on older stems from late spring through summer. Mountain snowberry is a frequently abundant and often dominant shrub species occurring in numerous communities, is an important forage species for deer, elk, and all classes of livestock, and has been used successfully to establish cover on disturbed sites (McMurray 1986). Once established it spreads rapidly through layering and rhizomes (McMurray 1986). Mountain snowberry inhabits all aspects, sites ranging from moist to dry, and a wide range of soil pHs (McMurray 1986). Mountain snowberry is usually a climax species, but in certain communities can be a major component throughout all successional stages (McMurray 1986).

True mountain mahogany (*Cercocarpus montanus*) is a shrub or small tree up to three meters tall with upright or spreading branches occurring on dry, rocky, shallow soils on hillsides, bluffs, and ridge tops at elevations of 1050-2750 meters (Harrington 1954, Vines 1960). Mountain mahogany occurs mostly on north-facing slopes in the lower elevations of its range (Woodmansee 1969), but in Colorado at elevations of 2500 meters, it occurs predominantly on southerly aspects (Smith 1971). Mountain mahogany has a natural range from Montana and South Dakota, south to Kansas, New Mexico, and Arizona (Harrington 1954, Vines 1960, Woodmansee 1969). Mountain mahogany often forms pure stands or is the dominant species in mixed stands (Woodmansee 1969). Mountain mahogany is well suited for reclamation as it can occupy sites that are unstable, erosive, of low fertility and receiving little moisture (Brotherson 1992). In addition, mountain mahogany is an actinorhizal plant forming a nitrogen-fixing symbiosis with *Frankia* bacteria (Paschke 1997). Mountain mahogany provides browse for big game and controls erosion on dry slopes (Deitschman et al. 1974).

Wax currant (*Ribes cereum*) is a many-branched spineless shrub reaching 50 to 200 cm tall (Harrington 1954, Vines 1960). Wax currant occurs on dry slopes, ridges, and plains at elevations of 1200-4000 meters from Montana west to British Columbia south to California and east to New Mexico (Vines 1960, Marshall and Winkler 1995). Wax currant is a potentially valuable species for the revegetation of disturbed sites. It occurs within numerous habitat types and plant communities- open forests, forest edges, and well as in shrub communities (Marshall and Winkler 1995). Wax currant grows on soil textures ranging from sandy to clayey, and has been observed to grow on rocky soils with little topsoil (Marshall and Winkler 1995). Wax currant occurs across a highly variable range of temperatures and precipitation amounts (Marshall and Winkler 1995). It has been observed to be an early colonizing species of disturbed sites within Douglas Fir communities, providing canopy favorable for the establishment of Douglas Fir seedlings (Marshall and Winkler 1995). This species can provide browse for deer when better browse is not available, and fruits are eaten by numerous bird species (Marshall and Winkler 1995).

Propagating native shrubs from vegetative material has potential advantages over propagation from seed. Seed propagation of native species can be made difficult by sporadic seed production in native stands, low seed viability necessitating seed refinement procedures, and seed dormancy, which must be overcome by scarification and stratification techniques (Dreesen and Harrington 1997). Some species may be propagated more easily, quickly, and economically by vegetative methods than by seed. The most widespread technique is rooting of stem cuttings.

Stem cuttings are able to develop into complete plants due to their ability to produce adventitious roots from within stem tissues. For most woody species propagation from stem cuttings requires exogenous auxin treatment (Kevers et al. 1997). Indole-3-acetic acid (IAA), a naturally occurring auxin, is known to promote adventitious root formation. Indole-3-butyric acid (IBA) and napthaleneacetic acid (NAA) are synthetic auxin found to be effective as root-promoting treatments for cuttings (De Klerk et al. 1999).

Little research has been conducted on the potential of vegetative propagation for large-scale production of these species. Some research from the horticultural industry has illustrated that stem cuttings from other members of *Symphoricarpos* and *Ribes* can be induced to root readily (Anonymous 1948, Dirr and Heuser 1987, Plummer et al. 1969, Pfister 1974, Young and Young 1992). However, published literature on vegetative propagation of any species of *Cercocarpus* is lacking.

The objectives of this study were to examine the possibility of using vegetative propagation as means of propagating these three species. Additional objectives were to examine the influence of timing of collection and exogenous auxin application on adventitious root development. Lastly, the study was designed to examine the influence of provenance along a latitudinal gradient within New Mexico and an elevational gradient at the northern most sampling point on rooting response of these three species.

Materials and Methods

For each species cuttings were taken at multiple locations (sources) throughout New Mexico in order to assess variability in response to various treatments. Sources were selected to encompass a range of latitudes across the state and a range of elevations at the Molycorp Mine in Questa, New Mexico (Table 9). Cuttings were stuck on four dates approximately one month apart: January 17, February 14, March 14, and April 11, 1998. Within 48 hours prior to each date 110 cuttings from each source of each species were taken, sealed in polybags, placed into coolers and brought to Mora, NM. Only cuttings from the current season's growth were used. Eighteen-centimeter cuttings were taken when possible. Many of the source plants at the Molycorp, Inc., site had insufficient growth the previous growing season to meet the eighteen centimeter cutting length target, however no cuttings less than 12.5 centimeters were used.

Table 9: Cutting Source Information

Species	Lot Name	Latitude (approx.)	Location	Elevation
mountain snowberry	Capulin	36 degrees 42'	Questa, NM	9,800 ft
mountain snowberry	Mill	36 degrees 42'	Questa, NM	8,200 ft
mountain snowberry	Spring Gulch	36 degrees 42'	Questa, NM	8,700 ft
mountain snowberry	Mora	36 degrees 00'	Mora, NM	7,200 ft
mountain snowberry(a)	Sandia	35 degrees 10'	Albuquerque, NM	7,700 ft
mountain snowberry (a)	Sacramento	32 degrees 58'	Cloudcroft, NM	8,600 ft
wax currant	Capulin	36 degrees 42'	Questa, NM	9,800 ft
wax currant	Mill	36 degrees 42'	Questa, NM	8,200 ft
wax currant	Mahogany Point	36 degrees 42'	Questa, NM	8,800 ft
wax currant	Mora	36 degrees 00'	Mora, NM	7,200 ft
mountain mahogany	Capulin	36 degrees 42'	Questa, NM	9,800 ft
mountain mahogany	Mill	36 degrees 42'	Questa, NM	8,200 ft
mountain mahogany	Mahogany Point	36 degrees 42'	Questa, NM	8,800 ft
mountain mahogany	Mora	36 degrees 00'	Mora, NM	7,200 ft
mountain mahogany	Sandia	35 degrees 10'	Albuquerque, NM	9,300 ft
mountain mahogany	Sacramento	32 degrees 58'	Cloudcroft, NM	8,600 ft

Cuttings from each source of each species were trimmed to 15 centimeters (or slightly less in the case of shorter cuttings) in length with a diagonal cut at the basal end. Terminal buds were removed, and cuttings were randomly divided into 5 groups of 20 cuttings each, by source. Each of the 5 groups underwent a different hormone treatment. The hormones used were equal parts IBA and NAA dissolved in 50% isopropyl alcohol. Hormone concentrations of 4000, 2000, 1000, 500, and 0 parts per million (ppm) were used for mountain mahogany and wax currant. Hormone concentrations were 2000, 1000, 500, 250, and 0 ppm were used for mountain snowberry. Cuttings were given a five-second quick-dip in their respective hormone treatments to a depth of 2 centimeters, allowed to air dry, and stuck to a depth of at least 7.5 cm into cells containing a mixture of 2 parts peat and 1 part each of perlite and vermiculite. Copper-coated, 77-cell styroblocks were used for wax currant and mountain snowberry, and copper-coated, 112-cell styroblocks were used for mountain mahogany. Cuttings were watered in and kept moist throughout the experiment.

Due to other activities in the greenhouse, three types of greenhouse benches were used to conduct this study. Bench one was a bottom-heated bench with a traveling boom mist system and a wet canvas canopy suspended 1.2 meters above the cuttings. The second bench used was also a bottom heat bench; however, humidity was enhanced by using a small greenhouse fogger with a clear polyethylene covering suspended 1 meter above the seedlings. The third bench was a conventional greenhouse bench with no special features to elevate humidity levels above greenhouse levels. The bottom heat temperatures were set at 20°C for the first two benches. Cuttings stuck on the first date were placed on a bench for 30 days then moved to the second bench for the remainder of the study. Cuttings stuck on the second date were placed on the first bench for 30 days at which they were moved to the third or conventional bench for the remainder of the study. Cuttings stuck on the third and fourth collection dates were placed on the first bench and remained there for the remainder of the study. Cuttings stuck on the third and fourth dates were placed on the boom bench and not moved. Thirty days after the cuttings were stuck the wet canvas covering was removed from the bench, in effect mimicking a typical greenhouse bench.

Cuttings were monitored for leaf burst at weekly intervals throughout the study. After 22 weeks (150 days) cuttings were removed from the media, and their roots were measured. Stem caliper, number of root loci and length of the longest primary root were measured, and a subjective rating from 0-4 for the amount of root branching was assigned. A rating of 0 represented no root branch and a rating of 4 represented heavy root branching

Categorical analysis of variance was used to determine treatment (collection date, hormone concentration, and cutting source and their interactions) differences in the number rooted cuttings. A generalized-least-squares approach was used in order to address the high frequency of low cell counts. Pairwise comparisons were made using an alpha value of .05 divided by the number of comparisons.

Analysis of root branching of rooted cuttings was only undertaken for mountain snowberry. The low rooting success of wax currant and mountain mahogany precluded any analysis of root branching in these species. To facilitate analysis of root branching, root branching ratings were divided into 2 categories. Ratings of 0, 1, and 2 were combined to form a low root-branching category, and ratings of 3 and 4 were combined to form a high root-branching category. Categorical analysis of variance was then used to determine how cutting source, collection date, and hormone concentration affected root branching. Pairwise comparisons were carried out using an alpha value of .05 divided by the number of comparisons.

Analysis of number of root loci and length of longest root for rooted cuttings was also undertaken for mountain snowberry only, because too few cuttings rooted successfully for wax currant or mountain mahogany. Analysis of variance (ANOVA) was used to determine differences in the number of root loci and length of longest root as effected by hormone concentration, collection date, and cutting source. Least square means were used for pairwise comparisons.

Results

The overall low rooting percentages of the wax currant (< 5%) and the mountain mahogany (< 1%) precluded any analysis of the data. Therefore the results and discussion will only relate to the responses found in the mountain snowberry portion of the study. Treatment effects were considered meaningful at the alpha < 0.05 level.

Cutting source, collection date, and hormone treatment all affected rooting response (Table 10), as did the interactions of cutting source with collection date (Figure 3) and collection date with hormone concentration (Figure 4). Cuttings from the Mill source at Molycorp Mine had the highest overall rooting percentage, averaging 50%, approximately double the lowest rooting percentage, 25%, for cuttings from the Sacramento site (Table 10). All other sources had overall rooting percentages ranging from 35% to 43%.

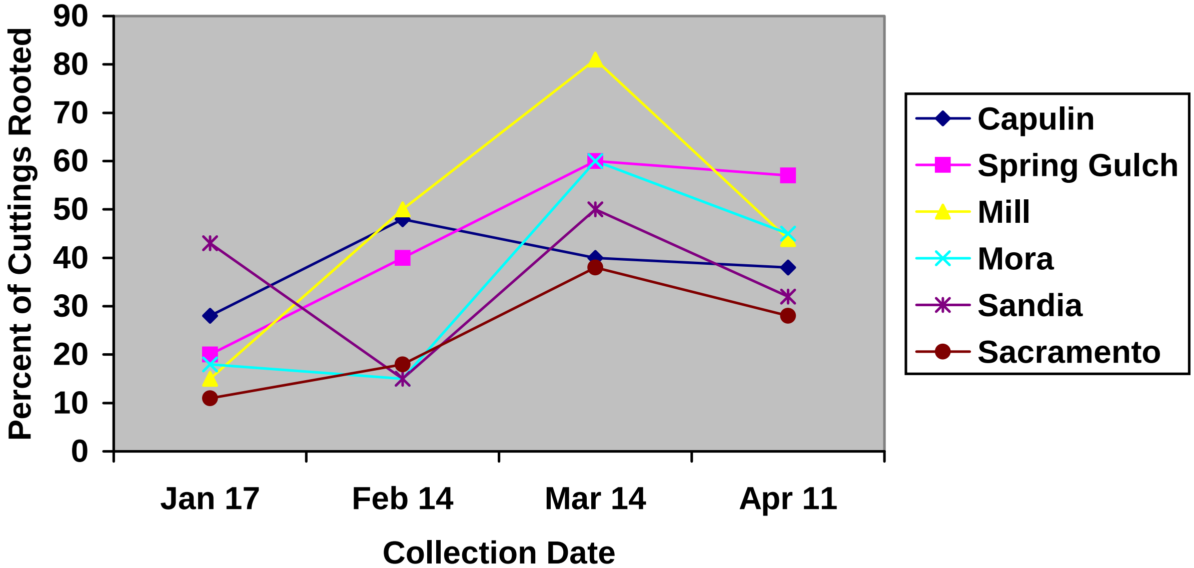

Figure 3: Mountain Snowberry Cutting Study–Effect of the interaction between cutting source and collection date on percentage of cuttings rooted 150 days after sticking

The greatest percentages of cuttings rooting successfully were collected in March followed by April, February, and lastly January (Table 10). Using rooting of cuttings collected in January as a baseline, March cuttings showed a 140% improvement, April cuttings showed an 87% improvement, and February cuttings showed a 41% improvement. Rooting percentage improved for most sources when collection date was delayed, reaching a maximum in March (Figure 1). However rooting percentage of Sandia cuttings fell when collection was delayed from January to February, but then rose to a maximum in March. Other exceptions to the overall trend were the February peak in rooting of cuttings from Capulin and the continued high rooting, relative to March, of Spring Gulch cuttings taken at the April sampling date.

Treatment with 250, 500, or 1000 parts per million IBA/NAA solution (Table 10) improved the percentage of cuttings rooted. Treatment with 2000 ppm IBA/NAA resulted in rooting percentages no different from that of the control.

Table 10: Mountain Snowberry Cutting Study–Main Effects of Source, Collection Date, and IBA/NAA Concentration on Percentage of Cuttings Rooted After 150 Days

Cutting Source	Mean Percent Rooted [1]	Standard Error
Capulin	39.0 (b)	2.44
Spring Gulch	43.0 (ab)	2.48
Mill	50.3 (a)	2.50
Sandia	36.5 (b)	2.41
Mora	35.0 (b)	2.38

Table 10: Mountain Snowberry Cutting Study–Main Effects of Source, Collection Date, and IBA/NAA Concentration on Percentage of Cuttings Rooted After 150 Days

Cutting Source	Mean Percent Rooted [1]	Standard Error
Sacramento	24.8 (c)	2.16

Collection Date	Mean Percent Rooted [1]	Standard Error
January 17	22.8 (d)	1.71
February 14	32.3 (c)	1.91
March 14	54.8 (a)	2.03
April 14	42.3 (b)	2.02

IBA/NAA Concentration (parts per million)	Mean Percent Rooted [1]	Standard Error
0	32.1 (b)	2.13
250	45.2 (a)	2.27
500	42.5 (a)	2.26
1000	40.8 (a)	2.24
2000	29.8 (b)	2.09

[1] Mean rooting percentages followed by the same letter are not significantly different.

Cuttings collected at different dates responded differently to hormone concentration (Figure 4). While overall cuttings taken in March had the best rooting, cuttings taken at this time did not benefit from any hormone treatment. Cuttings collected on the other 3 dates all benefited from the intermediate concentrations hormone concentrations of hormone application, but optimal concentration varied by source and collection date.

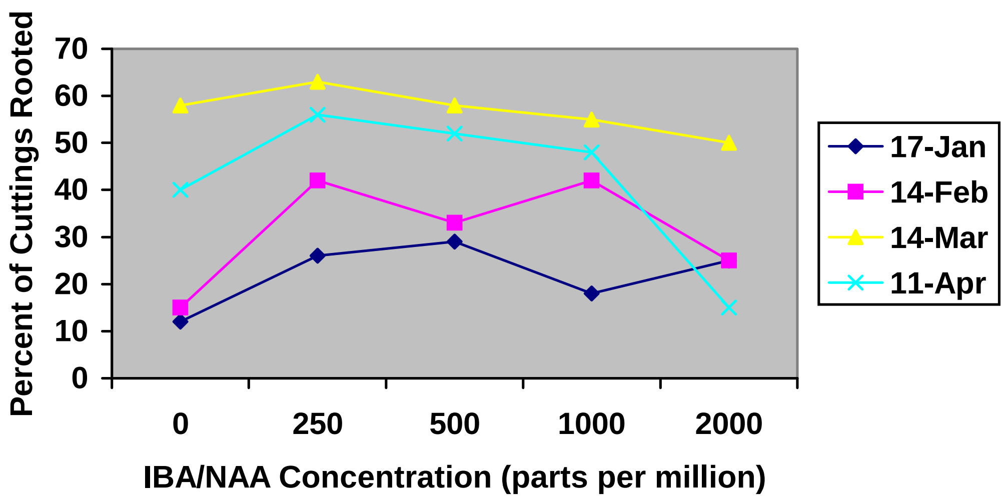

Figure 4: Mountain Snowberry cutting Study–Effect of interaction between hormone concentration and collections date on percent of cuttings rooted 150 days after sticking

Collection date was the only factor affecting the root branching of cuttings. Pairwise comparisons of collection dates indicated cuttings collected in January and February had a higher percentage with high root-branching ratings than did those collected in March or April (Table 11). This result contrasts sharply with the effect date had on rooting response, in which later collections, March and April, had greater frequencies of cuttings rooting (Table 10).

Table 11: Mountain Snowberry Cutting Study–Pairwise Date Comparisons for Root Branching Rating

Collection Date	Percent of Cuttings With High Root Branching [1]	Standard Error
January 17	83.9 (a)	3,1
February 14	85.6 (a)	2.5
March 14	60.6 (b)	2.7
April 11	54.8 (b)	3.1

[1] Mean cutting percents followed by the same letter are not significantly different.

Cutting source, collection date, hormone concentration, and all interactions of these factors affected the number of root loci per cutting (Table 12, Figures 5 and 6). Low numbers of root loci for Sacramento correlates with this sources low rooting percentage overall, but did not for the other sources (Tables 10 and 2). January and March cuttings had the highest number of loci, followed by April, and lastly by February (Table 12). This result varies from the rooting response analysis only in the relative position of January, which had the highest number of loci per cutting, but the lowest rooting percentage (Tables 10 and 11).

The number of root loci per cutting did not consistently increase with increasing hormone concentration (Table 12). Although all dosages except 1000 ppm resulted in a higher number of root loci per cutting than the control, the best treatment increased the number of root loci by only 16% of the control. The effect of hormone concentration on mean number of loci varied highly among sources (Figure 5). The shape of the response pattern as well as optimal hormone concentration varied among sources.

Table 12: Mountain Snowberry Cutting Study–Main Effects of Source, Collection Date, and Hormone Concentration on Number of Root Loci per Rooted Cutting

Cutting Source	Mean Number of Root Loci [1]	Standard Error
Capulin	10.9 (de)	0.37
Spring Gulch	11.1 (d)	0.40
Mill	12.8 (c)	0.39
Mora	14.0 (b)	0.52
Sandia	16.6 (a)	0.58
Sacramento	9.6 (e)	0.58

Collection Date	Mean Number of Root Loci [1]	Standard Error
January 17	14.0 (a)	0.64
February 14	10.3 (b)	0.34
March 14	13.6 (a)	0.34

Collection Date	Mean Number of Root Loci [1]	Standard Error
April 11	12.3 (b)	0.36

IBA/NAA Concentration (parts per million)	Mean Number of Root Loci [1]	Standard Error
0	11.5 (c)	0.43
250	12.7 (ab)	0.43
500	13.4 (a)	0.42
1000	12.3 (bc)	0.46
2000	12.9 (ab)	0.53

[1] Root loci means followed by same letter are not significantly different.

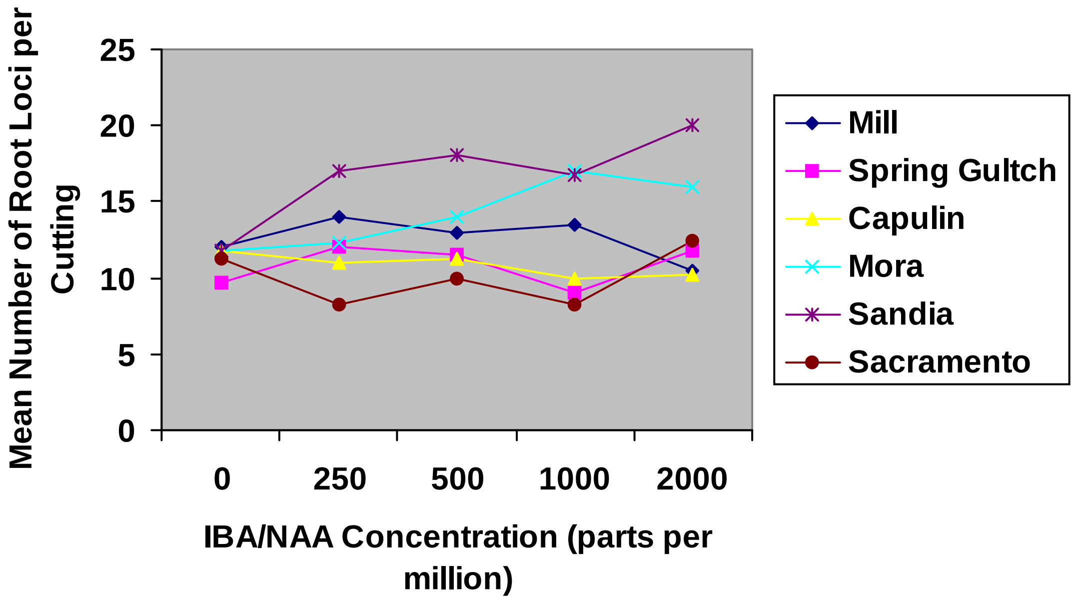

Figure 5: Mountain Snowberry Cutting Study–Effect of hormone concentration on mean number of root loci per rooted cutting 150 days after sticking by source

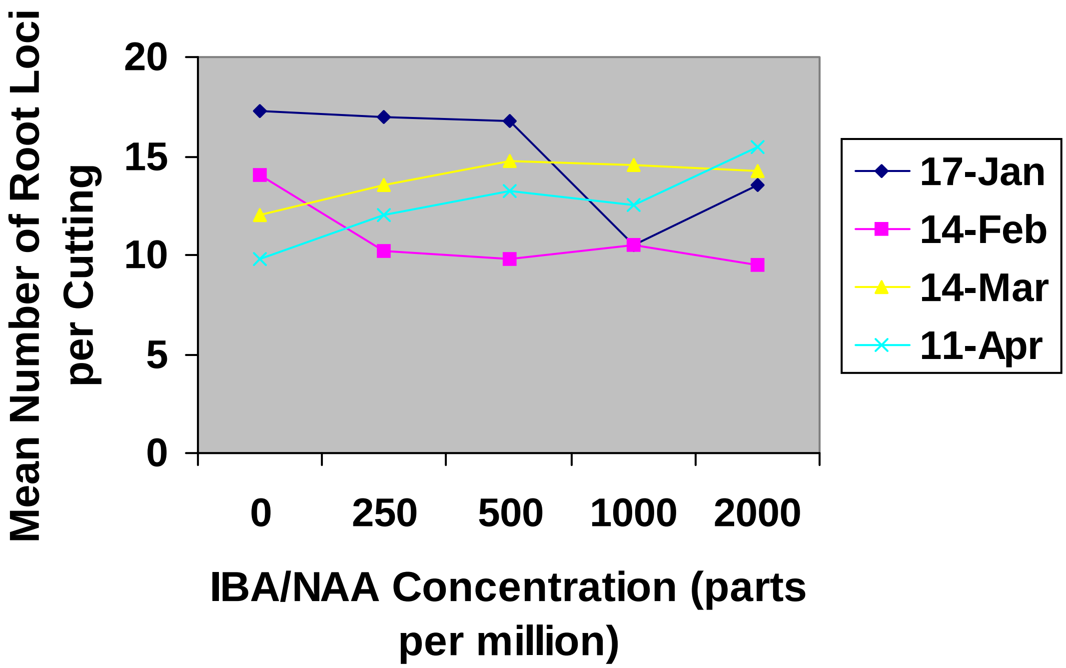

Figure 6: Moutain Snowberry Cutting Study–Effect of hormone concentration on mean number of root loci per rooted cutting 150 days after sticking by collection date

Collection date also influenced the effect of hormone concentration on number of root loci (Figure 6). Increasing hormone concentration negatively impacted January and February cuttings, while April cuttings had increased numbers of root loci with increasing concentration. March cuttings, on the other hand, showed a positive response to moderate concentrations of IBA/NAA, with a drop-off as concentration was increased.
Cutting source, collection date, and hormone concentration affected the length of the longest root per cutting, as did the interaction between cutting source and collection date (alpha<.05).

Average length of longest root increased from the southerly sources, (Sacramento) to the northerly sources, (Molycorp sources; Table 13). This trend strongly resembles the source trend found in rooting response (Table 10).

As collection date was delayed the mean length of longest root decreased (Table 13). This response contrasts with the results of the rooting response analysis (Table 10), but is more or less consistent with the root branching and root loci analysis (Tables 11 and 12).

Table 13: Mountain Snowberry Cutting Study–Main Effects of Source, Collection Date, and Hormone Concentration on Length of Longest root 150 Days After Sticking

Cutting Source	Mean Length of Longest Root (mm) [1]	Standard Error
Capulin	94.6 (a)	2.68
Spring Gulch	98.0 (a)	2.93
Mill	91.7 (ab)	2.41

Table 13: Mountain Snowberry Cutting Study–Main Effects of Source, Collection Date, and Hormone Concentration on Length of Longest root 150 Days After Sticking

Cutting Source	Mean Length of Longest Root (mm) [1]	Standard Error
Mora	85.6 (bc)	3.66
Sandia	78.7 (c)	2.39
Sacramento	63.4 (d)	3.27

Collection Date	Mean Length of Longest Root (mm) [1]	Standard Error
January 17	106.2 (a)	3.94
February 14	95.5 (b)	2.40
March 14	85.8 (a)	2.06
April 11	72.9 (b)	1.61

IBA/NAA Concentration (parts per million)	Mean Length of Longest Root (mm) [1]	Standard Error
0	84.1 (b)	2.84
250	88.3 (b)	2.48
500	86.6 (b)	2.13
1000	83.6 (b)	3.92
2000	95.4 (a)	3.66

[1] Mean longest root lengths followed by same letter are not significantly different.

Pairwise comparisons of hormone concentrations shows that the highest concentration (2000 ppm) resulted in the highest mean length of the longest root, and all other concentrations were equally worse (Table 13). This result contrasts with the result from the analysis of rooting response, in which 2000 ppm and the control treatment resulted in the fewest cuttings rooted (Table 10), and the root loci analysis in which there was no trend in response to increasing hormonal concentration (Table 12).

Source response to collection date measured as length of longest root varied (Figure 7). Although most sources show a decline in the mean length of the longest root as collection date was delayed, Spring Gulch shows an increase through March, followed by a decline from March to April. Also the mean longest root length for Mora cuttings taken in January is much higher than all other source by date combinations, but drops in February to a more mid-range level. There was also much variability in the source by date interaction for rooting response (Figure 3) and number of root loci (Figure 6).

For most sources cuttings from all collection dates leafed out rapidly following sticking and nearly all cuttings were leafed out after 3 weeks with the exception of the Mora cuttings taken in January and February which were poorly leafed out after 3 weeks (Figure 8).

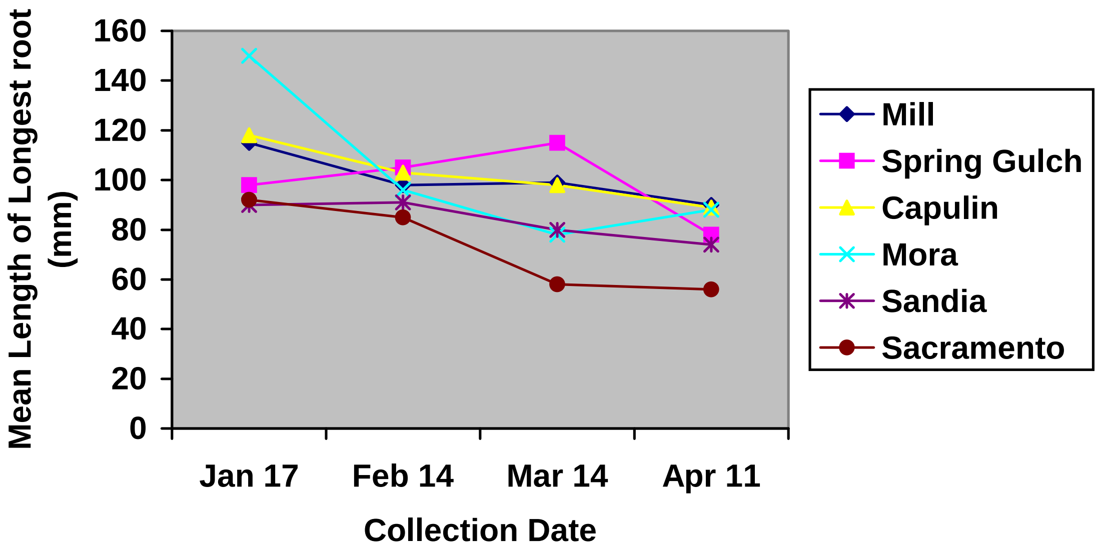

Figure 7: Mountain Snowberry Cutting Study–Effect of collection date on mean length of longest root by source 150 days after sticking

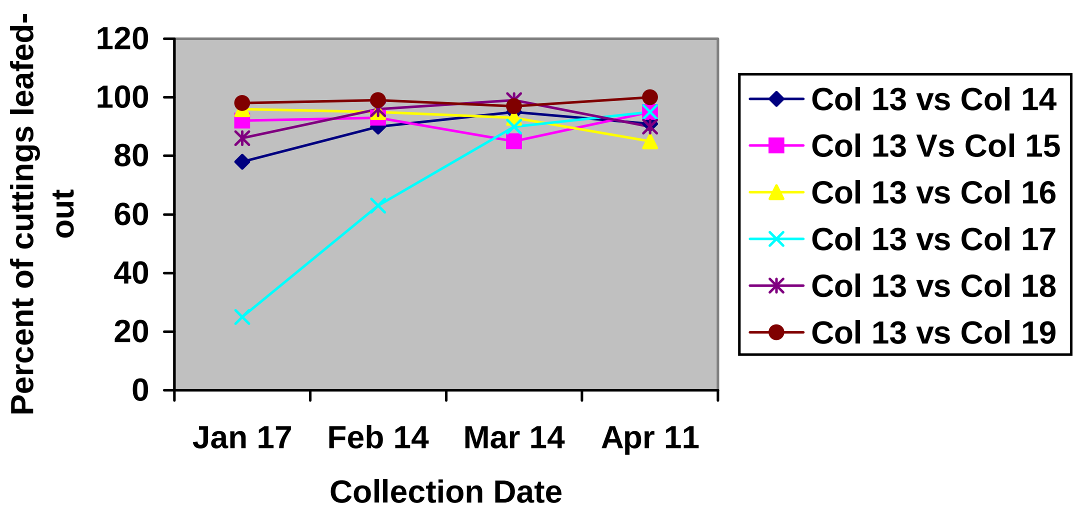

Figure 8: Effect of collection date on number of cuttings leafed-out by source 3 weeks after sticking

Discussion

Species of snowberry (*Symphoricarpos*) have been successfully propagated by stem cuttings (Anonymous 1948, Dirr and Heuser 1987). Wildings of mountain snowberry, consisting of a small piece of stem having a short length of root, were found to propagate easily (Plummer et al. 1969). Softwood and semi-hardwood cuttings of common snowberry (*S. Albus*) taken June through August rooted from 90%-100%, when treated with IBA-talc solutions of 1000-3000 ppm (Dirr and Heuser 1987). Hardwood cuttings of common snowberry taken in December and January and treated with 3000 ppm IBA-talc rooted 90-100% in 4-6 weeks (Dirr and Heuser 1987).

This study employed a quick dip in a solution of equal parts IBA and NAA to improve the potential for increased root initiation. Concentrations of 250-1000 parts per million IBA/NAA increased the rooting percentage in mountain snowberry cuttings compared to either the 2000 parts per million or no hormone treatments. However, this improvement varied by source and by collection date, and rooting did not improve with any hormone treatment for some source and collection date combinations. Variation in source response to hormone treatment may be ecotypic and/or related to differing environmental conditions at each collection site. Both of these factors could influence the stem morphology, affecting absorption of the hormone solution as well as the duration of time adequate levels of hormone was maintained within the stem.

The growing conditions of the parent plant strongly influence cutting rooting ability (Moe and Anderson 1988). Climate and microclimate of native stands influences the duration of bud dormancy in winter as well as the accumulation of carbohydrates within stem tissue in summer, and these factors will vary from year to year. Hardwood cuttings taken before adequate chilling has taken place root poorly unless chilled further, and cuttings taken too late in the season may root poorly if the parent plant is in a high state of water stress prior to cutting (Loach 1988). Carbohydrate content within stem tissue may also vary during the dormant season influencing the optimal date for cuttings to be collected (George and McKell 1978).

Rooting percent varied among the sources with the three sources from the more northerly latitudes having the highest percentage of cuttings rooting. Within, the most northerly sources, the three Molycorp mine sources, rooting percentage was inversely related elevation. The shorter growing season at higher elevations may result in less stored carbohydrates in stems. Cuttings from Sandia and Mora had less cuttings root when compared to the Molycorp sources, but a greater number when compared to the most southerly source, Sacramento. The lack of any climatic data from several of these collection sites precludes the assignment of these trends to the stock plant environment or stock plant genotype.

Timing of cutting also influences the response to cultural treatments. Typically, non-dormant hardwood cuttings should be stuck in advance of warm spring temperatures, which can induce rapid shoot growth before adequate root development has taken place resulting in tissue desiccation (Hartmann and Kester 1990). Reduction of the leaf-to-air vapor pressure gradient, which is the driving force behind leaf water loss in cuttings, can be accomplished by maintaining low leaf temperatures by cooling, shading, or misting and by maximizing the ambient humidity in the rooting environment (Loach 1988). These needs must be balanced by the need for adequate irradiance, and the need to maintain the base of cuttings at an optimal level of warmth (generally $23^{o}C$ - $27^{o}C$) for root initiation and development (Hartmann and Kester 1990). In this study, efforts were made to create similar greenhouse conditions and regimes for the various collection dates being examined, a span of 12 weeks. In this study, optimal rooting response occurred in late winter/early spring for all but the highest elevation source from the Molycorp site, which had optimal rooting at the preceding collection date. This may be related to the carbohydrate supplies of the cuttings.

Levels of non-structural carbohydrates in mature stems of mountain snowberry reach a yearly high just before the onset of dormancy, and this pool is partially depleted during dormancy (George and McKell 1978). These reserves provide resources to basal root sprouts, which rapidly elongate in the early spring prior to the resumption of growth along older stems (George and McKell 1978). Levels of carbohydrate reserves in stems may also influence the rooting response in stem cuttings as the new root tissues have to compete with other strong sinks, such as expanding leaves, for these reserves.

There were no discernable elevational or latitudinal patterns in meeting chilling requirement (timing of collection) based on initial leafing-out. Nor were there any discernable elevational or latitudinal patterns in rooting percent with the exception of the highest elevation source from the Molycorp site, Capulin.

Literature Cited

Anonymous. 1948. Woody Plant Seed Manual. USDA Forest Service Miscellaneous Publication No. 654.

Brotherson, J.D. 1992. Mineral nutrient concentrations in the mountain mahogany species *Cercocarpus montanus* and *Cercocarpus intricatus* and in their associated soils.

Davis, T.D. 1988. Photosynthesis during adventitious rooting. In Adventitious Root Formation in Cuttings. Edited by T. Davis, B. Haissig, and N. Sankhla. Discorides Press, Portland. pp.79-87.

De Klerk, G., Van der Krieken, W., De Jong, J. 1999. The formation of adventitious roots: new concepts, new possibilities. In Vitro Cellular Developmental Biology 35: 189-199.

Deitschman, G.H., Jorgenson, K.R., Plummer, A.P. 1974. *Cercocarpus* H.B.K. In Seeds of Woody Plants in the United States. Coordinated by CS Schopmeyer. USDA Forest Service Agriculture Handbook No. 450. pp. 309-312.

Dirr, M.A., Heuser, C.W. 1987. The Reference Manual of Woody Plant Propagation. Varsity Press, Athens, Georgia.

Dreesen, D.R., Harrington, J.T. 1997. Propagation of Native Plants for Restoration Projects in the Southwestern U.S.- Preliminary Investigations. In T.D. Landis, J.R. Thompson, tech. coords. National Proceedings, Forest and Conservation Nursery Associations. USDA Forest Service

George, M., McKell, C. 1978. Distribution of food reserves in snowberry (*Symphoricarpos oreophilus*). Journal of Range Management. 31(2): 101-104.

Harrington, H.D. 1954. Manual of the Plants of Colorado. Sage Books, Denver.

Hartmann, H.T., Kester, D.E. 1990. Plant Propagation. Prentice-Hall, Englewood Cliffs, New Jersey.

Kevers, C., Hausman, J.F., Faivre-Rampart, O., Evers, D., Gaspar, T. 1997. Hormonal control of adventitious rooting: progress and questions. Angewandte Botanik. 71: 71-79.

Loach, K. 1988a. Water relations and adventitious rooting. In Adventitious Root Formation in Cuttings. Edited by T. Davis, B. Haissig, and N. Sankhla. Discorides Press, Portland. pp. 102-116.

Marshall, K. 1995. Winkler, G. 1987. *Ribes cereum.* In: Fischer, W.C., compiler. The Fire Effects Information System [Data base]. Missoula, MT: U.S.D.A., Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory.

McMurray. 1986. *Symphoricarpos oreophilus*. In: Fischer, W.C., compiler. The Fire Effects Information System [Data base]. Missoula, MT: U.S.D.A., Forest Service, Intermountain Research Station, Intermountain Fire Science Laboratory.

Moe, R., Anderson, A.S. 1988. Stock plant environment and subsequent adventitious rooting. In Adventitious Root Formation in Cuttings. Edited by T. Davis, B. Haissig, and N. Sankhla. Discorides Press, Portland. pp. 214-234.

Monsen, S.B. 1984. Use of shrubs on mine spoils. In The Challenge of Producing Native Plants for the intermountain area. Proceedings: Intermountain Nurseryman's Association 1983 Conference. Las Vegas, Nevada. USDA Forest Service GTR-INT-168. pp.26-31.

Paschke, M.W. 1997. Actinorhizal plants in range lands of the western United States. Journal of Range Management. 50 (1) 62-67.

Pfister, R.D., 1974. *Ribes* L. Currant, gooseberry. In Seeds of Woody Plants in the United States. Coordinated by C.S. Schopmeyer. USDA Forest Service Agriculture Handbook No. 450. pp.720-727.

Plummer, A.P., Jorgensen, K.R., Christensen, D.R., Stevens, R. 1969. Cooperative Pittman-Robertson Project W-82-K, USDA Forest Serv., Intermt. Forest and Range Exp. Stn., and Utah Fish and Game, Ephraim, Utah.

Smith, D.R., 1971.Growth Responses of True Mountain Mahogany on Four Soil Types within the Front Range of Colorado. Ph. D. Dissertation. Utah State University.

Vines, R.A. 1960. Trees, Shrubs, and Woody Vines of the Southwest. University of Texas Press, Austin.

Woodmansee, R. G. 1969. Natural Reproduction of *Eurotia lanata*, *Atriplex canescens*, *Cercocarpus montanus*, and *Cowania mexicana* in New Mexico. Masters Thesis.

Young, J.A., Young, C.G. 1992. Seeds of Woody Plants in North America. Discorides Press, Portland.

One- and Three-Year Transplant Performance of Container Grown Stock Planted at a High Elevation, Disturbed Site[9]

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Abstract

The Molycorp, Inc. Questa mine is located in northern New Mexico in an area of steep topography. Rock pile construction from overburden during open pit operations utilized steep canyons to create the piles. The resulting rock pile slopes are relatively shallow, steep and high (over 500 feet). A state highway and river, located near the toe of the slopes preclude reshaping of the piles. The angle (steepness) of the slopes is similar to the natural topography, which supports primarily a mixed conifer ecosystem. Standard forestry techniques have been adapted for the revegetation program. In general, seedlings of the overstory and shrub species are hand planted on the slopes, directly into the overburden using hoedads. Development of a self-sustaining ecosystem appropriate to the site is the underlying goal of the revegetation program. The relatively rapid physical weathering of the overburden rock creates a suitable planting medium for the seedlings. Both the fast growing early successional overstory species (*Populus angustifolia, Robinia neomexicana,* etc.) and the slower growing, later successional overstory species (*Pinus ponderosa, P. flexilis, Abies concolor*, etc.) are planted simultaneously along with appropriate understory species. The differential growth of the two types of overstory species is intended to shorten the time frame to achieve a more stable, later successional plant community. First year survival for transplants has averaged 80% and 3-year stocking rates are between 80% and 97% of the original planting rates. This survival rate has been attributed to three main features of the program: 1) using site adapted (genetic) stock; 2) planting pre-conditioned container grown stock; and 3) proper planting techniques. The expanded revegetation program is in its fourth year with over 130,000 seedlings planted.

[9] This research was funded through grants from Molycorp, Inc., Questa, NM

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Introduction

The Molycorp Inc., Questa Molybdenum Mine has been in operation since 1921. The mine is located in an area of steep, mountainous topography in narrow canyons adjacent to the Red River five miles east of the town of Questa, New Mexico in Taos County. Underground mining occurred from 1921 to the early 1960s when open pit development of the ore body began. The open pit mine operated from 1965 through 1983. From 1983 to the present mining is an underground block caving operation.

The open pit period of extraction generated 328 million tons of overburden. Deposition of this overburden material utilized the natural steep, long slopes and narrow canyons for the development of the overburden rock piles. Today, the rock pile surfaces are steep and long, in some cases exceeding 500 feet in length. Unlike other mining operations where rock piles are situated on relatively flat ground and the height of the piles is indicative of pile depth, the depth of the rock piles at Molycorp range from 60 to 125 feet in thickness (depth) (Robertson GeoConsultants, Inc. 1999). The resulting overburden depth was a function of several factors including underlying topographic features including slope, slope length and overburden structural composition and its influence on angle of repose. The resultant surface of the rock piles has similar slope intensity to the adjacent natural topography.

The terrain surrounding the mine supports primarily coniferous ecosystems with riparian ecosystems in the bottoms of many canyons having perennial streams or rivers. The conifer dominated ecosystems range from ponderosa pine (*Pinus ponderosa*), to mixed conifer (*P. flexilis*, *Pseudotsuga menziesii*, *Abies concolor*) to spruce-fir (*Picea engelmannii* and *Abies concolor*) stands. Topographic features, specifically elevation and aspect strongly influence species distribution (Wagner and Harrington, 1994). Also, edaphic features, which include rooting mantle thickness, water holding capacity and nutrient availability, likely influence vegetation distribution in the area. Areas in which the coniferous overstory have been disturbed, various shrub (*Quercus* spp., *Cercocarpus montanus*, *Ribes* spp.), aspen (*Populus tremuloides*) and narrowleaf cottonwood (*P. angustifolia*) dominated communities occur.

The other natural feature that appears to strongly influence vegetation distribution in this region is hydrothermal scars. These naturally occurring areas have highly erodible, and acidic “soils” (Meyer and Leonardson 1990). During the open pit-mining operations, hydrothermal scars were excavated along with intervening areas of more neutral geologic materials. Heterogeneous overburden piles resulted with a wide range of particle sizes, and chemistries (specifically pH).

Consistent with the variability in vegetation surrounding the mine, the mine itself offers a broad range of planting sites. For example, elevation ranges from 8,000 feet to 10,000 feet and almost every aspect occurs. In addition to the variability in the overburden thickness, overburden particle size ranges from clay-sized fines to large cobble, and overburden pH ranges from neutral (pH 7) to very acidic (pH 3). This site diversity will require a range of revegetation techniques be employed to revegetate the site.

Goals of Revegetation Program

Traditional approaches to revegetation of overburden materials often involves drastic recontouring and capping with various materials to support plant growth, and in several cases manipulate water movement. However, many features of this site indicate that developing new revegetation techniques and technologies or modifying existing ones would be more advantageous to both Molycorp and the overall watershed. Some of the technologies and techniques developed from the *in situ* revegetation of the overburden would be applicable to other, natural areas in the watershed which are actively eroding.

The goals of the reclamation program at the mine site are to stabilize the site and reduce erosion, to reduce water infiltration and increase evapotranspiration and to establish a productive plant ecosystem compatible with the adjacent plant communities. The rationale behind using forestry as a post-mining land use a the mine site is that this is a consistent land use to the previous as well as surrounding current land use. This post-mining land use is also consistent with the underlying principles of restoration ecology (Bradshaw, 1987). Further, using a mixture of plant types (trees, shrubs, forbs and grasses) will broaden the depth and quality of the overall root system, thereby improving site stability (Gray and Sotir, 1996). The reclamation program is also based on the natural regeneration and establishment of conifers on the low pH, highly erodible scar areas surrounding the mine site.

The mine site revegetation is focused on the concept of using a nurse tree crop along with an economic (or crop) tree and establishing both simultaneously. The nurse trees are trees and sometimes shrubs that make the site more suitable for crop tree (or the long term tree) establishment and growth. The nurse trees also aid and expedite site stabilization and uses early successional species.

The operational revegetation is based on site-specific and published research results as well as a technique's ability to meet the specific goals for the planting unit. Research areas have included species and seed source screening on overburden pHs, stock type suitability, local seed source propagation, planting windows, and fertilizer incorporation (Harrington et al., 2000). The operational plantings utilize hand planting of tree and shrub seedlings that have been produced form local seed sources whenever possible. This process is consistent with the regeneration ecology of adjacent stands. Hand planting reduces the compaction and does not impede deep root exploration.

Previous Revegetation Research

Beginning in the mid-1970s Molycorp has been actively funding revegetation research at their Questa mine. Initially, this research effort began with the then Soil Conservation Service Plant Materials Center in Los Lunas, New Mexico (currently, the Natural Resource Conservation Service, Los Lunas Plant Materials Center (NRCS-LL-PMC). This research effort continues today. In 1992, Molycorp expanded this effort by expanding funding to include New Mexico State University researchers at the Mora Research Center (NMSU-MRC). This research effort also continues today.

Materials and Methods

The plants used in these studies and the operational program are container grown seedlings produced in greenhouses. The majority of seedlings are produced in 10 in^3 containers® (Steuwe and Sons, Inc. Corvallis, OR). Other containers used have included D-16, D-40 and styroblocks. The NMSU-MRC and NRCS-LL-PMC facilities have produced the plant materials used in the operational plantings under appropriate production regimes. When possible and depending on availability, local seed sources have been used. Planting of seedlings uses traditional container planting techniques (dibble bars, hoedads, etc.) adjusted to accommodate unique site features such as rockiness and steep slopes.

Operational Planting Techniques

In September of 1996, the first operational planting was conducted on the top portion of one of the lower (elevation) rock piles, (Spring and Sulphur Gulch rock pile, SSG). The elevation of this rock pile ranges from 8,200 ft. to 8,650 ft with a field pH of >6.0 and is composed of aplite and black andesite rock (SRK, 1995). The planting was done by hand using a contract planting crew. The plant material consisted of a wide range of plant species (Table 14). In general the relative proportion of plant forms was as follows: 35% deciduous trees; 40% coniferous trees; and, 25% shrubs. All plant materials were grown in reforestation containers as described above at the NMSU-MRC Research Nursery or the NRCS-LL-PMC. Planting crews were told to select plant materials to maximize diversity at the planting site. (Note: some members of the planting crew were better at this than others.) The planting crews were given instructions to plant seedlings 3 ft apart within rows and the rows were to be 4 ft apart (1.0 m X 1.2 m).

Table 14: List Of Species And Plant Form Category By Year Of Planting

Plant Species		**Plant Form Category**	**Year**	
Common Name	**Scientific Name**			
Bristlecone Pine	*Pinus aristata*	Coniferous tree	1996	1997
Ponderosa Pine	*Pinus ponderosa*	Coniferous tree	X	
Southwestern White Pine	*Pinus strobiformis*	Coniferous tree	X	X
Limber Pine	*Pinus flexilis*	Coniferous tree	X	X
Douglas fir	*Psuedotsuga menziesii*	Coniferous tree		X
White Fir	*Abies concolor*	Coniferous tree	X	
Engelmann Spruce	*Picea engelmannii*	Coniferous tree	X	
Blue Spruce	*Picea pungens*	Coniferous tree		X
Rocky Mountain Juniper	*Juniperus scopulorum*	Coniferous shrub	X	
Pinyon Pine	*Pinus edulis*	Coniferous shrub	X	X
New Mexico Locust	*Robinia neomexicana*	Deciduous tree	X	X
Chokecherry	*Prunus virginiana*	Deciduous shrub		X
Oak	*Quercus gambelii*	Deciduous shrub		X
Kinnikinnik	*Arctostaphylus uva-ursi*	Deciduous shrub	X	
Narrowleaf cottonwood	*Populus angustifolia*	Deciduous tree	X	
Fringed Sage	*Artemisia frigida*	Deciduous shrub	X	X

Table 14: List Of Species And Plant Form Category By Year Of Planting

Plant Species		Plant Form Category	Year	
Common Name	**Scientific Name**			
Rubber Rabbitbrush (Chamisa)	*Chrysothamnus nauseosus*	Deciduous shrub	X	X
Four-wing Saltbush	*Atriplex canescens*	Deciduous shrub	X	
Mountain Mahogany	*Cercocarpus montanus*	Deciduous shrub	X	X
Fernbush	*Chamaebatiaria millefolium*	Deciduous shrub	X	X
Alder	*Alnus tenuifolia*	Deciduous tree		X
Currant	*Ribes spp.*	Deciduous shrub		X

The following year, June 1997, two additional sites were planted in the same manner. The first site was the lower level of the Middle rock pile immediately to the west of the 1996 planting and this site is similar in elevation, pH and rock type. The second site was the Capulin rock pile, one of the highest locations on the site ranging from 9,250 ft. to 9,800 ft. in elevation, with a field pH of 3.6 to 3.8 and composed of mixed volcanic rocks (SRK 1995). Approximately 30,000 to 35,000 seedlings were planted (total) using the same method described for the 1996 planting. Species for these plantings are listed in Table 14 and percentages of life forms were similar to the 1996 planting. Species mixes were adjusted to the planting site conditions. For example, fewer pinyon or junipers (evergreen shrubs) were planted at the Capulin site because of its elevation.

Vegetation Analysis

In August of 1997, nine 100m^2 (50m x 2m) transects in the 1996 planting area were randomly selected and measured to evaluate survival and stocking (number of plants / hectare). Species composition and frequency were recorded. Status categories included: living, dead, living and partially covered, dead and partially covered. No interpretations of the vigor of the seedlings were made. For ease of installation and consistency, all transects were placed perpendicular to the slope direction.

In May, 2000 stocking levels were determined for the three planting sites discussed in this report. Transects were placed as described for the August 1997 survival measurements. At the Capulin rock pile, 3 transects were placed, 3 transects were placed for the Middle rock pile and 6 transects for the SSG rock pile. Species composition and frequency were recorded. Status categories included number of living seedlings, number of covered seedlings (living), and number of seedlings with broken tops (browse damaged). These status categories were used to quantify the condition of the established seedlings. Covered indicates that there have been movement of rocks, small particles or other material over the seedling. This category includes plants that appear to be unaffected by the covering (small amount of stem covered) to those with a larger portion of the stem covered but still living. The number of living seedlings per hectare is reported as adjusted and non-adjusted stocking levels. The adjusted stocking level accounts for areas with large cobble or scree slopes that were deemed unplantable by the planting crew and therefore no seedlings were transplanted in these areas. Stocking levels are determined by multiplying the numbers in the transect by 100 for non-adjusted rates. Adjusted levels reflect the shortened transects due to the presence of cobble.

Data were analyzed using descriptive statistics including means and standard deviation (SAS Institute, Inc. 1996). Sums were generated from the raw data for plot by species combinations.

Results

Overall, first year survival of the 1996 planting was 81% (Table 15). Survival by plant category ranged from 94% for coniferous shrubs (juniper and pinyon pine) to 63% for deciduous trees. Observations indicate that the narrowleaf cottonwood planted in the fall of 1996 was likely planted without sufficient dormancy for an early frost. Percentage of covered seedlings ranged from 5% for deciduous trees to 16% for coniferous shrubs. Overall, only 9% of the seedlings showed signs of covering.

Table 15: One year survival for September 1996 planting at Spring and Sulphur Gulch rock pile (SSG). Plot was measured in August 1997. The target planting rate based on a 3 ft. by 4 ft. (1.0 X 1.2 m) spacing was 9075 seedlings per hectare.

Plant Category	Evaluation for Planted [1]	Mean	Std. Deviation	Evaluation for Planted[2]	Mean	Std. Deviation
Coniferous trees	Planted (#/Ha)	4870	1388	Planted (#/Ha)	4656	1536
	% Live	87.4	1.6	% Live	87.4	1.6
	% Covered	9.5	1.4	% Covered	9.5	1.4
Coniferous shrubs	Planted (#/Ha)	204	187	Planted (#/Ha)	189	183
	% Live	94.1	5.7	% Live	94.1	5.7
	% Covered	5.9	5.7	% Covered	5.9	5.7
Deciduous Shrubs	Planted (#/Ha)	1179	759	Planted (#/Ha)	1133	786
	% Live	92.2	2.7	% Live	92.2	2.7
	% Covered	15.7	3.6	% Covered	15.7	3.6
Deciduous Trees	Planted (#/Ha)	2638	722	Planted (#/Ha)	2478	728
	% Live	63.2	3.2	% Live	63.2	3.2
	% Covered	4.5	1.4	% Covered	4.5	1.4
Total	Planted (#/Ha)	8930	1263	Planted (#/Ha)	8489	1771
	% Live	80.8	1.4	% Live	80.8	1.4
	% Covered	8.8	1.0	% Covered	8.8	1.0

[1] Planted is the number of seedlings counted (dead and alive) based on a 2 m by 50 m transect.
[2] Planted is the number of seedlings counted (dead and alive) based on the actual transect measured. Some transects were shortened because of the presence of cobble and those areas were unplantable.

Stocking levels were also evaluated, for the SSG site both one and three years after planting and for the other two sites, three years after planting (Table 16). All life forms were represented in all the areas. Plant density ranged from 6856 plants per hectare to 8833 plants per hectare when adjusted for cobble areas. The target planting rate was 9075 plants per hectare (unadjusted for cobble). The stocking rate for the SSG site is higher in 2000 than in 1997. There are two possible explanations for this change, one is that some of the seedlings evaluated as dead in 1997 may have root sprouted subsequently. The increase in stocking is evident for both deciduous trees and deciduous shrubs. The other explanation is that natural encroachment from the surrounding area is occurring at the site and some of these new seedlings may be volunteers.

Table 16: Stocking levels of planting sites (number per hectare) at Spring and Sulphur Gulch (SSG), Middle and Capulin rock piles. Plantings occurred in 1996 and 1997.

Planting Site	Plant Category	Years in ground at evaluation	Stocking [1]	Std. Deviation	Stocking [2]	Std. Deviation
SSG	Coniferous tree	1	4232	1553	4067	1667
	Coniferous shrub	1	187	184	178	186
	Deciduous shrub	1	1090	692	1044	714
	Deciduous tree	1	1662	546	1567	563
	Total	1	7171	1414	6856	1797
SSG	Coniferous tree	3	3778	918	3550	701
	Coniferous shrub	3	56	62	50	55
	Deciduous shrub	3	1228	777	1217	791
	Deciduous tree	3	2226	449	2133	524
	Total	3	7288	752	6950	1106
Middle	Coniferous tree	3	3907	140	3567	321
	Coniferous shrub	3	421	312	367	252
	Deciduous shrub	3	1644	600	1533	666
	Deciduous tree	3	1541	581	1433	666
	Total	3	7513	667	6900	1253
Capulin	Coniferous tree	3	5167	1595	N/A	N/A
	Coniferous shrub	3	67	58	N/A	N/A
	Deciduous shrub	3	1767	351	N/A	N/A
	Deciduous tree	3	1800	755	N/A	N/A
	Unknown	3	33	58	N/A	N/A
	Total	3	8833	2312	N/A	N/A

Stocking [1] is stocking levels (no./ha) not adjusted for areas of cobble that are unplantable.
Stocking [2] is stocking levels (no. / ha) adjusted for areas of cobble that are unplantable.
N/A = Not applicable, for the Capulin rock piles no areas of cobble were found that were unplantable

The number of seedlings affected by cover and browse varies greatly (Table 17). In the 2000 evaluation, all the seedlings noted as covered or browsed were still alive. Conifer seedlings at the Capulin rock pile appear to be the most affected by browse. Covering varies from site to site. The Spring and Sulphur Gulch rock pile shows the least evidence of covering (717 plants/ha), with the Middle and Capulin rock piles showing similar levels of covering (2000 and 1700 plants/ha respectively).

Table 17: Condition of Plants as Measured in the Field 1 And 3 Years Post-Planting. Numbers are reported in number of plants per hectare.

Planting Site	Plant Category	Covered [1]	Std. Dev.	Covered [2]	Std. Dev.	Browsed [1]	Std. Dev.	Browsed [2]	Std. Dev.
SSG (1997 evaluation)	Conif. tree	463*		442*					
	Conif.shrub	12*		11*					
	Decid.shrub	185*		178*					
	Decid. tree	119*		112*					

Table 17: Condition of Plants as Measured in the Field 1 And 3 Years Post-Planting. Numbers are reported in number of plants per hectare.

Planting Site	Plant Category	Covered [1]	Std. Dev.	Covered [2]	Std. Dev.	Browsed [1]	Std. Dev.	Browsed [2]	Std. Dev.
	Total	786*		747*					
SSG (2000 evaluation)	Conif. tree	494	332	467	327	193	121	183	117
	Conif.shrub	18	43	17	41	0	0	0	0
	Decid.shrub	83	98	83	98	0	0	0	0
	Decid. tree	155	163	150	164	0	0	0	0
	Total	750	398	717	407	193	121	183	117
Middle	Conif. tree	1038	529	969	569	187	76	167	58
	Conif.shrub	227	131	200	100	77	7767	67	58
	Decid.shrub	658	285	600	265	0	00	0	0
	Decid. tree	250	145	233	153	0	00	0	0
	Total	2173	870	2000	900	264	143	233	115
Capulin	Conif. tree	1133	513	N/A	N/A	1600	872	N/A	N/A
	Conif.shrub	33	58	N/A	N/A	33	58	N/A	N/A
	Decid.shrub	1133	379	N/A	N/A	33	58	N/A	N/A
	Decid. tree	900	889	N/A	N/A	33	58	N/A	N/A
	Unknown	33	58	N/A	N/A	0	0	N/A	N/A
	Total	3233	1644	N/A	N/A	1700	954	N/A	N/A

[1] Indicates numbers are not adjusted for cobble areas that are unplantable.
[2] Indicates numbers are adjusted for cobble areas that are unplantable.
* Indicates numbers estimated from Table 2.
N/A = Not applicable, for the Capulin rock piles no areas of cobble were found that were unplantable.

Summary

The initial results and three year stocking rates demonstrate that the planting techniques and planting stock used at the site allow for successful establishment of forest seedlings. All three sites are still stocked at 80% of the target planting rate. Capulin, the rock pile at the highest elevation and the lowest pH shows stocking at 97% of the planting rate. However, it was noted that some planters planted closer than the 1 m by 1.2 m spacing standard which could in part explain the higher stocking levels at Capulin.

The target stocking rates for evaluation of the reclamation to determine successful establishment is currently proposed at 150 to 275 crop trees per acre depending upon the site conditions. There is also provision for measuring the understory and/or nurse crop trees with a separate standard. These evaluations do not take place until a minimum of twelve years post planting or fertilization (if applicable).

While there is evidence of browse damage and covering of seedlings, this does not yet appear to be at a level to significantly impact the revegetation efforts. These conditions should continue to be monitored in these plantings as well as in future plantings. In many cases observed, while the seedling is impacted by either browse or covering, the seedling continues to survive.
Growth has not yet been measured or used as an indicator of success. At this site previous plantings (early 1990s) and the natural regeneration on surrounding slopes seems to indicate that growth lags behind establishment. From unpublished data collected to date, seedlings (both

transplanted and natural regeneration) appear to put energy into root development and little into shoot growth for the first four to six years after establishment (Harrington 2000, unpublished data). After four to six years shoot growth becomes evident on an annual basis. It is anticipated that within the next two years, shoot growth will be measured to assist in determination of successful establishment at these sites.

The successful establishment of seedlings at the site has been attributed to three factors. As noted above, whenever possible, site adapted (genetic) plant material is used in the planting program. For some species this appears to be a critical component of successful establishment (Harrington et al., 2000). The second factor is using pre-conditioned, container grown stock. The higher than expected mortality of the narrowleaf cottonwood in the 1996 Fall planting was in part because the plants were not conditioned properly and were susceptible to an early frost kill. Lastly, proper planting techniques, as is seen in any forestry planting, are critical to successful establishment of the seedlings. The 80% survival and the subsequent stocking levels three years after transplanting are evidence that the seedlings are planted properly.

This reclamation program is in the early stages of implementation with approximately 15% of the disturbed acreage planted to date. The program is intended to plant incremental areas over the period of anticipated mine operations (30 years) which will allow for continued development and research of plant material, planting techniques and post-planting maintenance. The reclamation program has a long-term objective of establishing a self-sustaining forest ecosystem at the site that is appropriate to the area.

Literature Cited

Bradshaw, A.D. 1987. Restoration: an Acid Test for Ecology. In: Restoration Ecology, Chapter 2. M.E. Gilpin and J.A. Aber (eds.). Cambridge University Press. 342 pp.

Gray, D.H. and R.B. Sotir. 1996. Biotechnical and Soil Bioengineering Slope Stabilization. John Wiley and Sons, Inc. New York. 378 pp.

Harrington, J.T., A.M.Wagner and D.R. Dreesen. 2000. Successful Techniques for High

Altitude Steep Slope Revegetation. Proceedings: 2000 Billings Land Reclamation Symposium. March 20-24, 2000. Billings, MT.

Meyer, J. and R. Leonardson. 1990. Tectonic, Hydrothermal and Geomorphic Controls on Alteration Scar Formation near Questa, New Mexico. New Mexico Geological

Society Guidebook, 41st Field Conference, Southern Sangre de Cristo Mountains, New Mexico, 1990.

Robertson GeoConsultants, Inc. 1999. Interim Report: Questa Waste Rock Pile Drilling, Instrumentation and Characterization Study. Interim Report 052007/1. Prepared for Molycorp, Inc., September 6, 1999.

SRK. 1995. Questa Molybdenum Mine Geochemical Assessment. Prepared for Molycorp, Inc., April 13, 1995. Steffen Robertson and Kirsten (U.S.), Inc. Project No. 09206.

Wagner, A. M. and J. T. Harrington. 1994. Revegetation Report for Molycorp, Inc. Report prepared for Molycorp, Inc. – New Mexico Mine Permit TA001RE.

Blunt panic (*Panicum obtusum*)

By: E. Ramona Garner[13]

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Blunt Panic is a native, stoloniferous, perennial, warm-season grass. It is found typically in sandy or gravelly soil, chiefly in moist sites along stream and ditch banks. It is fair to good forage for livestock and wildlife and can withstand heavy grazing. Because of its stoloniferous habit blunt panic often grows in dense stands and is may be used to stabilize washes and prevent soil erosion.

Seed of blunt panic typically has low germination. This low germination is due to a low percent of seed fill. Populations of blunt panic typically have three ploidy levels; diploid (2n=36), triploid (2n=27) and tetraploid (2n=36 and 2n=40). Of the three ploidy levels present, only the diploid plants were sexual in their mode of reproduction. The triploid and tetraploid plants are facultative apomictics with both sexual and apomictic florets.

Bulk seed collections of blunt panic were made from 80 collections throughout New Mexico. In 1983, seedlings were transplanted to the field into non-replicated accession rows. Plots were 2 rows of 14 plants per row. In 1995 seed was hand harvested for each of the 80 accessions in the preliminary evaluation field. In 1997, germination tests were conducted on the eighty accessions. Single plants from the 30 accessions with the highest germination were grown and transplanted into the field in August 1997. Upon maturity these accessions will be evaluated for seed fill and forage yield.

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Mexican white sagebrush (*Artemisia ludoviciana mexicana*)

By: E. Ramona Garner[14]

Project Number: NMPMC-P-9801-WL

Mexican white sagebrush is a native, fast growing, aromatic, long-lived perennial forb. Plants usually occur in clusters 1 to 3 ft tall. It is extremely drought and cold tolerant. Mexican White Sagebrush may reproduce both sexually and asexually. It produces numerous wind-dispersed seed in the fall. Vegetative reproduction is by rhizomes. Colonies have been reported to reach diameters of 50 feet. It has a wide ecological scope and is able to occupy a diversity of sites throughout the western United States. Mexican white sagebrush may be more palatable than the other species of Louisiana sagebrush. However, all species of Louisiana sagebrush have value as food and environmental protection for livestock and wildlife. It is a very important species in restoring disturbed sites. It is easily established and plants spread rapidly by rhizomes, providing excellent soil cover and stabilization.

Mexican white sagebrush was collected from various sites throughout the San Juan basin in northwestern New Mexico in 1995 and 1996. In 1997 the seed was mixed and planted as individual plants into a small preliminary evaluation. The plants were visually evaluated in 1998, 1999 for time of flowering, seed yield, seed viability and various agronomic characters related to harvest. From the test planting it was determined that this accession produced large amounts of viable seed and reached a mature height that facilitated easy harvest. It was determined that there was relatively no difference in time of flowering. The seed from these plants was used to produce containerized plants to use in an advance evaluation planting in the fall of 1999. In early spring 2000 there was no visible sign of these plants, jackrabbit predation had destroyed all above ground plant parts. However, by late spring shoots appeared and there was no lasting damage. These plants will be evaluated in 2001 for plant size and clump size.

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Prairie junegrass (*Koelaria marcantha*)

By: E. Ramona Garner[15]

Project Number: NMPMC-P-9801-RA

Prairie junegrass is a cool season perennial grass, native to North America and temperate areas of Europe. Its range extends across the western, central and northeastern United States. In New Mexico it occurs at elevations between 5,500 and 10,000 feet. It provides excellent forage for all classes of livestock and wildlife. Populations of prairie junegrass may be either diploid (2n=14) or tetraploid (2n=28). Researchers have reported that ploidy level increases with drought stress and that tetraploid populations may reach anthesis as much as 21 days before their diploid counterpart.

Collections of prairie junegrass were made from 98 locations throughout New Mexico. The populations from New Mexico and two exotic populations were planted into non-replicated preliminary evaluation in 1984. These plots consisted of 2 rows of 14 plants. In 1989, three early flowering and three late flowering accessions were visually selected from this evaluation. The ploidy level of the selected accessions is unknown. The three early maturing accessions were collected from similar areas suggesting that they may have the same ploidy (Table 1). Two of the late maturing accessions are from Torrance County, NM suggesting that they may have the sam ploidy level

Table 18: Collection site information for prairie junegrass (*Koelaria macrantha*) accessions selected in 1989 for vigor and forage value.

Accession or PI Number	Maturity	Origin	MLRA	Elevation
9035465	early	Catron	39	6519
9035466	early	Catron	39	7483
9035467	early	Catron	39	6598
9035559	late	Torrance	70	6798
9035594	late	Torrance	70	6699
PI-207489	late	Afghanistan	-	-

Polycross blocks were established for the early and late accessions in 1989. Plants for both blocks were derived from the original collections. The polycross block for the late maturing accessions did not perform as expected and was abandoned in 1997. In 1998 superior plants were selected from the late maturing polycross block established in 1989. Seed was collected from these plants and clones were established from the parents. A preliminary evaluation was established in 1999 to compare the parents to the progeny. This planting is replicated 6 times and is a latin square design. Upon maturity these accessions will be evaluated for forage and seed yield.

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New Mexico feathergrass (*Stipa neomexicana*) and needleandthread (*Hesperostipa comata*)

By: E. Ramona Garner[16]

Project Number: NMPMC-P-9504-CR

New Mexico feathergrass and needleandthread are native perennial cool-season grass. They provides fair to good forage for livestock and wildlife. However, their long awns may prove injurious to livesock. It is widely believed that both can tolerate high levels of soil salinity; however this can not be verified through scientific literature. The breeding system of needleandthread is self-pollination. New Mexico feathergrass also appears to be primarily self-pollinated.

Seed of 61 needleandthread and 6 New Mexico feathergrass accessions were obtained from bulk seed collections throughout New Mexico, Arizona and Montana. In 1985 these bulk collections were established in a field into non-replicated accession rows. Plots consisted of 2 rows of 14 plants. Fifteen needleandthread accessions and 3 New Mexico feathergrass accessions were selected based on survival, foliage height and basal width. Seed was bulk harvested from all plants of the selected accessions.

A replicated entry evaluation of the selected accessions was established at two sites in 1994. The experimental units consisted of a plot containing 2 plants. The experiment at both sites was conducted in a randomized complete block with 9 replications. Site 1 has salinity levels ranging from 3.3 to 4.5 ms,cm^{-1} and site 2 ranges from 0.42 to 0.44 ms,cm^{-1}. In 1996 site 1 was abandoned because the site was overun with weeds and a majority of the plants had died.
In 2000 the site 1 planting was evaluated for possible evaluation. It was determined that the condition of the planting would distort any comparisons that might be made. In an attempt to salvage the project it was decided that we would visually select the superior plants. The species were divided by placing flags at each New Mexico feathergrass accession. The species were then visually evaluated for vigor and 12 superior plants from each species were selected. Of the 15 original needleandthread accessions 8 were represented selection of superior plants. All three of the original New Mexico feathergrass accessions were represented (Table 19).

Table 19: **Selection Of Superior Plants Of needleandthread And New Mexico feathergrass**

New Mexico feathergrass Accessions		Needleandthread Accessions	
Accession	**Percent of Superior Selections**	**Accession**	**Percent of Superior Selections**
9032448	50%	9012934	17%
9032447	33%	9032478	8%
Wapaki	17%	9029816	17%
		9029823	17%

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Table 19: **Selection Of Superior Plants Of needleandthread And New Mexico feathergrass**

New Mexico feathergrass Accessions		Needleandthread Accessions	
Accession	**Percent of Superior Selections**	**Accession**	**Percent of Superior Selections**
		9027066	8%
		9025658	8%
		9032478	8%
		9029812	17%

Desert needlegrass (*Achnatherum speciosum*)

By: E. Ramona Garner[17]

Project Number: NMPMC-P-9504-CR

Desert needlegrass is a native, cool-season, perennial bunchgrass. It is occurs from Colorado west to Nevada and south into Arizona, southern California and northern Mexico. It produces significant foliage and provides good forage when young. Summer forage contains as much as 6.7% protein which drops to 2.3% when dormant. It is palatable to livestock and wildlife. Desert needlegrass may reproduce asexually and sexually. It is wind pollinated and each plant has the potential to produce large amounts of seed. Vegetative reproduction occurs with the annual growth of new tillers. Compared to other needlegrasses, desert needlegrass occurs in the most arid and harsh environments.

Desert needlegrass was collected from various rocky sites in or near the hogbacks region of northwestern New Mexico in 1995 through 1996. In 1997 all seed was mixed and placed into an evaluation planting. These plants will be evaluated for time of flowering when they become mature. Seed of like flowering plants will be mixed and put into an advanced evaluation.

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Giant sacaton (*Sporobolus wrightii*)

By: E. Ramona Garner[18]

Project Number: NMPMC-P-8401-CP

Giant sacaton is a native, robust perennial warm-season bunchgrass. It is distributed throughout the southwestern United States, usually occurring on low alluvial flats and flood plains. It is useful forage for livestock and wildlife. Under irrigation giant sacation may reach heights exceeding 2 m. Based upon its density and height it has potential as a windbreak plant for irrigated cropland.

Seed collections of giant sacaton were made from 37 locations throughout New Mexico. These collections were used to establish non-replicated accession rows in the field. Based on a visual evaluation of vigor and height 10 superior plants were selected. From these 10 plants 1 super selection was made.

In 1992 clonal shoots of each selected plant were planted into a testcross block with the super plant as the male tester. In 1995 seed was hand harvested from each female parent. This seed was used to establish an evaluation containing parents and progeny. The progeny were derived from seed and the parents were vegetatively propagated. Both sets of plants were grown in 6-inch square pots for 8 months in an attempt to equalize carbohydrate reserves in the seed derived plants and the clones.

At maturity these plants will be evaluated for height, width and vigor.

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Longtongue muttongrass (*Poa fendleriana longiligula*)

By: E. Ramona Garner[19]

Project Number: NMPMC-P-9504-CR

Longtongue muttongrass is a native cool-season bunchgrass with occasional short rhizomes. Although muttongrass species are dioecious, populations may have 85% female plants that produce seed without pollination. *Poa fendleriana longiligula* differ in that populations are mostly or totally female. Longtongue muttongrass provides good forage for wildlife and livestock. It may be grazed throughout the year, but it is most beneficial in early spring when other green forage is scarce. It has a deep fibrous root system that provides good soil erosion control, however it use in restoration projects is limited by the lack of seed availability. Longtongue muttongrass was collected from various sites throughout the San Juan basin in northwestern New Mexico in 1995 and 1996. In 1997 the seed was mixed and planted as individual plants into a preliminary evaluation. The plants were visually evaluated in 1998, 1999 and 2000 for time of flowering. It was determined that there was no difference in time of flowering. The seed from these plants will be used to plant an advance evaluation planting in 2001.

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Survival and Growth of Containerized Shrub Seedlings Six Years After Planting on Molycorp Overburden Piles 1994 Study[20]

By: David R. Dreesen[21]

Project Number: NMPMC-P-9803-CR

Abstract

The objective of this experimental planting was to evaluate the performance of shrub species on neutral and low pH overburden piles at the Molycorp mine near Questa, New Mexico. An extensive number of shrub species are components of the surrounding mountain shrub community and mixed conifer forest and some of these species have invaded the overburden piles and road cuts. A total of 17 species were planted; 15 species were grown from seed collected at the Molycorp site. A total of 24 ecotypes were evaluated and 22 ecotypes were Molycorp collections. Controlled release fertilizer application at planting and overburden type were factors investigated in this experiment. The overall mean survival percentage for all species/ecotypes was 54% after 6 years. The fertilizer treatment had little effect on survival, 54%, versus the control value of 53%. The Upper Blaster site had much lower survival, 38%, than the Spring Gulch site, 66%. If the plots with low pH overburden are not included, the mean survival was 53% at the Upper Blaster site. The shrub species/ecotypes with the highest overall survival were the following Molycorp ecotypes: Woods rose (*Rosa woodsii* Acc. 195) 90%, Fendler's barberry (*Berberis fendleri*) 79%, chokecherry (*Prunus virginiana* Acc. 203) 74%, wax currant (*Ribes cereum*) 71%, Woods rose (*Rosa woodsii* Acc. 196) 70%, and mountain mahogany (*Cercocarpus montanus*) 70%. The overall mean height of surviving seedlings after 6 years was 17 cm and the mean of the 22 species/ecotypes maximums was 41 cm. The tallest species based on means and maximums were New Mexico locust (*Robinia neomexicana* - 46 cm and 102 cm), bristly locust (*Robinia fertilis* - 28 cm and 76 cm), cliffbush (*Jamesia americana* - 26 cm and 66 cm), mountain mahogany (*Cercocarpus montanus* - 21 cm and 76 cm), raspberry (*Rubus* sp. - 20 cm and 41 cm), and rabbitbrush (*Chrysothamnus* sp. Acc. 237 - 19 cm and 51 cm). The overall mean crown width of surviving seedlings was 24 cm and the mean of the 22 species/ecotypes maximums was 54 cm. The species with the widest crown spread based on means and maximums include New Mexico locust (*Robinia neomexicana* - 50 cm and 127 cm), buckwheat (*Eriogonum* sp. Acc. 243 - 40 cm and 76 cm), buckwheat (*Eriogonum* sp. Acc. 242 - 39 cm and 76 cm), bristly locust (*Robinia fertilis* - 35 cm and 112 cm), rabbitbrush (*Chrysothamnus* sp. Acc.237 - 28 cm and 76 cm), and mountain mahogany (*Cercocarpus montanus* - 26 cm and 81 cm). The best performing species was *Rosa woodsii* Acc. 195 with excellent survival and good growth. Those species with good survival and good to excellent growth include *Cercocarpus montanus, Berberis fendleri*, *Chrysothamnus* sp. Acc. 237, *Ribes cereum*, *Eriogonum* sp. Acc. 242, and *Rubus* sp. *Robinia neomexicana* and *Jamesia americana* had good or excellent height and width growth but only fair survival. The large difference in

[20] Prepared for Molycorp, Inc., Questa, NM

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performance for *Rosa woodsii* ecotypes and *Chrysothamnus* sp. ecotypes implies that seed source may be an important factor in determining the effectiveness of revegetation with certain species. Survival patterns over 6 years indicate that *Robinia fertilis*, *Atriplex canescens*, and *Artemisia tridentata* were not adapted to these sites at 9000 feet; *Artemisia frigida* appears to be adapted but to be a short lived species.

Objective

The objective of this experimental planting was to evaluate the performance of shrub species on neutral and low pH overburden piles at the Molycorp mine near Questa, New Mexico. Of the 17 tested species, 15 species were grown from seed collected in the vicinity of the mine.

Differences in growth and survival among several ecotypes of 6 species from the Molycorp mine area were determined. Controlled release fertilizer application in the planting hole was compared with a control receiving no fertilizer at planting. Factors evaluated included 2 planting sites and 3 or 4 blocks per site which represented a variety of overburden types characterized by variation in particle size distribution, ripping depth, overburden chemistry, and rock type.

Introduction and Application

Several tree, shrub, and subshrub species have invaded the overburden piles and road cuts including *Populus angustifolia, Populus tremuloides, Salix scouleriana*, *Chrysothamnus* sp., *Eriogonum* sp., and *Artemisia frigida*. An extensive number of other shrub species are components of the surrounding mountain shrub community and mixed conifer forest including *Ribes cereum, Holodiscus dumosus, Philadelphus microphyllus, Symphoricarpos sp., Cercocarpus montanus, Fallugia paradoxa, Jamesia americana, Rhus trilobata, Prunus virginiana*, *Rosa* sp., and other *Ribes* sp. Most of these species exhibit adaptation to south aspects, steep slopes, and rocky soils that are the predominant site conditions encountered on the overburden piles and the surrounding natural terrain. The expense of planting containerized seedlings necessitates testing to determine which species and ecotypes have superior survival and growth characteristics to enable cost effective large scale reclamation efforts.

Methods

The species and ecotypes included in the 1994 planting are listed in Table 1 along with tentative identifications of species of uncertain taxonomic classification. The seed source, collection elevation, number of plots, and number of seedlings per plot are presented in the Table 20.

Table 1: The species and ecotypes used in the 1994 shrub planting along with seed source, collection elevation, and number of seedlings planted.

Species Abbr. in Tables	Genus	Species	Access. No.	Seed Source	Coll. Elev. (ft.)	No. of Seedlings (Plots x Plants)
Achil.	Achillea	sp. (lanulosa?) *	9066248	Slope NE Admin. Bldg.	8100	14 x 7
ARTR4	Artemisia	frigida	9066234	SW of Truck Yard (low pH)	9400	14 x7

Table 1: The species and ecotypes used in the 1994 shrub planting along with seed source, collection elevation, and number of seedlings planted.

Species Abbr. in Tables	Genus	Species	Access. No.	Seed Source	Coll. Elev. (ft.)	No. of Seedlings (Plots x Plants)
ARTR5	Artemisia	frigida	9066235B	Front Dump First Terrace	8500	14 x 5
ARTR6	Artemisia	frigida	9066236	Pinon Knob	9500	14 x 7
Artem.	Artemisia	sp. (franserioides?) *	9066236C	Pinon Knob	9500	14 x 7
ARTR	Artemisia	tridentata	9066249	Slope NE Admin. Bldg.	8100	14 x 6
ATCA	Atriplex	canescens	9066244	Slope E of Mill	8100	14 x 7
BEFE	Berberis	fendleri	9066214	Slope E of Mill	8100	14 x 1
CEMO	Cercocarpus	montanus	9066241	Logged Site East of Pit	8800	14 x 7
Chrys.7	Chrysothamnus	sp. (nauseosus?) *	9066237	Spring Gulch & Pinon Knob	9000	14 x 7
Chrys.9	Chrysothamnus	sp. (nauseosus?) *	9066239	Slope East of Mill	8100	14 x 7
Eriog.2	Eriogonum	sp. (jamesii?) *	9066242	Front Dump First Terrace	8500	14 x 7
Eriog.3	Eriogonum	sp. (jamesii?)*	9066243	SW of Truck Yard (low pH)	9400	14 x 7
JAAM	Jamesia	americana	9066252	Goathill Gulch Slope	8300	14 x 5
PRVI3	Prunus	virginiana	9066203	Red River Flood Plain	7900	14 x 6
PRVI4	Prunus	virginiana	9066204	Slope East of Mill	8100	14 x 7
RICE	Ribes	cereum	9066200	Slope East of Mill	8100	14 x 7
Ribes7	Ribes	sp. (leptanthum?) *	9066197	Red River Flood Plain	7900	14 x 7
Ribes0	Ribes	sp. (leptanthum?) *	9066200	Slope East of Mill	8100	14 x 7
ROFE	Robinia	fertilis		Ernst Seed Co.		14 x 6
RONE	Robinia	neomexicana	9066007	Cibola NF	8000	14 x 6
ROWO5	Rosa	woodsii	9066195	Red River Flood Plain	7900	14 x 7
ROWO6	Rosa	woodsii	9066196	Slope East of Mill	8100	14 x 6
Rubus	Rubus	sp. (strigosus?) *	9066180	Raspberry Ridge	9500	14 x 7

* Tentative identification

The planting took place on 7/26 and 7/27/94 at 2 overburden pile sites (Upper Blaster 9300 ft. and Spring Gulch 9000 ft.). The planting rows were ripped with a small bulldozer equipped with multiple rippers. The rows were watered immediately before and after planting. The rows were watered before planting to prevent the collapse of the dibbled holes. Dibbles specifically designed for Ray Leach Super Cell containers (10 in^3) were used. Planting holes were placed approximately 8 to 12 inches apart. The species/ecotype plots were arranged in random order in each row. Pairs of rows, one control and one fertilized, were installed in each of the 7 blocks. The overburden within blocks was less heterogeneous than among blocks. The fertilized treatment involved the placement of one heaping teaspoon (~6 g) of Sierra 17-6-12 controlled release fertilizer with minor nutrients (3-4 month release at 70°F) in each planting hole. On July 23, 1996, approximately 6 g of slow release fertilizer was top-dressed on each plant including the controls using an EZ Feeder Chemical Applicator. The fertilizer applied in 1996 and 1997 was Scotts 17-17-17, a polymer encapsulated sulfur-coated urea with ammoniated phosphate and potassium chloride (6.5% ammonium N, 10.5% urea N, and 4% free sulfur). On July 31,1997, Scotts 17-17-17 was hand scattered on each plot including the controls at an approximate rate of 1 to 2 kg per plot. On July 29, 1998, July 7, 1999, and August 1, 2000, a fertilizer blend with an average composition of 23-14-10 was hand scattered on each plot including the controls at an approximate rate of 1 to 2 kg per plot. This fertilizer was a mix of 50% Scotts Turf Starter (16-25-12) and 50% Scotts Turf Fertilizer Plus 2% Iron (30-3-9). The planting design is summarized below:

Planting Sites	Fertilizer	Plot Number and (Location Designation - Block)
Upper Blaster	No	1 (West), 2 (Middle), 3 (East)
Upper Blaster	Yes	4 (West), 5 (Middle), 6 (East)
Spring Gulch	No	7 (Far West), 8 (West), 9 (Northeast), 10 (Far East)
Spring Gulch	Yes	11 (Far West), 12 (West), 13 (Northeast), 14 (Far East)

In late April 1997, 40 superior plants of 8 Molycorp ecotypes were dug from some of the plots to establish seed stock plants. The analysis of survival data in this report assumes that these 40 plants would have survived until the year 2000 because of their superior size at the time of harvesting. In August 2000, the number of live plants, individual height, and individual maximum crown width were recorded. The height and width were estimated by observation. One-way completely randomized analysis of variance testing was used to determine significant effects of plots, sites, or treatments. Approximate Least Significant Difference testing was used for mean separation analysis.

Results and Discussion

The survival, height, and width data have been analyzed and compiled into 3 tables: survival percentage (Table 2`); mean height (cm) based on surviving seedlings after 6 years growth (Table 22); and, mean width (cm) based on surviving seedlings after 6 years growth (Table 23). The overall mean survival percentage for all species/ecotypes was 54% after 6 years (Table 21). The fertilizer treatment had little effect on survival percentage, 54%, versus the control value of 53%. In contrast, the 1995 planting showed a profound negative effect due to fertilizer application, 24%, versus the control, 61% (Dreesen 2001). The timing of planting (one week's difference) and planting methods were similar for the two experimental plantings. Precipitation patterns at Red River differed between the two years; 1995 had much less precipitation in August (2.1 vs. 4.3 inches) but much greater precipitation in September (3.3 vs. 1.5 inches). The greater precipitation in August 1994 could have leached excess nutrients out of the root zone of plants receiving controlled release fertilizer. The reduction in salts and nutrients could have reduced potentially deleterious osmotic potential and the possibility of late growth flushes for the 1994 planting. The greater precipitation in September 1995 could have resulted in a growth flush and prevented hardening off before a severe cold snap for the 1995 planting. Temperature data for Red River did not show substantial differences between the 2 years for first fall minimums except for the first fall minimum below 20 degrees F; the minimums were 17 degrees on 10/6/95 and 14 degrees on 10/18/94. The 1995 planting had 3 fewer weeks between planting and a hard freeze event than the 1994 planting. The combination of precipitation and temperature patterns may have resulted in the fertilized plants in the 1995 study being less likely to have undergone dormancy before hard freezes. A few species exhibited somewhat reduced survival with fertilizer (e.g., *Eriogonum* sp. and *Prunus virginiana*).

The Upper Blaster site had much lower survival, 38%, than Spring Gulch, 66%. In the 1995 planting, survival values were approximately 10% lower with 30% survival for Upper Blaster compared with 55% for Spring Gulch (Dreesen 2001). If the low pH overburden plots are not included (Plots 2, 3, 5, and 6), the mean survival of all species/ecotypes in the 1994 planting was 68% in the control and 62% in the fertilizer treatments at Upper Blaster. The 1995 planting had a nearly identical survival percentage in the control treatments excluding low pH plots at Upper Blaster, 67% (Dreesen 2001). In Table 21, the row labeled “Not Acid” presents mean results for each species with the acid plots excluded; the average survival for all species at Upper Blaster in this category is 53%. At Spring Gulch, the 1994 planting showed the highest survival in the far western block (Plot 7 control 71% and Plot 11 fertilized 78%). The other Spring Gulch blocks had survival percentages 9 to 10% less for controls and 7 to 19% less for fertilized plots than the corresponding far western blocks, probably a result of differences in overburden characteristics. Two species had growth patterns that made it difficult to determine survival, *Achillea* sp. and *Artemisia* sp. The proliferation of small stems resulting from substantial rhizome development made it difficult to identify the original plants. For the *Achillea* sp., plants had filled the entire plot or were completely absent; therefore, survival was estimated from presence in the plot and not from individual plant survival (all plots without low pH overburden were filled, 10 out of 14). To a lesser degree the same difficulty occurred with *Artemisia* sp.; however, voids in the plot were obvious so plant numbers could be estimated. Because of the stem proliferation, the height and width results for these 2 species are presented as persistent and spreading (P&S) rather than as a numerical entry.

The species/ecotypes with the highest overall survival percentages were all of Molycorp origin: *Rosa woodsii* (Acc. 195) 90%, *Berberis fendleri* 79%, *Prunus virginiana* (Acc. 203 and Acc. 204) 74% and 69%, *Ribes cereum* 71%, *Cercocarpus montanus* 70%, *Rosa woodsii* (Acc. 196) 70%, *Chrysothamnus* sp. (Acc. 237) 66%, *Rubus* sp. 63%, and *Eriogonum* sp. (Acc. 242 and Acc. 243) 63% and 62%. Estimates of survival for the rhizomatous entries *Achillea* sp. and *Artemisia* sp are in the 70 to 80 % range with most mortality in the low pH plots. At the Spring Gulch site, 4 non-rhizomatous species had over 90% survival in the control treatment. At the Spring Gulch site in the 1995 planting, 9 species had over 90% survival in the control treatment (Dreesen 2001). In the 1994 planting at Upper Blaster, 15 species had high survival (>70%) in the control and fertilizer plots without low pH overburden (Plots 1 and 4). In the 1995 planting, 7 species had high survival (>70%) in the control plots excluding low pH overburden at Upper Blaster.

One ecotype, *Artemisia frigida* Acc. 235, had substantially greater survival at Upper Blaster, 23%, than at Spring Gulch, 8%. *Rosa woodsii* Acc. 195, *Rosa woodsii* Acc. 196, *Berberis fendleri*, *Cercocarpus montanus*, *Jamesia americana*, and *Artemisia* sp. had high (>50%) survival at both sites. Three species (*Artemisia frigida* Acc. 234 and Acc. 236, *Berberis fendleri*, and *Chrysothamnus* sp. Acc. 239) had at least 10% higher survival in the fertilizer treatment than the control. Three species (*Eriogonum* sp. Acc. 243, *Prunus virginiana* Acc. 203 and Acc. 204, and *Robinia fertilis)* had at least 10% higher survival in the control than in the fertilizer treatment.

An examination of survival over time can be developed from preliminary survival data taken one and three years after planting (Dreesen 1997). For all species, the survival at Spring Gulch was 90% in 1995, 78% in 1997, and 66% in 2000. Several species had excellent survival in 1995, fair survival by 1997 and poor to fair survival by 2000: the 3 *Artemisia frigida* ecotypes, *Artemisia tridentata*, and *Atriplex canescens*. By 1997 *Robinia fertilis* had poor survival. The two *Chrysothamnus* sp. had similar survival percentages in 1995 and 1997, but by 2000 Acc. 237 had 20% higher survival than Acc. 239 at Spring Gulch.

The overall mean height for surviving seedlings (Table 22) was 17 cm and the mean of the 22 species/ecotypes maximums was 41 cm. The mean height at Spring Gulch for all species was 58% greater than Upper Blaster (19 cm vs. 12 cm). The fertilizer treatment yielded a mean height for all species 43% greater than the control (20 cm vs. 14 cm). The 4 fertilized plots at Spring Gulch had a mean height for all species 6 cm greater than the mean for the 4 control plots. Maximum heights greater than 50 cm were recorded for 6 species. The tallest species based on means and maximums were *Robinia neomexicana* (46 cm and 102 cm), *Robinia fertilis* (28 cm and 76 cm), *Jamesia americana* (26 cm and 66 cm), *Cercocarpus montanus* (21 cm and 76 cm), *Atriplex canescens* (20 cm and 30 cm), *Rubus* sp. (20 cm and 41 cm), and *Chrysothamnus* sp. Acc. 237 (19 cm and 51 cm).

The overall mean width (Table 23) was 24 cm and the mean of the 22 species/ecotypes maximums was 54 cm. The mean width at Spring Gulch for all species was 19% greater than Upper Blaster (25 cm vs. 21 cm). The fertilizer treatment yielded a mean width for all species 29% greater than the control (27 cm vs. 21 cm). The 4 fertilized plots at Spring Gulch had a mean width for all species 7 cm greater than the mean for the 4 control plots. Maximum widths greater than 50 cm were recorded for 11 species. The species with the widest crown spread based on means and maximums were *Robinia neomexicana* (50 cm and 127 cm), *Eriogonum* sp. Acc. 243 (40 cm and 76 cm), *Eriogonum* sp. Acc. 242 (39 cm and 76 cm), *Robinia fertilis* (35 cm and 112 cm), *Chrysothamnus* sp. Acc. 237 (28 cm and 76 cm), *Cercocarpus montanus* (26 cm and 81 cm) and *Rosa woodsii* Acc. 195 (24 cm and 51 cm).

The species with combined excellent height and width growth include *Robinia neomexicana*, *Robinia fertilis, Cercocarpus montanus*, and *Chrysothamnus* sp. Acc. 237. *Jamesia americana* and *Rubus* sp. show good height growth but fair width growth. While *Eriogonum* sp. Acc. 242 and *Eriogonum* sp. Acc. 243 show good width growth but poor height growth. The poorest performing species based on height (<15 cm) and width (<19 cm) were *Artemisia frigida* Acc. 234, Acc. 235, and Acc. 236, *Prunus virginiana* Acc. 203 and Acc. 204, and *Ribes* sp. Acc. 200 and Acc. 197.

Summary and Conclusions

A gauge of superior performance was developed by summing the rankings of survival, height, and width means for the Spring Gulch, Upper Blaster, Control, Fertilized and All groups (Table 24). The sum rank of survival has been doubled to give survival equal weight with height and width growth. The total ranks for survival (doubled), height, and width have been summed for an overall ranking. The best performing species was *Rosa woodsii* Acc. 195 with excellent survival and good growth. Those species with good survival and good to excellent growth include *Cercocarpus montanus, Berberis fendleri, Chrysothamnus* sp. Acc. 237, and *Ribes cereum*. *Rosa woodsii* Acc. 196 and *Prunus virginiana* Acc. 203 had good to excellent survival but poor to fair height and width growth. The 2 *Eriogonum* sp. ecotypes had excellent width growth, but only fair survival and height growth. *Rubus* sp., *Robinia neomexicana,* and *Jamesia americana* had good or excellent height and width growth but only fair survival. The steady decline in survival for *Robinia fertilis*, *Artemisia tridentata*, and *Atriplex canescens* from good survival after one year to fair to poor survival after 6 years indicates that these species are not adapted to these site conditions at 9000 feet and higher. In contrast, the high survival percentages for *Artemisia frigida* after one year and its subsequent decline may indicate that it is a short lived subshrub. The rhizomatous species, *Achillea* sp. and *Artemisia* sp., are able to persist for 6 years and spread in their planting row. The large difference in rankings for the *Rosa woodsii* ecotypes and *Chrysothamnus* sp. ecotypes implies that seed source may be an important factor in revegetation of certain species. However, the similar rankings for ecotypes of *Eriogonum, Prunus, Ribes* sp., and *Artemisia frigida* indicate that the particular seed source of these species from the vicinity of the mine is not an important revegetation consideration.

Literature Cited

Dreesen, D.R. 2001. Final Report – Survival and Growth of Containerized Shrub Seedlings 5 Years After Planting on Molycorp Overburden Piles, 1995 Study. Prepared for Molycorp Inc., Questa, NM, February 2001. Plant Materials Center, U.S. Department of Agriculture, Natural Resources Conservation Service, 1036 Miller St. SW, Los Lunas, NM 87031.

Dreesen, D.R. 1997. Progress Report on Shrub Species Evaluation, 1994 Planting. Prepared for Molycorp Inc., Questa, NM, November 1997. Plant Materials Center, U.S. Department of Agriculture, Natural Resources Conservation Service, 1036 Miller St. SW, Los Lunas, NM 87031.

Survival and Growth of Containerized Shrub Seedlings Five Years After Planting on Molycorp Overburden Piles, 1995 Study[22]

By: David R. Dreesen[23]

Project Number: NMPMC-P-9803-CR

Abstract

The objective of this experimental planting in 1995 was to evaluate 17 species/ecotypes to determine which species exhibit superior survival and growth on overburden to enable cost effective large-scale reclamation. At this site, superior species must be adapted to south aspects, steep slopes, and rocky soils that are the predominant site conditions encountered on the overburden piles. In this experiment, controlled release fertilizer application at planting was compared with a control receiving no fertilizer at planting. Site factors evaluated included 2 planting sites and 3 blocks per site representing a variety of overburden types differentiated by particle size distribution, ripping depth, overburden chemistry, and rock type. The overall mean survival percentage for all species/ecotypes was 43% after 5 years. The fertilizer treatment had a profound negative effect on survival percentage, 24%, versus the control, 61%. These results contrast with the 1994 planting where the survival percentages in the control and fertilizer treatments were similar. Overall, the Upper Blaster planting site (including low pH overburden) had much lower survival, 30%, than the Spring Gulch site, 55%. At the Spring Gulch site the control treatment had 84% survival 5 years after planting. The survival of the control treatment at the Upper Blaster site was 40%, but increased to 67% if the plots with low pH overburden were excluded. Height and crown width measurements after 5 years revealed 9 species/ecotypes (5 Molycorp ecotypes) with maximum individual plant heights greater than 50 cm and 8 species/ecotypes (5 Molycorp ecotypes) with maximum crown widths greater than 50 cm. *Fallugia paradoxa* (Molycorp ecotype) was the best performing species with good survival, height growth, and width growth at both sites as well as in both control and fertilized treatments. Other species that showed good performance for survival or growth included *Philadelphus microphyllus* (Molycorp ecotype), *Amelanchier alnifolia*, *Holodiscus dumosus* (Molycorp ecotype), *Forestiera neomexicana*, *Rhus trilobata* (Molycorp ecotype), *Chrysothamnus* sp. (Molycorp ecotype), and *Shepherdia argentea*.

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[22] Prepared for Molycorp, Inc., Questa, NM

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Objective

The objective of this experimental planting was to evaluate species and ecotypes not included among the 24 species/ecotypes used in the 1994 planting. Of the 17 ecotypes and 14 species included in the 1995 study, 9 ecotypes and 6 species were grown from seed collected in the vicinity of the Molycorp mine. Controlled release fertilizer application in the planting hole was compared with a control receiving no fertilizer at planting. Factors evaluated included 2 planting sites and 3 blocks per site; these blocks represented a variety of overburden types distinguished by differences in particle size distribution, ripping depth, overburden chemistry, and rock type.

Introduction and Application

Several shrub and subshrub species have invaded the mine overburden piles and road cuts (*Eriogonum sp., Artemisia frigida,* and *Chrysothamnus* sp.) and many shrub species are dominant components of the surrounding mountain shrub community and mixed conifer forest. Most of these species exhibit adaptation to south aspects, steep slopes, and rocky soils that are the predominant site conditions encountered on the overburden piles. The expense of planting containerized seedlings necessitates testing to determine which species and ecotypes have superior survival and growth characteristics to enable cost effective large scale reclamation efforts.

Methods

The species and ecotypes included in the 1995 planting are native to southern Rocky Mountains (except *Caragana arborescens*) and are listed in Table 25 along with the seed source, collection elevation, number of plots, and number of seedlings per plot.

Table 25: Species and ecotypes tested in the 1995 shrub seedling planting including accession number, seed source, collection elevation, number of plots, and number of plants per plot.

Species Abbr. in Tables	Genus	Species	Access. No.	Seed Source	Coll. Elev. (ft.)	No. of Seedlings (Plots x Plants)
ALTE	Alnus	tenuifolia		Costilla Creek, NM		12 x 7
AMAL	Amelanchier	alnifolia		Granite Seed Co.		12 x 5
AMUT	Amelanchier	utahensis		Granite Seed Co.		12 x 5
CAAR	Caragana	arborescens	(exotic)	Granite Seed Co.		3 x 7
Chrys.	Chrysothamnus	sp.	9066237B	Above Upper Blaster	9500	3 x 7
FAPA	Fallugia	paradoxa	9066210	Headframe Hill	8500	12 x 7
FONE	Forestiera	neomexicana	Mixed	Diverse		12 x 7
HODU-Capulin	Holodiscus	dumosus	9066212C	Capulin	9800	3 x 7
HODU-GHS	Holodiscus	dumosus	9066212D	Goat Hill Slope	8100	12 x 7
HODU-Mill	Holodiscus	dumosus	9066212E	Slope East of Mill	8100	12 x 5
JAAM-GHS	Jamesia	americana	9066252B	Goat Hill Slope	8100	12 x 7

Table 25: Species and ecotypes tested in the 1995 shrub seedling planting including accession number, seed source, collection elevation, number of plots, and number of plants per plot.

Species Abbr. in Tables	Genus	Species	Access. No.	Seed Source	Coll. Elev. (ft.)	No. of Seedlings (Plots x Plants)
JAAM-UB	Jamesia	americana	9066252C	Upper Blaster	9300	12 x 7
PHMI	Philadelphus	microphyllus	9066253	Goat Hill Slope	8100	12 x 7
PHMO	Physocarpus	monogynus	9066133	Cibola National Forest	8000	12 x 7
RHGL	Rhus	glabra		Cibola National Forest	8000	9 x 7
RHTR	Rhus	trilobata		Slope East of Mill	8100	6 x 7
SHAR	Shepherdia	argentea		Granite Seed Co.		12 x 7

The planting took place on August 2, 1995 at 2 overburden sites (Upper Blaster 9300 ft. and Spring Gulch 9000 ft.). The ripped rows were watered immediately before and after planting. The rows were watered before planting to prevent the collapse of the dibbled holes. Dibbles specifically designed for Ray Leach Super Cell containers (10 cubic inch) were used. Planting holes were placed approximately 8 to 12 inches apart in the ripped row. The species/ecotype plots were installed in random order in each row. Pairs of rows, one control and one fertilized, were installed in each of the 6 blocks. The overburden within blocks was less heterogeneous than among blocks. The fertilized treatment involved the placement of one heaping teaspoon (~6 g) of Sierra 17-6-12 controlled release fertilizer with minor nutrients (3-4 month release at 70F) in each planting hole. On July 23, 1996, approximately 6 g of slow release fertilizer was top-dressed on each plant including the controls using an EZ Feeder Chemical Applicator. The fertilizer applied in 1996 and 1997 was Scotts 17-17-17, a polymer encapsulated sulfur-coated urea with ammoniated phosphate and potassium chloride (6.5% ammonium N, 10.5% urea N, and 4% free sulfur). On July 31,1997, Scotts 17-17-17 was hand scattered on each plot including the controls at an approximate rate of 1 to 2 kg per plot. On July 29, 1998, July 7, 1999, and August 1, 2000, a fertilizer blend with an average composition of 23-14-10 was hand scattered on each plot including the controls at an approximate rate of 1 to 2 kg per plot. This fertilizer was a mix of 50% Scotts Turf Starter (16-25-12) and 50% Scotts Turf Fertilizer Plus 2% Iron (30-3-9). The planting design is described below:

Planting Sites	Fertilizer	Plot Number (Location Designation – Block)
Upper Blaster	No	1 (NW), 2 (SW), 3 (NE)
	Yes	4 (NW), 5 (SW), 6 (NE)
Spring Gulch	No	7 (NE), 8 (SE), 9 (SW)
	Yes	10 (NE), 11 (SE), 12 (SW)

In late April 1997, 21 superior plants of 4 Molycorp ecotypes were dug from these plots to establish seed stock plants. The analysis of survival data in this report assumes that these 21 plants would have survived until the year 2000 because of their superior size at the time of harvesting. In August 2000, the number of live plants, individual heights, and individual maximum crown widths were recorded. The height and width were estimated by observation.

One-way completely randomized analysis of variance testing was used to determine significant effects of plots, sites, or treatments. Approximate Least Significant Difference testing was used for mean separation analysis.

Results and Discussion

The survival, height, and width data have been analyzed and compiled into survival percentages (Table 26), mean height (cm) of surviving plants after 5 years growth (Table 27), and mean crown width (cm) of surviving plants after 5 years growth (Table 28).

The overall mean survival percentage for all species/ecotypes was 43% after 5 years (Table 26). The fertilizer treatment had a profound negative effect on survival percentage, 24%, versus the control, 61%. These results contrast with the survival percentages found in the 1994 planting that had similar survival in the control and fertilized treatments (Dreesen 2001). The timing of planting (one week's difference) and planting methods were similar for the two experimental plantings. Precipitation patterns at Red River differed between the two years; 1995 had much less precipitation in August (2.1 vs. 4.3 inches) but much greater precipitation in September (3.3 vs. 1.5 inches). The greater precipitation in August 1994 could have leached excess nutrients out of the root zone of plants receiving controlled release fertilizer. The reduction in salts and nutrients could have reduced potentially deleterious osmotic potential and the possibility of late growth flushes for the 1994 planting. The greater precipitation in September 1995 could have resulted in a growth flush and prevented hardening off before a severe cold snap for the 1995 planting. Temperature data for Red River did not show substantial differences between the 2 years for first fall minimums except for the first fall minimum below 20 degrees F; the minimums were 17 degrees on 10/6/95 and 14 degrees on 10/18/94. The 1995 planting had 3 fewer weeks between planting and a hard freeze event than the 1994 planting. The combination of precipitation and temperature patterns may have resulted in the fertilized plants in the 1995 study being less likely to have induced dormancy. However, the fact that several species did not have significantly reduced survival in the fertilized treatment in the 1995 planting indicates that some species (e.g., *Fallugia paradoxa*, *Forestiera neomexicana*, and *Rhus glabra*) were not affected by the fertilizer treatment. These species were probably sufficiently dormant at the onset of hard freeze events. Other species exhibited dramatically reduced survival with fertilizer (e.g., *Alnus tenuifolia*, *Amelanchier utahensis*, *Jamesia americana* (both ecotypes), and *Physocarpus monogynus*).

Examination of a preliminary evaluation of survival in 1996 (Dreesen unpublished data) shows only two species with drastically different overall survival (>10%) between 1996 and 2000. The limited *Chrysothamnus* sp. planting had survival change from 81% to 29% over 4 years, while *Shepherdia argentea* went from 61% to 41%. Both these species were the most heavily browsed of all the tested ecotypes. The poor survival resulting from the fertilizer treatment was readily apparent by 1996 indicating the mortality occurred during the first winter after planting.
The Upper Blaster site had much lower survival, 30%, than Spring Gulch, 55% (Table 26). The difference in survival between sites remains substantial when only the control treatment is considered: Spring Gulch 84% versus Upper Blaster 40%. If the plots with low pH overburden are not included, the mean survival of all species/ecotypes in the control treatment at Upper Blaster was 67%. The highest survival among plots was noted for 5 out of the 6 control plots (Plots 1,2,7,8, and 9), 56% to 86%. The remaining control plot (Plot 3) was in a block with

exclusively low pH overburden; all of the 14 entries planted in this block (control and fertilized) were exposed to high soluble salts and low pH overburden.

Among the species planted in all blocks, 3 species had the highest overall survival: *Fallugia paradoxa* 68%, *Forestiera neomexicana* 60%, and *Amelanchier alnifolia* 53%. The species with highest survival in the control treatment were *Rhus trilobata* 100%, *Amelanchier alnifolia* 80%, *Fallugia paradoxa* 76%, and *Holodiscus dumosus* GHS 74%. At the Spring Gulch site, 9 species had over 90% survival in the control treatment. At Upper Blaster, 7 species had high survival (>70%) in the control plots excluding low pH overburden plots.

Although 9 species/ecotypes had substantially greater survival at Spring Gulch, only one species, *Shepherdia argentea*, had significantly higher survival at the Spring Gulch site compared with the Upper Blaster site (69% vs. 12%). *Alnus tenuifolia* was the only species with a higher survival value at Upper Blaster, but the means were not significantly different (21% vs. 14%). For 11 species, the control treatment had much greater survival than the fertilizer treatment; 8 of these species were determined to be significantly greater by means testing. However, 3 species had similar survival percentages in the fertilizer treatment and control: *Fallugia paradoxa* (60 % vs. 76%), *Forestiera neomexicana* (64% vs. 55%), and *Rhus glabra* (33% vs. 48%, planted at the Spring Gulch site only).

The mean height values based on surviving seedlings (Table 27) show the overall mean height for all species was 22 cm and the mean of the 17 species/ecotypes maximums was 52 cm. The mean height at Upper Blaster for all species was 20% greater than Spring Gulch (24 cm vs. 20 cm). The fertilizer treatment yielded a mean height for all species 37% greater than the control (26 cm vs. 19 cm). All of the 6 fertilized plots had the greater mean height (24 cm to 35 cm) than the 6 control plots (10 cm to 22 cm).

The 6 tallest entries based on means and maximums included 5 Molycorp ecotypes: *Holodiscus dumosus* Capulin (52 cm and 102 cm), *Holodiscus dumosus* Mill (32 cm and 76 cm), *Fallugia paradoxa* (31 cm and 91 cm), *Philadelphus microphyllus* (26 cm and 61 cm), *Alnus tenuifolia* (26 cm and 76 cm), and *Holodiscus dumosus* GHS (24 cm and 66 cm).

The mean overall crown width (Table 4) was 24 cm for all species and the mean of the 17 species/ecotypes maximums was 52 cm. The mean width at Upper Blaster for all species was 25% greater than Spring Gulch (25 cm vs. 20 cm). The fertilizer treatment yielded a mean width for all species 35% greater than the control (27 cm vs. 20 cm). All of the 6 fertilized plots had the greater mean width (27 cm to 34cm) than the 6 control plots (11 cm to 24 cm).
The 8 entries with the greatest crown spread based on means and maximums included 6 Molycorp ecotypes: *Holodiscus dumosus* Capulin (50 cm and 76 cm), *Chrysothamnus* sp. (39 cm and 51 cm), *Fallugia paradoxa* (36 cm and 81 cm), *Holodiscus dumosus* Mill (30 cm and 46 cm), *Alnus tenuifolia* (26 cm and 76 cm), *Philadelphus microphyllus* (24 cm and 51 cm), *Shepherdia argentea* (23 cm and 76 cm), and *Holodiscus dumosus* GHS (23 cm and 71 cm).
The 2 species that are in the list with the greatest crown widths but not in the tallest list, *Chrysothamnus* sp. and *Shepherdia argentea* showed evidence of browsing probably by elk. The poorest performing species based on height and width of surviving seedlings were *Caragana arborescens, Amelanchier utahensis, Rhus trilobata, Rhus glabra*, and *Jamesia americana* UB.

A gauge of superior performance can be developed by assessing the rank of survival, height, and width means for the Spring Gulch, Upper Blaster, Control, Fertilized and All groups (Table 29). The sum rank of survival has been doubled to give it equal weight with the summed growth rankings (height plus width). The total ranks for survival, height, and width have been summed to yield a grand total. The total value has been modified for those species that were not planted in all 12 plots by multiplying by a weighting factor equal to the total number of possible rankings, 20 (10 from doubling survival + 5 from height + 5 from width) divided by the number of actual rankings.

The best performing species is *Fallugia paradoxa* with excellent rankings in survival, height, and width growth. At the next level, 7 species had superior performance for different variables, sites, or treatments:

- *Philadelphus microphyllus* – good height and width growth and fair to good survival for both sites and treatments
- *Holodiscus dumosus* GHS – fair to good survival with good height and width growth particularly with fertilizer
- *Holodiscus dumosus* Mill – fair survival but excellent height and width growth
- *Amelanchier alnifolia* - good survival and fair height and width growth with better growth results at Spring Gulch and with fertilizer
- *Forestiera neomexicana* – excellent survival except in the control treatment, fair height growth, and poor width growth with inferior growth at Upper Blaster
- *Holodiscus dumosus* Capulin – limited results show excellent height and width growth but poor survival for fertilized plots at Upper Blaster
- *Rhus trilobata* – limited results from only Spring Gulch show excellent survival but poor height and width growth.

Other noteworthy results include excellent width growth for *Chrysothamnus* sp., good survival and width growth for *Shepherdia argentea* at Spring Gulch, good survival of *Physocarpus monogynus* at Upper Blaster and good growth with fertilizer, excellent survival for *Caragana arborescens* at Upper Blaster, good survival for *Rhus glabra*, good growth for *Alnus tenuifolia* at Upper Blaster, and excellent height growth for *Jamesia americana* GHS at control Spring Gulch plots.

Summary and Conclusions

The most important findings of this study include the determination of superior species and ecotypes for direct planting of containerized seedlings on neutral overburden. *Fallugia paradoxa* (Molycorp ecotype) exhibited the best overall performance with a 2 other Molycorp species showing promising growth and survival (*Philadelphus microphyllus* and *Holodiscus dumosus*). At the Spring Gulch site *Shepherdia argentea*, *Forestiera neomexicana*, and *Amelanchier alnifolia* had good or better performance for survival and growth. *Physocarpus monogynus* had good survival at the Upper Blaster site and fair to good growth performance. The poor growth and excellent survival of *Rhus trilobata* may indicate that this species is appropriate at lower elevations at the Molycorp mine, but not at 9000 ft and above. Although the limited *Chrysothamnus* sp. planting at Upper Blaster did not show favorable results, the much more extensive 1994 test planting showed this species to be a superior performer (Dreesen 2001).

Differences in performance were somewhat evident among *Holodiscus dumosus* ecotypes. The Goat Hill slope (GHS) ecotype had somewhat better survival compared to the other 2 ecotypes, but the growth of this ecotype was inferior. The overall performance of the 2 *Jamesia americana* ecotypes was poor, but the Goat Hill Slope ecotype had excellent height growth at Spring Gulch.

Literature Cited

Dreesen, D.R. 2001. Final Report – Survival and Growth of Containerized Shrub Seedlings 6 Years After Planting on Molycorp Overburden Piles, 1994 Study. Prepared for Molycorp Inc., Questa, NM, February 2001. Plant Materials Center, U.S. Department of Agriculture, Natural Resources Conservation Service, 1036 Miller St. SW, Los Lunas, NM 87031.

National Park Service
Grand Canyon National Park, Arizona

By: Danny G. Goodson[24]

Project Number: NMPMC-NS-0003-RA

Abstract

An agreement between the Plant Materials Center (PMC) in Los Lunas, New Mexico and the Grand Canyon National Park (GCNP) in Arizona was first established in July 1990. The agreement provides for the collection, propagation, and increase of grasses, forbs, shrubs, and trees.

The GCNP will use the plant materials produced by the PMC in Los Lunas to revegetate disturbed sites, and also for native landscaping. Both the North and South rim areas of the park are covered in the agreement, and plant materials will be produced for use at both of these areas.

Accessions Involved

Table 30 lists the accessions involved in the Grand Canyon National Park Year 2000 project.

Table 30: Accessions Involved

Common Name	Scientific Name	Plant Symbol	Accession Number	Vegetation Association
Indian Ricegrass	*Oryzopsis hymenoides*	ORHY	9062857	122.3233
Squirreltail	*Sitanion hysterix*	SIHY	9062858	122.3233
Needle and thread	*Stipa comata*	STCO	9062859	122.3233
Western wheatgrass	*Agropyron smithii*	AGSM	9062860	122.3233
Muttongrass	*Poa fendleriana*	POFE	9062861	122.3233
Penstemon (blue)	*Penstemon spp.*	PE SPP.	9062862	122.3233
Penstemon (red)	*Penstemon spp.*	PE SPP.	9066054	122.3233
Lupine	*Lupinus spp.*	LU SPP.	9062863	122.3233
Apacheplume	*Fallugia paradoxa*	FAPA	9062865	122.3233
Fernbush	*Chamaebatiaria millifollium*	CHMI	9062866	122.3233
Curl-leaf mountain mahogany	*Cercocarpus ledifolius*	CELE	9062867	122.3233
Elderberry	*Sambucus spp.*	SA SPP.	9066047	122.3233
Utah serviceberry	*Amelanchier utahensis*	AMUT	9062869	122.3233
Wolfberry	*Lycium spp.*	LY SPP.	9062870	122.3233
Gambels oak	*Quercus gambelii*	QUGA	9062872	122.3233
Fourwing saltbush	*Atriplex canescens*	ATCA	9062873	122.4149

[24] Agronomist, Natural Resources Conservation Service, New Mexico Plant Materials Center

Table 30: Accessions Involved

Common Name	Scientific Name	Plant Symbol	Accession Number	Vegetation Association
Century plant	*Agave utahensis*	AGUT	9062874	122.4149
Blue grama	*Bouteloua gracilis*	BOGR	9062875	122.4149
Rabbitbrush	*Chrysothamnus nauseosus*	CHNA	9062877	122.4149
Cliffrose	*Purshia mexicana*	COME	9062876	122.4149
Utah juniper	*Juniperus osteosperma*	JUOS	9066055	122.3233
Pinon pine	*Pinus edulis*	PIED	9066467	122.3233
Ponderosa pine	Pinus ponderosa	PIPO	9066466	122.3233
Big sagebrush	*Atriplex tridentata*	ARTR	9066056	122.3233
Currant	*Ribes spp.*	RI SPP.	9066057	122.3233
Datil yucca	*Yucca baccata*	YUBA	9066058	122.3233
Desert barberry	*Berberis fremonti*	BEFE	9066059	122.3233

Collection Information

The GCNP collected seed and sent it to the PMC in Los Lunas, New Mexico for propagation. Table 31 shows the seed species, weight and the location of the accession.

Table 31: Inventory of Seeds Sent to the PMC by GCNP – July 2000

Species	Weight (grams)	Location of Collection
ARTR	757	SR Village
FAPA	301	SR Village
ARTR	701	SR Desert View
FAPA	2	SR Desert View
PIED	56	SR Desert View
COME	160	SR Desert View
AGUT	1	SR Desert View
ATCA	96	SR Desert View
JUOS	247	SR Desert View
CELE	50	NR Pt. Imperial
ARPA	461	NR Pt. Imperial
RONE	6	NR Pt. Imperial
AMUT	127	NR Dev. Area
BERE	13	NR Dev. Area

Seed Condition Information

The condition of the seed collections made in the year 2000 by the Park will be reported in the 2001 report.

Seed Production Establishment

The PMC established a ½ acre field of Muttongrass at the PMC in Los Lunas, NM using seedling transplants. On October 17, 2000, PMC personnel used a mechanical transplanter to transplant the seedlings into field 20 North. After transplanting, the seedlings were irrigated and fertilized. Depending on maturity of plants, seed maybe produced in the spring of 2001.

Seed Production

Table 32 shows the climatological data for year 2000 at the PMC in Los Lunas, New Mexico.

Table 32: Climatological Data for Year 2000 – Los Lunas PMC Weather Site

	Average Temperature Fahrenheit			
Month	**High**	**Low**	**Monthly**	**Precipitation/Inches**
Jan	59.8	17.1	38.5	0.00
Feb	63.4	23.5	43.5	0.27
Mar	65.4	29.3	47.4	2.02
Apr	76.7	38.1	57.4	0.45
May	88.3	46.6	67.5	0.00
Jun	93.6	57.3	75.5	0.80
Jul	95.7	60.7	78.2	2.03
Aug	94.4	59.0	76.7	0.96
Sep	90.6	49.2	69.9	0.10
Oct	71.0	40.7	55.85	2.59
Nov	54.8	22.0	38.4	1.05
Dec	53.6	19.1	36.5	0.52
				Total 10.79

Harvest Data

The blue grama field was combined in October, but during the cleaning process no viable seed was detected. The Muttongrass field was not combined in 2000.

Seed Delivery

Table 33 lists the seed delivered by the PMC to GCNP in the year 2000.

Table 33: Seed Delivery – Year 2000

Species	PLS Pounds
Western wheatgrass	55.49
Blue grama	3.5
Bottlebrush Squirreltail	0.5
Penstemon	0.4
	Total 59.8

Field Management

9062875 Blue Grama

Field Residue Burned	2/16
Field Ripped to 12" depth	2/16
Fertilization, Broadcast spreader 50 lbs. nitrogen	6/02

Irrigation, 3" water application	6/02, 6/29, 8/03, 10/06
Herbicide Application 2,4-D @ 1.5 quart per acre	4/07, 5/15, 5/31
Cultural Weed Control	
Hand Hoeing	7/10, 8/05
Mechanical Cultivation	4/24, 6/13, 7/24
Harvest Combine	10/01

9062861 Muttongrass

Fertilization, Broadcast spreader	
50 lbs. nitrogen	3/20, 7/25
50 lbs. P2O5	3/20, 7/25
Irrigation	
3" water application	2/11, 3/15, 4/17, 4/20, 5/02, 5/11, 5/26, 6/06, 6/03, 6/27, 7/28, 8/11, 8/15, 9/15, 10/02
Herbicide Application 2,4-D @ 1.5 quart per acre	3/17
Cultural Weed Control	
Hand Hoeing	4/06, 4/17, 6/09, 6/27, 7/17
Mechanical Cultivation	4/05, 6/26, 9/15
Harvest	
No harvest in 2000.	

Transplant Production

Table 34 describes the transplant production and delivery for the GCNP for year 2000.

Table 34: Transplant Production

Common Name	Treepots delivered – Year 2000
Mexican Cliffrose	38
Fernbush	258
Rubber rabbitbrush	152
Apache plume	298
Big Sagebrush	164
Gambel Oak	92
Utah Serviceberry	61
Desert Barberry	209
Curl-leaf Mountain Mahogany	116
Mormon Tea	107
Ponderosa Pine	252
Pinon Pine	130
Currant	95
Mountain Snowberry	80
NM Locust	178
	Total 2230

Table 35 lists the year 2000 plant inventory for the north and south rim of the GCNP.

Table 35: Grand Canyon North and South Rim Plant Inventory as of December 2000

Genus	Species	Rim	Collection	One-Gallon Treepots Ready by Spring 2001	One-Gallon Treepots Ready by Fall in 2001	One-Gallon Treepots Ready in 2002	Super Cell (10 in^3) Seedlings Started Dec 2000	Mortality Risk
Agave	*utahensis*	South		300				
Amelanchier	*utahensis*	South	Yavapai		40	120		Moderate
Amelanchier	*utahensis*	South		140	120	120		Moderate
Artemisia	*nova*	South	Desert View		20	80		High
Artemisia	*nova*	South	Mather Pt.		10	30		High
Artemisia	*tridentata*	South			25		500	High
Artemisia	*tridentata*	South	Desert View				300	High
Atriplex	*canescens*	South	Desert View	20	40	20	400	
Berberis	*fremontii*	South		90	300	400		
Cercocarpus	*ledifolius*	South		10	40	20		Moderate
Cercocarpus	*ledifolius*	South	Grandview		60	60		Moderate
Chamaebatiaria	*millefolium*	South		30	230	100		
Chrysothamnus	*nauseosus*	South			100			
Cowania	*mexicana*	South		40	140	130		High
Cowania	*mexicana*	South	Hermits Rest		25	150		High
Cowania	*mexicana*	South	Trailview		20	40		High
Cowania	*mexicana*	South	Mather Pt.		10	40		High
Ephedra	*viridis*	South			70	270		
Fallugia	*paradoxa*	South		200	100		1100	
Fallugia	*paradoxa*	South	BA Cabins		120	120		
Pinus	*edulis*	South		30	100	200		Moderate
Pinus	*ponderosa*	South		50	150	100		
Quercus	*gambelii*	South		10	10			
Ribes	*cereum*	South	Desert View		10	10		Moderate
Ribes	*cereum*	South			50	100		Moderate
Ribes	*cereum*	South	Shoshone		30	20		Moderate
Ribes	*velutina*	South			50	70		Moderate
Ribes	*velutina*	South	Grandview		20	30		Moderate
Robinia	*neomexicana*	South		30	100			
Symphoricarpos	*oreophilus*	South		80	190	50		
Symphoricarpos	*oreophilus*	South	Village		140	40		
Yucca	*baccata*	South			80	220		
Total				**1030**	**2400**	**2540**	**2300**	
Berberis	repens	North	Developed Area			40		
Cercocarpus	ledifolius	North	Developed Area		30	160		Moderate

Table 35: Grand Canyon North and South Rim Plant Inventory as of December 2000

Genus	Species	Rim	Collection	One-Gallon Treepots Ready by Spring 2001	One-Gallon Treepots Ready by Fall in 2001	One-Gallon Treepots Ready in 2002	Super Cell (10 in^3) Seedlings Started Dec 2000	Mortality Risk
Cercocarpus	ledifolius	North	Pt Imperial		20	40		Moderate
Ribes	cereum	North	Developed Area		20	40		Moderate
Robinia	neomexicana	North	Developed Area		20			
Robinia	neomexicana	North	Pt Imperial		20			
Rosa	arizonica	North	Pt Imperial		25	25		
Symphoricarpos	oreophilus	North	Pt Imperial		10	20		
Symphoricarpos	oreophilus	North	Developed Area		40	100		
Total					**185**	**425**		

Specialized Treatments

Outplanting Site: Grand Canyon National Park, South Rim

Target Seedling Information:

Stock Type:
One Gallon Tree Pot, 4" x 4" x 14"
Root system:
Consolidated root mass sufficient to prevent root ball disintegration during outplanting.

Seed Propagation:

Propagation Equipment:

Greenhouse 70°F day 55°F night during winter, maximum summer temperatures 85 F. A watering bench with mini-sprinklers automatically waters plug trays once a day in early morning. In extremely hot periods during the summer, twice a day watering is programmed. The watering bench is covered with a copper-coated fabric (Texel Forestry Fabric) to reduce root egress from the plug cells via capillary water movement.

Seed Propagation Method:

Dry or pretreated seed are sown in plug flats with square deep cells (288 or 512 cells per flat). Media is a commercial soil-less mix (Sunshine #1); plug trays are loosely filled with dry to slightly moist media, leveled off, and then compressed with an empty plug tray. The number of seed sown depends on size and estimated germination. Small or fluffy seed are dispersed as evenly as possible. Larger and more easily handled seed are sown with a goal of 2 to 5 seed per cell. Very small seed is not covered if its size will allow the seed to be washed into the media with overhead sprinkling. Larger seed with a possible light requirement are lightly covered with perlite. Fluffy seed receive a light covering of media enough to provide contact between seed and the moist plug media. Larger seed is covered with 5 to 10 mm of media.

Seed Treatment:

Cold Stratification:

Those species which require cold stratification are typically sown in plug trays as described above and placed on the watering bench for several days to ensure that the media is thoroughly moist an seed are imbibed. The seeded plug flats are covered with an inverted empty plug flat; to allow space between the seeded flats, then 4 to 5 seeded flats are stacked with the spacers. These stacked flats are placed in clean or disinfected polyethylene bags used for soil-less media and are sealed with twist ties; these bags contain perforations punched by the media manufacturer, which allow air exchange. These plug tray stacks are placed in a walk-in cooler held at 40 F and periodically checked for signs of germination or the need for adding moisture. When germination has started or when a sufficient stratification period has passed, the plug flats are moved to the greenhouse and placed on the watering bench.

Soaking/Leaching:

A number of species may benefit from a rigorous imbibition treatment and/or leaching of germination inhibitors. These seed are put in a rubber-lined rock tumbler jar along with tap water to undergo a wet tumbling which agitates the seed allowing easy oxygen and water entry into the seed. The water in the tumbler is changed daily to remove any inhibitors that may have leached out. The duration of tumbling is a guess me species with hard seed coats, carborundum grit and pea gravel are added to the tumbling water; this procedure can provide a scarification treatment for suitable species. based on the appearance of the seed and the leach water. For so

Seedling Production:

Container Type and Volume:

Ray Leach Super Cell – 10 cubic inch volume, 1.5 inch diameter, and 8.25-inch depth.

Growing Media:

Mix of 2 parts Sunshine #1 or #2 with 1 part perlite. 2 to 4 kg of controlled release fertilizer (CRF) Osmocote Plus 15-9-12 incorporated per cubic yard of mix. For plants started in the greenhouse during winter, 8-9 month release CRF is used, but for spring growth material 3-4 month release CRF is used.

Total Time:

The time required to produce a seedling ready for transplanting into a gallon tree pot is very dependent on species and the time of year in the greenhouse. Fast growing species can be ready in 3 to 4 months from germination. Slow growing species can take over a year.

Planting Technique:

The filled Super Cells are dribbled to provide a hole for the plug seedling. The plug seedling root ball is removed using a flat powder spatula with a blade about 6mm wide and 30mm long attached to a handle. The blade is plunged along the side of the root ball and the seedling plug is levered out of the cell. The plug is dropped into the dibbled hole. Top watering firms and fills any voids around the plug. If excessive numbers of seed have germinated, excess seedlings are cut off during the plug transplanting process.

Establishment Phase:

The Super Cell seedlings in the greenhouse are fertilized with a soluble fertilizer at every other watering. The fertilizer solution is Peters Peat Lite Special 20-10-20 at a rate of 200 mg/l nitrogen. Thinning of seedlings down to one per container occurs during this phase, usually when the seedlings are 2 to 4 cm tall.

Rapid Growth Phase:

Fertigation continues as described above.

Hardening Phase:

The goal is to have the Super Cell seedlings ready to move outside in early May after the last freeze, but before excessively hot outdoor temperatures. In the outdoor nursery, larger seedlings may require watering every day, smaller seedlings generally every other day. The seedlings are fertigated about once a week with Peters Peat Lite Special 20-10-20 at a rate of 200 mg/l nitrogen.

One-Gallon Treepot Production

Container Type and Volume:

One Gallon Tree Pot, 4"x4"x14"

Growing Media:

Commercial nursery canning mix of aged screened softwood bark, pumice, and sphagnum peat moss.

Total Time:

The fastest growing species can be ready in one year after transplanting, if transplanting occurs in May. The slowest growing species can take 3 or more years.

Planting Technique:

The treepots are filled with media and dibbled with a Super Cell planting dibble. Controlled release fertilizer is topdressed at planting or soon thereafter. Osmocote Plus or Sierrablen CRF was used. For pots transplanted in late spring, a 5 to 9 month release CRF is used. Seedlings transplanted later in the summer will receive 3 to 4 month release CRF. The treepots are supported in cages 36"x36"x8" constructed of 4" galvanized steel fence that holds 81 pots.

Establishment Phase:

Watering frequency in this phase is usually once or twice a week. Plants are grown without shade cloth or with (30%) shade). The shade has not been required to produce any of the species thus far.

Rapid Growth Phase:

Watering frequency can be as often as every day for large plants of certain species with substantial leaf areas. The most xeric species may only require once a week watering even in mid-summer.

Hardening Phase.

The watering frequency is reduced in late September to early October to promote hardening-off. The treepot cages are surrounded by straw bales before winter to lessen temperature fluctuations and provide some insulation for the root systems

Table 36 lists the specifics about the species grown for the GCNP.

Table 36: Species Specifics

Agave utahensis

Planting Technique:

Must be transplanted soon after germination before radical elongates excessively.

Stratification:

None required. Very slow growing, water infrequently.

Amelanchier utahensis

Seed Treatment:

Pre-soaking or wet tumbling results in mucilaginous mass that makes sowing difficult.

Stratification:

2 to 3 months. Fast seedling growth; moderate later growth, moderate water requirement.

Artemisia tridentata

Seed Treatment:

No cover for seed.

Stratification:

None required. Moderate seedling growth; moderate later growth, moderate water requirement, evergreen (needs more frequent winter watering). Have encountered catastrophic losses from unknown fungal pathogen.

Berberis fremontii

Seed Treatment:

Wet tumbling seems beneficial.

Stratification:

None required. Slow seedling growth; moderate later growth, moderate water requirement, evergreen (needs more frequent winter watering).

Cercocarpus ledifolius

Seed Treatment:

Wet tumbling has been used, followed by 3% hydrogen peroxide soak for 1 hour for disinfecting purposes.

Stratification:

1 to 2 months. Moderate seedling growth; slow to moderate later growth, low to moderate water requirement, evergreen.

Chamaebatiaria millefolium

Seed Treatment:

No seed cover or very light covering.

Stratification:

2 to 4 weeks. Moderate seedling growth, moderate later growth, moderate to high water requirement, semi-evergreen (needs more frequent winter watering).

Chrysothamnus nauseousus

Seed Treatment:

Table 36: Species Specifics

Bulk sowing of plumed seed with light covering.

Stratification:

None required. Moderate seedling growth, requires clipping during phase to promote branching, moderate later growth, moderate water requirement.

Ephedra viridis

Seed Treatment:

Wet tumbling seems beneficial.

Stratification:

2 to 6 weeks. Slow seedling growth, requires clipping during seedling phase to promote branching, slow later growth, low water requirement, and evergreen.

Fallugia paradoxa

Seed Treatment:

Bulk sowing of plumed seed with light covering.

Stratification:

None required. Slow to moderate seedling growth, benefits from clipping during seedling phase to promote branching, moderate to fast later growth, low to moderate water requirement, semi-evergreen.

Juniperus osteosperma

Seed Treatment:

Have tried long warm stratification followed by long cold stratification with very little success. Presently examining scarification techniques that will be followed by warm stratification and then cold stratification. Very slow seedling growth, evergreen.

Pinus edulis

Seed Treatment:

Soaking or wet tumbling seed for several days.

Stratification.

2 to 8 weeks. Slow seedling growth, slow later growth, low to moderate water requirement, evergreen (needs more frequent winter watering).

Pinus ponderosa

Seed Treatment:

Soaking or wet tumbling seed for several days.

Stratification:

2 to 8 weeks. Slow seedling growth; slow later growth, moderate water requirement, evergreen (needs more frequent winter watering).

Quercus gambelli

Seed Treatment:

Cold moist storage immediately after collection, radicle will emerge in cold.

Stratification:

Some acorns behave as if cold is required to overcome epicotyl dormancy. Slow seedling growth; moderate later growth, moderate water requirement.

Purshia mexicana (Cowania mexicana)

Table 36: Species Specifics

Seed Treatment:

Wet tumbling seems beneficial

Stratification:

1 to 2 months. Slow seedling growth, slow later growth, low water requirement, prone to winter mortality probably because of moisture extremes, evergreen.

Ribes cereum

Seed Treatment:

Wet tumbling seems beneficial.

Stratification:

2 to 3 months. Moderate seedling growth, moderate to fast later growth, moderate water requirement.

Rosa arizonica?

Seed Treatment:

Wet tumbling seems beneficial.

Stratification:

Moderate seedling growth, moderate to fast later growth, moderate water requirement.

Robinia neomexicana

Seed Treatment:

Scarification using dry tumbling with grit and pea gravel for 5 to 7 days.

Stratification:

None required. Fast seedling growth, fast later growth, high water requirement.

Symphoricarpos oreophilus?

Seed Treatment:

Wet tumbling seems beneficial.

Stratification:

2 to 4 months. Fast seedling growth, requires clipping during seedling phase to promote branching, moderate to fast later growth, high water requirement.

Yucca baccata

Planting Technique:

Must be transplanted soon after germination before radicle elongates excessively.

Stratification:

None required. Very slow growing, water infrequently.

Observations

A new field of Muttongrass has been established, and it could possibly produce seed in 2001.The Blue grama field looked very promising in 2000, with abundant seedheads being produced. Upon cleaning of the harvested material, it was determined that no viable seed was produced. From the beginning of the Muttongrass establishment at the PMC, this ecotype has been notorious for very low seed yields. A new field of Blue grama was established in 2001 and seed could be produced in 2001. The existing Blue grama will be checked for insect damage and a spraying maybe initiated in 2001 to try to get a seed crop.

Tall-Pot Transplants Established With Hydrogel A Technique for Revegetation in the Arid Southwest without Intensive Irrigation

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Introduction

Developing a successful transplanting system that has minimal follow-up maintenance, particularly irrigation was needed for landscaping highway medians and right-of-ways in the arid southwest. Container planting of shrubs, with some irrigation, is essential for successful revegetation of most dry sites. The selection of tall-pot containers coupled with the application of a superabsorbent hydrogel (sodium carboxymethyl cellulose) for irrigation is being tested at three locations in northern New Mexico that receive an average annual precipitation of 10 to 14 inches. Two superabsorbents having substantially different cost per application are also being evaluated. The New Mexico State Highway and Transportation Department primarily funded this study and demonstration project. Other funding sources include the Wildland Native Seed Foundation and the Plant Materials Center (PMC) Interagency Riparian Group.

The superior performance of containerized transplants grown in tall-pots (containers longer than 24 inches) has been well-documented (see Figure 9). After eight years of field experience testing different container size transplants, Bainbridge (1994) concludes that seedlings grown in deep containers (i.e. PVC pipe) have improved survival and growth compared to smaller transplants grown in Super Cells or plant bands. He has found that excellent seedling survival and growth can be expected even in areas with less than 3 inches of rain per year if plants are properly planted and provided with minimal water (2-3 supplemental waterings totaling about 2 quarts). *The Center for Arid Lands Restoration* at Joshua Tree National Monument in California has developed a tall-pot made with 32 inch tall, 6 inch diameter PVC pipe with a wire mesh base held by cross wires. Survival rates improved more than 40 percent (Holden, 1992) these transplants on a south facing slope in the low desert (compared to 16 inch transplants). In Australia, tall-pots have been used with consistent success (Newman 1990).

Figure 9: 28-inch root-ball of a shrub grown in a PVC tall-pot

Plant trials on tailing ponds (beginning as early as1968) have shown it is essential to supply irrigation water during the first two growing seasons where annual precipitation is 11 to 12 inches (Ludeke, 1977). As an alternative to traditional irrigation, a superabsorbent hydrogel can be applied. A superabsorbent hydrogel is a crosslinked polymer or acrylonitrile with cellulose that absorbs and retains water hundreds of times its own weight. There are several types of superabsorbents that have been developed (see Table 37).

Table 37: Types of Superabsorbents

Chemical Name or Ingredient	Market Application	Period
Polyethylene Oxide/sawdust	Soil amendment	1965 –1978
Polyvinyl Alcohol	Diapers	1975 –present
Acrylonitrile/starch	Tampons, napkins, soil amendment,	1979 – present

Table 37: Types of Superabsorbents

Chemical Name or Ingredient	Market Application	Period
	planting seedlings	
Potassium Propenoate/Propenamide copolymer	Soil amendment, gel seeding, plug-mix planting, root-dip,	1982 – present
Acrylic Acid	Diapers, sanitary napkins, water treatment, soil amendment	1981 – present
Acrylamide	Diapers, sanitary napkins, soil amendment	1983 – present
Acrylic Acid/Acrylamide	Diapers, soil amendment	1985 – present

Copied from Erazo (1987)

Some superabsorbents have been traditionally used in horticulture and agriculture successfully as soil additives as reported by Erazo (1987) to: 1) improve water holding capacity, 2) improve aeration and drainage of soil mix, 3) reduce irrigation frequency, and 4) increase shelf life of plants in cold storage. Also, some superabsorbents have been used as root dips for shipping bare root seedlings.

DRiWATER, Inc. has developed a unique usage for a superabsorbent as an irrigation source for transplants in arid environments. When the powdered product is hydrated, each granule acts as a tiny water reservoir that becomes available to plants as microbial degradation of the cellulose product that releases free water available for movement into soil or plants through root absorption. DRiWATER, Inc. sells their product either as a powder or already hydrated in quart containers to be opened. The product in containers is turned upside down and partially buried in the root zone of a plant. This product gravity feeds water into the soil of plant root zones. Additionally, the superabsorbant sold by DRiWATER, Inc. (like some other hydrogels) are appropriate for use with plants because they are nonphytotoxic and have a neutral pH (see Attachment 1).

Methodology

Native shrub species of ecotypes generally with origins within a 200 mile radius of the planting sites were grown in 30-inch tall, 4 inch diameter PVC DWV (drain, waste and vent) pipe (see Table 38) at the Plant Materials Center in Los Lunas, New Mexico.

Depending upon species, it generally takes about three years to produce a mature root ball from seed in this container (some take four years or longer, for example, mountain mahogany, winterfat and Mormon tea). These containers have two split seams that run most of the pipe length to encourage spiraling roots to grow downward and ease root ball removal. The bottoms of the containers are sealed with a porous fabric to allow drainage. The fabric was manufactured with a Spin Out coating (copper hydroxide) to control root penetration.

During the Fall of 2000, more than 1,500 transplants of 16 different species (see Table 38) were planted in northern New Mexico at three locations: Milan, Santa Fe, and Eldorado Village.

Table 38: Native Plant Species and Origin of Shrubs Planted at Milan, Eldorado, and Santa Fe

Scientific Name	Common Name	Accession Number or Cultivar Name	Origin
Amelanchier uthensis	Utah Serviceberry	Commercial	Southwest CO
Cercocarpus montanus	Mountain mahogany	Commercial	North Central NM
Cercocarpus ledifolius	Curl leaf mahogany	Commercial	Southeastern Utah
Forestiera neomexicana	New Mexico privet	Jemez	North Central NM
Philadelphylls micropyllus	Littleleaf mockorange	Commercial	Southwest CO
Prunus virginiana	Chokecherry	9004629	North Central NM
Quercus gambelli	Gambel oak	Commercial	North Central NM
Quercus undulata	Wavyleaf oak	9066437	North Central NM
Rhus trilobata	Three leaf sumac	Bighorn	Bighorn
Ribes cereum	Wax current	9066057	North Central AZ
Robinia neomexicana	New Mexico locust	9066428	Northeastern NM
Rosa woodsii	Wood's rose	9066421	North Central NM
Shepherdia argentea	Silvery buffaloberry	9066475	Southwest CO
Chamaebatiaria millefolium	Fernbush	9062866	North Central CO
Berberis fremontii	Fremont barberry	9066439	Southwest CO
Ceratoides lanata	Winterfat	9066471	Southwest CO

Planting holes were dug with 9-inch diameter, 40-inch long Beltec auger powered by a 50-horsepower farm tractor. Holes, 3-foot in depth, were hand cleaned using standard post-hole diggers. Plants were then removed from containers, placed in holes, and back-filled. Prior to back filling, an irrigation tube was placed in each hole (see Figure 10).

Figure 10: Watering plants through irrigation tubes to remove air pockets and hydrate the soil in the root zone (November 2000)

This tube allows the plant to be irrigated with either hydrated sodium carboxymethyl cellulose (HSCC) or water near the bottom of the root-ball to encourage growth of a deeper root system. The irrigation tubes are constructed from a PVC DWV pipe 3-inches in diameter and 40-inches in length, (see Figure 11). The orifice is capped to prevent animal entry and exposure of the root systems to sunlight. The 10-inch top section of the tube can be removed from the 30-inch perforated main tube body. After the end of the irrigation period (two years), the top 10-inch section of pipe will be removed and the remainder will be back-filled with soil. Because the lower portion of the tube should contain substantial root development, it will remain in place. The three plantings will be evaluated for survival in fall of 2001 through 2003.

Figure 11: Irrigation tubes used in the 3 plantings

The Milan Planting

A total of 96 shrubs and trees were planted on September 12, 2000 on Highway NM 124 median in Milan, NM in front of the New Mexico Highway Department District Office. This area receives an annual average precipitation of 10- to 12-inches. The subsurface soil was damp from recent precipitation. The planting covers about 1/4 mile of highway median with the plants spaced on 10-foot centers and separated into four groups (see Figure 12 and Attachment 2). Additionally, 16 ponderosa pine and 25 pinion pine will be planted when the root-balls of these plants are fully developed (possibly Fall, 2001).

Figure 12: The planting on the median of NM Highway 124 in Milan (February 22, 2001)

Approximately 3-gallons of water were applied to each irrigation tube on September 13, 2000. The apache plume plants on the northwest end of Group Four did not have irrigation tubes and were watered by surface soaking with a garden hose (approximately 10 gallons per plant). Likewise, the two apache plume plants at the southeast end of Group Two did not have irrigation tubes and were watered only by surface soaking with a garden hose.

The three apache plume plants that did not have irrigation tubes were wilted and had initiated leaf dropping by our return to apply the HSCC (nine days after planting). The weather during this period had daytime high temperatures of 90 degrees F, and coupled with strong winds. These desiccated plants were surfaced watered heavily once again. All the other plants that had been irrigated through the tubes looked vigorous. On September 22, 2000, approximately 2 gallons of HSCC was applied to each plant by filling the irrigation tubes. The most southeast plant of each of the four plant groups did not receive HSCC, but they were irrigated with a second application of water (3 gallons) in the irrigation tubes. The HSCC was hydrated, mixed, and pumped by a modified hydromulcher. Plants will receive a second treatment of HSCC in fall of 2001.

Figure 13: The irrigation tubes are exposed about 4 inches from the soil surface of the northwest planting on the Ridgecrest inter-change on NM Highway 599 (January 2001)

The Santa Fe Planting

Seven hundred tall-pot native shrubs were planted on the Ridgetop Road interchange on Highway 599 in Santa Fe, NM (see Figure 13) from October 3 to 10, 2000. This area averages about 12 to 14 inches of annual precipitation. The shrubs were planted on hillside terraces, in separate 100- to 200-foot single rows on 8-foot centers (see Figure 13 and Attachment 3). Plants had received 3 gallons of water in irrigation tubes immediately after planting. Because the area had been receiving heavy precipitation during and after the planting, the HSCC was not applied.

The HSCC will be applied to 75 percent of the plants in April, 2001 (once the plants break winter dormancy). The remaining 25 percent will receive either 3 gallons of water or 2 gallons of a different brand of starch-based hydrated superabsorbent. A less expensive superabsorbent that provides slow-release water would improve the affordability of this technique to more potential users.

The Eldorado Village Planting

From November 6 to December 8, 2000, 808 tall-pot, native shrubs were planted on the median of NM Highway 285 (beginning at the Interstate 25 junction and continuing 3 miles south). This area is known as the Eldorado Village, and it receives approximately 10- to 12-inches of annual precipitation. The actual planting only took 11 days to complete, but because of snowstorms, the planting was frequently delayed. Volunteers and PMC Staff installed the plants in 5- to 15-unit random clusters on the median Project (see Figure 14) in areas selected by the NM State Highway and

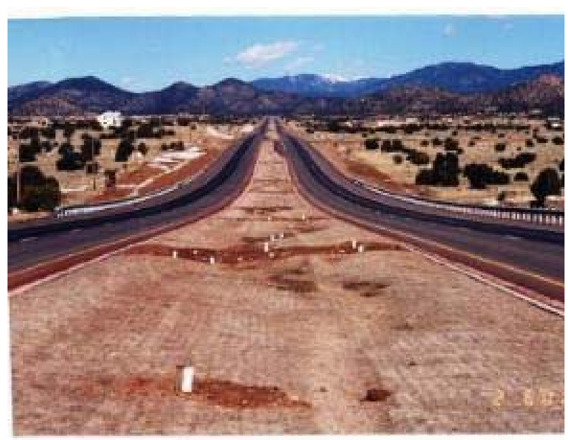

Figure 14: Plants were installed in open areas of a mulch blanket seeding on the median of NM Highway 285 (January 2001)

Transportation Department and by Ms. JoEllen Schilmoeller, liaison for the Eldorado Community Highway 285). Ms. Schilmoeller also arranged for the more than 25 Eldorado community volunteers to help with planting, and water for irrigating was supplied by the Eldorado Fire Department. All plants were watered during the last week of the planting period. In April 2001 (when the plants break winter dormancy) 75 percent will receive a 2-gallon application of HSCC. The remaining 25 percent will receive either 3-gallons of water or 2-gallons of a less expensive starch based hydrated superabsorbent (approximately 1/4 of the cost). Plants will receive a second treatment in Spring of 2002. The first year application of HSCC was purchased by the Wildland Native Seed Foundation and donated to this project.

In March 2001, approximately 300 dormant pole cuttings (100 black willow and 200 Rio Grande cottonwoods) will be planted on the roadside in areas that receive extra runoff (rainfall harvesting areas). The NM State Highway and Transportation Department and Ms. JoEllen Schilmoeller have already selected the locations

Approximately 1,000 additional native shrubs in tall-pots will be planted in the Fall of 2001. 87 percent of these plants will receive a 3-gallon application of water and two applications of a hydrated superabsorbent during the first two years of establishment. For comparison, the remaining 13 percent will receive three, 3-gallon applications of water during the two-year establishment period.

Acknowledgements

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Literature Cited

Bainbridge, D.A. 1994. Container Optimization – Field Data Support Container Innovation. National Proceedings: Forest and Conservation Nursery Association: 99-104.

Erazo, F. 1987. Superabsorbent Hydrogels and Their Benefits in Forestry Applications. Meeting the Challenge of the Nineties: Proceedings, Intermountain Forest Nursery Association: 14 – 17.

Holden, M. 1992. The Greening of a Desert. American Nurseryman 4/15: 22-29.

Ludeke, K.L. 1977. Tailing Reclamation. Reclamation and use of Disturbed Land in the Southwest, The University of Arizona Press: 271

Newman, R., S. Neville, and L. Duxburg. 1990. Case Studies in Environmental Hope, EPA Support Services, Perth Australia