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Table Of Contents

Root Growth of Apache Plume and Serviceberry on Molybdenum Mine Overburden in Northern New Mexico[1]

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Abstract

This study evaluated root growth of Apache plume (*Fallugia paradoxa*) and Saskatoon serviceberry (*Amelanchier alnifolia*) on overburden at the Molycorp, Inc. Mine near Questa, NM. Container grown, 1-year-old seedlings were transplanted, and either fertilized or not fertilized at the time of planting in August 1995. Survival and shoot growth were monitored in 1996 and 2000. Root density was determined at three distances (planes) from the base of the plant at six depths in 2000. Fertilization effects on serviceberry root densities were depth dependent. Total root density of unfertilized plants was greater than fertilized plants. Serviceberry total root density differed among planes (distances from base of plant) between fertilization treatments. Fertilized plants had fewer roots in the 10-cm plane relative to the 20- and 30-cm planes. Fertilized plants of Apache plume had higher total root densities at depths >20 cm within the 20-cm plane than plants not fertilized at time of planting. Although overall performance in terms of shoot growth was positive for both species, survival was generally low and root density varied when fertilized at time of planting. Factors including fertilizer characteristics, planting date, and site conditions may have influenced species performance.

[1] In: Hild, Ann L.; Shaw, Nancy L.; Meyer, Susan E.; Booth, D. Torrance; McArthur, E. Durant, comps. 2004. Seed and soil dynamics in shrubland ecosystems: proceedings; 2002 August 12-16; Laramie, WY. Proceedings RMRS-P-31. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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Introduction

New Mexico State and Federal laws require that mined lands be reclaimed to support a designated post-mining land use (State of New Mexico 1999). Forestry as a post mining land use has been encouraged by regulatory agencies since the mid- to late-1990s (Boyce 1999). Metal mines within the mountainous Western United States including the Molycorp, Inc. molybdenum mine near Questa, NM, are selecting forestry as a post mine land use to re-establish a plant community comparable to adjacent native vegetation.

Open-pit mining at the molybdenum mine generated over 300 million metric tons of overburden from 1965 until 1983. The overburden exists in piles that range in altitude from 2,400 to 3,000 in and are composed of mixed igneous rocks (rhyolite and andesite) and black andesite and aplite materials (referred to as neutral rock). Mine overburden can be low in organic matter, soil micro-organisms, and plant nutrients such as nitrogen and phosphorus and can lack soil structure and texture that are important to soil fertility and water holding capacity (Allen 1989; Feagley 1985). These properties make it challenging for plants to establish, thus overburden or plant amendments are often recommended (Brown and others 1996; Gardiner 1993).

Research studies on the survival of directly transplanted trees and shrubs on the overburden began in the early 1990s (Harrington and others 2001a,b,c). These studies indicated that the overburden was suitable to support plant life, in terms of transplant survival. In most instances, however, shoot growth was limited. Other research has shown that shoot growth of newly transplanted tree and shrub seedlings can benefit from supplemental fertilization in both minimally disturbed (Fan and others 2002; Houle and Babeux 1994; Walker 1999a) and drastically disturbed ecosystems (Fisher and others 1983; Voeller and others 1998; Walker 1999b). Growth response to fertilizer application, however, can be both species specific (Voeller and others 1998; Houle and Babeux 1994) and site specific (Gleason and others 1990).

The ability of transplanted seedlings to establish new roots into a planting medium is essential to their survival and subsequent growth. Plants with a well-established root system add to the success of post mine revegetation, control erosion, and improve overall post mine conditions. Most fertilization studies, however, focus primarily on shoot growth characteristics and disregard belowground growth. Early plantings of ponderosa pine (*Pinus ponderosa*) at the Molycorp, Inc. Mine were evaluated for root growth after 6 years of growth. Rooting depth of some plants extended beyond 2 m in the overburden (Harrington, unpublished data). This observation led to questions regarding growth allocation of directly transplanted trees and shrubs at the Molycorp, Inc. Mine with fertilization treatments.

This study evaluated the influence of fertilization at time of planting on root distribution and growth of two native woody shrubs, Saskatoon serviceberry (*Amelanchier alnifolia*) (hereafter referred to as serviceberry) and Apache plume (*Fallugia paradoxa*), transplanted into overburden at the Molycorp, Inc. Questa Mine. Root densities and distributions were described at six depths and three distances from the base of each plant to examine the effects of fertilizer applications at the time of planting.

Materials and Methods

Site Description

Molycorp, Inc., molybdenum mine is located near Questa, NM, in the Red River Canyon and produces the largest amount of molybdenum in the state (Schilling 1965, State of New Mexico 1999). Overburden from open-pit mining was deposited on the steep mountainsides of Red River Canyon. The overburden piles are highly heterogeneous, consisting of parent materials with a range of acidic and soluble salt levels (Steffan and Kirsten 1995).

Vegetative communities surrounding the mine consist of coniferous forests dominated by ponderosa pine, mixed conifer (Douglas fir [*Pseudotsuga menziesii*] and limber pine [*P. flexilis*]), and spruce-fir (Engelmann spruce [*Picea engelmannii*] and white fir [*Abies concolor*]) stands (Harrington and Wagner 1994). Naturally formed alteration scars occurring in acidic (pH = 1.8 to 3.5) materials, occur at the mine and throughout the Red River Canyon (Meyer and Leonardson 1990; Steffan and Kirsten 1995). Plants from adjacent communities have established in the periphery of these scars (Wagner and Harrington 1994).

Two planting sites (Blind Gulch and Spring Gulch) were located on terraced portions of overburden piles at the molybdenum mine. Spring Gulch (2,780 m) is composed primarily of neutral rock with an average pH of 7.7, electrical conductivity (EC) of 0.5 dS/m, and coarse fragment fraction (content) of 69 percent. Blind Gulch (2,860 m) consists of both acidic and neutral overburden materials. Chemical composition of the overburden across the planting area at Blind Gulch was varied. Average values for pH, EC, and coarse fragment fraction (content) in planting blocks one and two were 4.4 and 7.3, 1.2 and 1.3 dS/m, and 60 and 59 percent, respectively.

Planting Stock

Seedlings of Apache plume (Questa, NM, seed source) and serviceberry (Utah seed source) were propagated at the Natural Resources Conservation Service Plant Materials Center in Los Lunas, NM. Seedlings were grown in 164-cm^3 containers (Ray Leach Super Cells) in a peat:perlite growing media (two parts peat moss and one part perlite by volume). Plants were fertilized with a water soluble 20-10-20 fertilizer (Peter's Peat Lite Special).

Fertilization Treatments

Prior to transplanting, sites were ripped to a depth of 45 cm and irrigated. Ripping was accomplished using three 65-cm ripping bars attached to the back of a crawler tractor. In August 1995, seedlings (approximately 10 to 20 cm tall) were transplanted into the two sites in a randomized complete block design and irrigated the day after planting. Three blocks per site were established and each block had two parallel rows, 50 cm apart. Within each row, plant spacing was 30 cm. One row of each replicate block received fertilization treatment at the time of planting and the other row did not receive fertilizer (control plots). Six grams of Sierra, Inc., 17-6-12 plus micronutrients slow-release fertilizer (Scotts Company, Marysville, OH) were placed into each planting hole prior to transplanting the seedlings. Release duration of this fertilizer is 3 to 4 months at 21° C. From 1996 through 2000 all plants received supplemental fertilization once each year.

Survival and Shoot Growth

In September 1996 and August 2000 survival of both species was documented. In spring 2001, shoot growth (height and crown width) was measured to the nearest centimeter for each plant. An average crown width was calculated for each plant using two perpendicular measurements of crown width oriented at 45 degrees to the direction of the planting row.

Root Measurements

In blocks one and two from each site, two plants per species per fertilization treatment were measured for root growth and distribution. Roots were evaluated using techniques described by Parsons and others (1998). Initial excavation in November 2000 was performed using a backhoe to create a trench 1.5 m deep and 2 m long, 45 cm from the base of each shrub row. A 30 by 30 cm vertical plane was hand excavated 30 cm from the base of each plant where a 30 by 30 cm sampling frame was placed for root evaluation. The frame was constructed out of clear Plexiglas and divided by lines into 36, 5 by 5 cm grid cells. In each grid cell, roots were counted and divided into three diameter classes: <0.5, 0.5 to 2.0, and >2.0 mm. Root measurements were repeated at 20 and 10 cm from the base of each plant within the same vertical sampling frame.

Data Analysis

The experimental design was a completely randomized design set in a split-split plot. Whole plot treatment was site and block within site was the whole plot error term. The split factor was fertilization treatment and the split- split factors were plane and depth. 'Plane" refers to the horizontal distance away from the plant perpendicular to the row (10, 20, or 30 cm).

Survival of each species in 1996 and 2000 was analyzed through Chi-square tests in SAS using PROC FREQ (SAS Institute 1997). Shoot growth (height and crown width) was analyzed for each species using analysis of variance in SAS (PROC GLM) to indicate simple and interaction effects of site and treatment.

Root counts were analyzed separately for each species using analysis of variance in a 2 (site) x 2 (fertilization treatment) x 3 (plane) x 6 (depth) factorial (PROC MIXED, SAS Institute 1997). Roots from three categories were combined for a weighted total to obtain a total root density (number of roots per 150 cm 2). Roots 0 to 0.05 mm were assigned a midpoint value of 0.025, roots 0.05 to 2.00 mm were assigned a midpoint value of 1.25, and roots greater than 2.00 mm were assigned a midpoint value of 2.25.

For root response, PROC MIXED calculated F statistics, means, and standard errors of both main effects and interaction combinations. Main effects of plane and depth and their interactions with fertilization treatments were evaluated, and least significant differences (LSD) were carried out for pairwise comparisons of main effects of plane and depth on root growth. All treatment effects for survival, and shoot and root growth were evaluated for significance at the 0.05 alpha level.

Results

Saskatoon Serviceberry

Fertilization at time of planting increased serviceberry crown width relative to unfertilized control plants ($p = 0.0015$). Crown widths of fertilized and control plants were 31.2 and 19.0 cm, respectively. However, fertilization at time of planting reduced survival of serviceberry, compared to controls, at both planting sites in 1996 ($P = 0.0006$) and 2000 ($p = 0.0002$). Survival of nonfertilized control plants was highest at the Spring Gulch site (Table 1).

Table 1: One- and five-year survival of serviceberry by site and fertilization at time of planting

		Survival[a]		
Site	**Treatment**	**1996**	**2000**	**Percent[b]**
Spring Gulch	Control	15	14	93
Blind Gulch	Control	10	10	67
Spring Gulch	Fertilize	6	4	27
Blind Gulch	Fertilize	5	4	27

a Survival as in number of individual plants, n – 15.
b Percent survival in 2000

Fertilization at time of planting influenced total root density of serviceberry depending on sampling depth ($P < 0.0001$; Figure 1). Fertilized plants had lower total root densities at 5- to 10- and 10- to 15-cm depths than control plants. Across horizontal planes, fertilization treatments influenced total root density of serviceberry (P < 0.010, Figure 22). Service- berry plants not fertilized at time of planting had greater total root density in the 10-cm plane than fertilized plants.

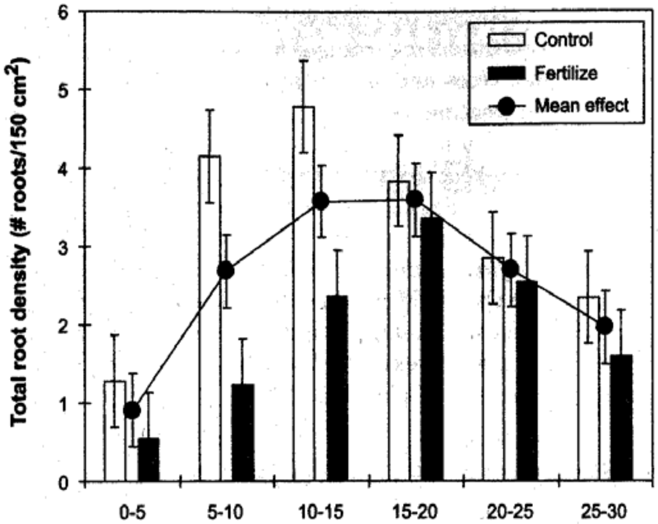

Figure 1: **Total root density of serviceberry for control and fertilization treatments across overburden depths. Mean represents the effect of overburden depth averaged across fertilization treatments. Bars represent ± one standard error, n = 4.**

Apache Plume

Shoot growth of Apache plume plants fertilized at time of planting was greater than unfertilized plants (height, P < 0.0001; crown width, P = 0.0022). Average height and crown width of fertilized plants were 42.4 and 43.2 cm, while average height and crown width of control plants were 21.3 and 29.0 cm, respectively. Survival of Apache plume was influenced by site and fertilization treatments in 1996 (p = 0.0035) and 2000 (p = 0.0018). Nonfertilized plants at Spring Gulch had the highest survival in both years out of all site by treatment combinations, while fertilized plants at Blind Gulch had the lowest survival in 1996 and 2000 (Table 2).

Table 2: One- and five-year survival of Apache plume by site and fertilization at time of planting

		Survival[a]		
Site	**Treatment**	**1996**	**2000**	**Percent[b]**
Spring Gulch	Control	21	20	95
Blind Gulch	Control	13	12	57
Spring Gulch	Fertilize	16	16	76
Blind Gulch	Fertilize	11	9	43

a Survival as in number of individual plants, n – 21.
b Percent survival in 2000

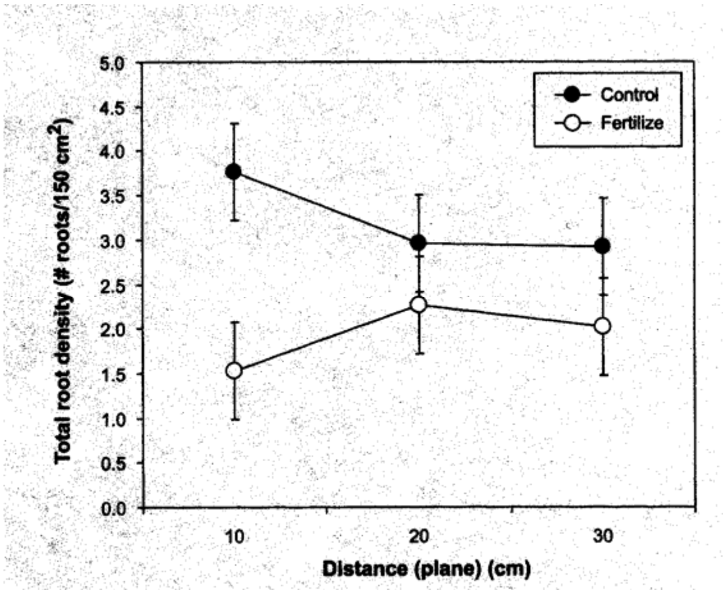

***Figure 2*: Total root density of serviceberry for control and fertilization treatments at three distances (planes). Bars represent ± one standard error, n = 4.**

Fertilization at time of planting influenced Apache plume total root density depending on depth and plane (P = 0.0012; Figure 3). In the 20-cm plane, total root density of fertilized plants was greater at depths below 20 cm than all other treatments.

Discussion

Survival and Shoot Growth

Survival of fertilized serviceberry and Apache plume plants was low the first year after planting, although fertilized plants that survived were larger than control plants. Increased shoot growth with fertilizer applications is concurrent with other literature. Burgess and others (1995) found NPK fertilization treatments improved shoot growth of white pine (*Pinus strobiformis*). Fertilizer applications on a reclamation site in Idaho increased growth of both native and introduced plant species (Williams and others 1990). Nitrogen and phosphorus applications greatly increased pine seedling height on mine overburden in Alabama (Zarger and others 1973).

Low survival has been associated with the use of slow-release fertilizers in other studies. Fisher and others (1983) observed slow-release fertilizer caused high mortality in juniper seedlings (*Juniperus monosperma*). At an eastern Sierra Nevada surface mine, slow-release fertilizers applied at doses of 30 g increased mortality of containerized, transplanted Jeffrey pine (*Pinus jeffreyi*), whereas doses of 10 and 20 g did not affect mortality (Walker 1999b). Transplanting date and release time of the fertilizer used in the study may have caused the observed mortality during the first year for serviceberry. Fisher and others (1983) suggest transplanting and fertilizing containerized tree seedlings during the summer rainfall period (July) in the Southwest rather than in late summer and fall. Slow-release fertilizer applications in August were more detrimental to juniper seedling growth and survival than May and July applications. It was speculated that low night temperatures following recent nutrient additions resulted in frost damage in August (Fisher and others 1983). Mortality of ponderosa pine seedlings in northern Idaho was influenced by dose and rate of slow-release fertilizer, with high doses and 9- and 12-month release times increasing mortality (Fan and others 2002).

Survival and shoot growth of transplanted and fertilized woody seedlings appear to be influenced by many abiotic factors including planting date and the amount, formulation, and rate of release of slow-release fertilizer. Based on published reports and our findings, transplanting Apache plume and serviceberry earlier in the growing season, early to midsummer, with a concurrent application of a slow-release fertilizer that releases nutrients when plants are actively growing, may reduce mortality and promote shoot growth for both species.

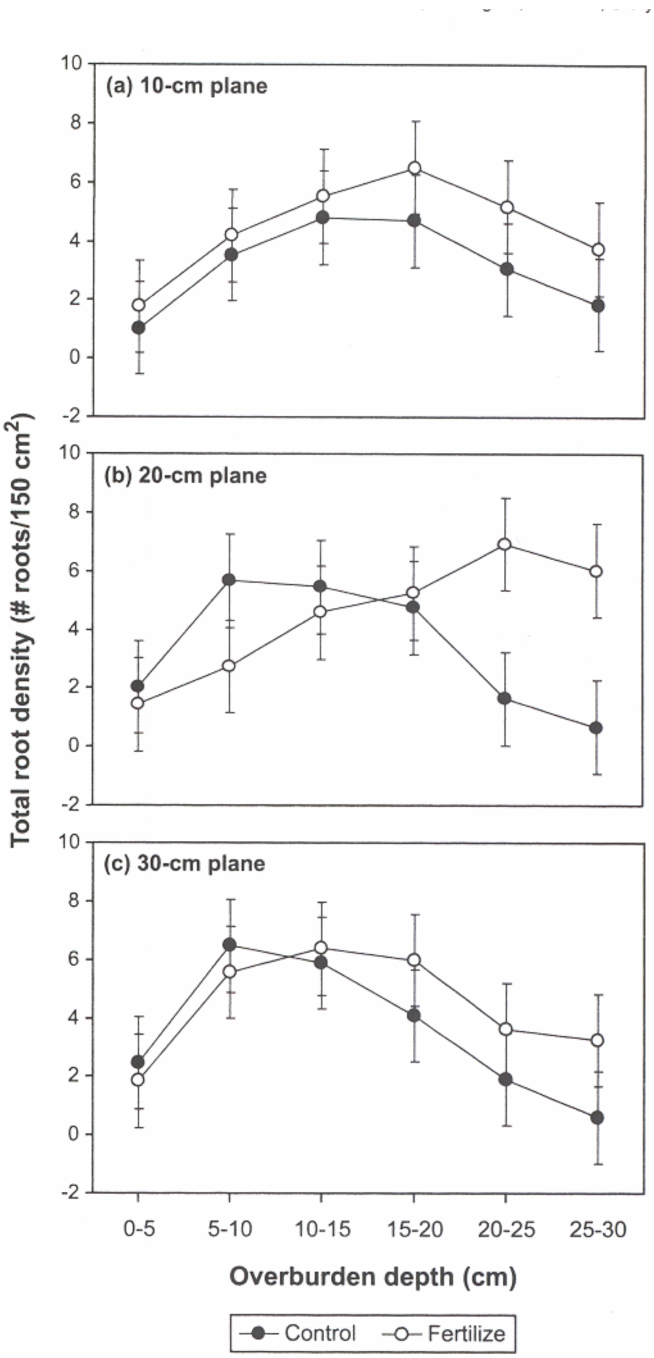

Figure 3: Total root density of Apache plume for control and fertilization, treatments across overburden depths at three distances (planes). Bars represent ± one standard error, n = 4.

Root Growth

Fertilization treatment effects on plant root density and distribution vary in the literature. In this study, there was no main effect of fertilization on overall root density for either species, but fertilization at time of planting did affect root distribution. Studies have shown alteration in plant root distribution in relation to fertilizer applications. For example, grasses increased their root growth in response to increased soil nutrients (Eissenstat and Caldwell 1988). Friend and others (1990) found that Douglas-fir plants produced more roots in nitrogen-rich than in nitrogen-poor micro-environments. In nitrogen stressed environments, Douglas-fir plants had a greater frequency of roots within nitrogen rich microenvironments than in nonstressed environments (Friend and others 1990). Similarly, Ringwall and others (2000) observed that fertilized leafy spurge plants allocated a greater portion of root biomass within the first 10 cm of soil and distributed a larger portion of roots in fertilized areas of the planting medium. It appears that root system distribution can be manipulated by fertilization at time of planting, but responses may be species dependent, as seen in our study.

Fertilization at time of planting had a negative effect on total root density of serviceberry at the base of the plant relative to the nonfertilized control. The rapid release of nutrients coupled with transplanting in late summer when plants were still actively growing may have promoted shoot development at the expense of root development into the overburden. As a consequence, plants receiving fertilizer at time of planting may have had insufficient root systems to support their growth and survival during the first year following plantings. Fertilization had an overall positive effect on total root density of

Apache plume deeper in the profile at 20 cm from the base of the plant. Although fertilization decreased survival of Apache plume, its effect on shoot growth and root density suggests that the treatments were not as detrimental to the plant's performance as it was in serviceberry. Species were analyzed separately in this study; however, comparisons as to their response to fertilization at time of planting are important for future decisions about species selection and revegetation designs.

Fertilizer applications at time of planting may increase the establishment of herbaceous species (annuals, grasses, and forbs), which can negatively impact (for example, nutrient and water competition) survival and shoot and root growth of transplanted shrubs and trees (Cook and others 1974). Although not measured, plots fertilized at time of planting did have an observable increase of volunteer herbaceous plants (grasses and annual forbs) compared to control plots in 2000. It is not known when these plants became established, but favorable conditions did exist for them to establish within these plots. Favorable conditions may include fertilizer applications and lack of root competition near the soil surface (<20 cm), since both species fertilized at time of planting allocated a greater portion of roots deeper in the soil than at the surface. However, further evaluations are needed to determine whether the observed root response in both species was due directly to fertilizer applications or indirectly from competition from volunteer plants, or both.

Conclusions

Although overall performance in terms of shoot growth was positive for both species when fertilized at time of planting, other fertilizer related factors will need to be investigated to enhance establishment, growth, and long- term survival of plants planted directly into mine overburden at high elevations. Slow-release fertilizer formulation, release rate and total amount applied should be investigated more closely. While these factors have been investigated in other systems (Fan and others 2002; Walker 1999a,b), the impact of these treatments on plants at high elevations (>2,500 m) remains largely unknown.

Additional factors, which need further investigation, are related to fertilizer treatments for high elevation planting and include time of planting relative to the end of the growing season. Previous studies at this mine indicate two periods suitable, in terms of available moisture, for transplanting. These are during the midsummer rain period and in early fall. Incorporation of fertilizer, in particular nitrogen fertilizer, on fall plantings is not recommended; however, further work is warranted to look at planting and fertilizing earlier in the growing season than was performed in this study. The effects of incorporating slow- release fertilizer at this time will impact plant response. Too slow a release rate or too short a timeframe to the end of the growing season may increase mortality rates. Transplanting in midsummer, as recommended by Fisher and others (1983), may have prevented mortality in both species when fertilized. Timed properly this treatment can result in larger, more vigorous plants.

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Propagation Protocol For Container Willows In The Southwestern U.S. Using Seeds[1]

By: David R. Dreesen[2]

Study Number: NMPMC-T-0501-OT

Key Words: *Salix arizonica, S. bebbiana, S. exigua, S. irrorata, S. scouleriana*, Arizona willow, bebb's willow, coyote willow, bluestem willow, Scouler willow, height growth, stem diameter growth, caliper, Salicaceae, controlled release fertilizer.

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Introduction

The genetic and sexual diversity provided by seed propagation of *Salix* L. (Salicaceae) species is an important consideration when planning riparian restoration projects. A standard seed propagation protocol has been successful with a number of *Salix* species from montane habitats as well as low elevation floodplains. Despite the very small seed size, most *Salix* are extremely rapid growers, which helps negate some of the advantage typically attributed to cutting propagation. Perhaps the largest hurdle to seedling propagation of *Salix* is the collection of seeds in the wild. However, rapid development of nursery seed orchards is possible using reproductive cuttings representing a mix of male and female plants or seedling stock which rapidly becomes reproductive for many species.

Two principal differences between *Salix* and *Populus* L. (Salicaceae) influence seedling propagation strategies if nursery seed stock plants are desired. The first relates to the location of juvenile and mature wood in the 2 genera and where cuttings are usually taken. Often, *Populus* cuttings are juvenile because they are taken from stems close to the root crown, not from mature stems in the upper canopy. Therefore, cuttings are unlikely to have preformed floral buds that can be forced in the current year. In contrast, *Salix* cuttings (particularly those from shrub-form willows) are often taken from mature wood allowing same-year flowering of stock plants. Secondly, the progression from juvenile to mature phase in *Salix* seedlings can be very rapid (2 to 3 y) especially when grown under near optimum conditions; such early maturing species include *Salix bebbiana* Sarg., *S. irrorata* Andress., and *S. scouleriana* Barratt ex. Hook. Conversely, *Populus* seedlings after more than 5 y of growth in the nursery have yet to become reproductive even after attaining appreciable size.

Figure 1: A collection of willow cotton and the paper bag used to transport it back to the nursery.

Some of the willow propagation protocols that follow address using reproductive phase cuttings to produce seed stock plants, and probably would be effective for reproductive phase *Populus* cuttings; this approach is currently being investigated for *Populus fremontii* S.Wats. *Populus* seed production from seed grown stock, however, will likely be a very prolonged endeavor, as with most tree species.

Obtaining Seeds

Two approaches can be used for collecting *Salix* seeds:

1. Collect seeds from wild plants on an annual basis; or
2. Bring back either cuttings or seeds to grow plants to establish a seed orchard for future collections.

Annual Collections from Wild Plants

The identification of female plants before cotton emergence can be determined by examination of the individual flowers or maturing seed capsules on the catkins. The most critical factor in the collection of viable *Salix* seeds is frequent observation of catkin development. For this reason, establishment of stock plants in a nursery provides significant advantages over wild-land collections. Catkin harvest is typically planned to coincide with the appearance of cotton emerging from partially opened capsules (Schreiner 1974). I have harvested high percentages of viable seeds if harvest is timed to coincide with this stage of capsule opening. It might be preferable to wait until the capsules are almost fully open, but spring winds can disperse seeds very quickly once capsules reach this stage. Female catkins are placed in paper sacks to capture seeds as the capsules open during drying (Figure 1). In a normal room environment, seeds are released from the catkins in a few days. If the number of catkins collected forms a layer 1 or 2 catkins thick in the sack, the seeds will disperse easily without much oversight. If a thick layer of catkins is placed in the sack, occasional turning and stirring of catkins will be required to facilitate uniform drying and seed release. Avoid plastic bags as they cause moisture buildup and subsequent decomposition.

Figure 2: Just a few months after being collected, a female cutting has rooted, flowered, and is dispersing cotton and seeds in the nursery.

Using Cuttings or Seeds to Establish Seed Production Areas

If you desire to establish a seed orchard for specific willow species and seed sources, you can use either cuttings or seeds to start the process. Generally, using cuttings already having reproductive tissues speeds up the process (Figure 2). The development of catkins and flower pollination on recently stuck cuttings can have variable results. With vigorous cuttings of certain species, pollination and seed set can occur soon after sticking, resulting in rapid seed production. However, less vigorous wild-collected cuttings will often result in little if any seed set during the first spring. Insects play a role in pollination of many willows so this fact should be considered if cuttings are flowering in a greenhouse. For *Salix* cuttings, you must either know the sex of the donor plants having observed catkins the year before, identified the sex by microscopic observation of reproductive buds (see Landis and others 2003), or collected cuttings from a large number of plants so it is likely that you have collected both sexes. I stick small cuttings into 164 ml (10 in3) Ray Leach Super CellIs™ (SC-10) and larger cuttings into 2.8 l (1 gal) Treepots™ (1GTP) (both containers distributed by Stuewe & Sons Inc, Corvallis, Oregon). I either top-dress 1GTPs with 15 g of 5 to 6 mo controlled release fertilizer (CRF) Osmocote Plus 15N:9P_2O_5:11K_2O (Scott's Company, Marysville, Ohio) or incorporate 3.5 kg/M^3 (6 lb/yd^3) for SC-10. I tag plants for gender, harvest and clean seeds, and sow seeds to produce initial containerized seedlings. By summer, small stock plants from cuttings can be transplanted into 1GTPs (15 g 3 to 4 month CRF) and the larger stock plants can be planted into seed orchards.

During the second growing season, expect abundant catkin production and enough seeds for large-scale seedling production. By fall, all remaining stock plants are transplanted to the seed orchard–males and females can be mixed to enhance pollination.

The process is similar if seeds are collected. Frequent field observations of willow stands of known species will allow seed collection if female plants are present and are flowering or dispersing seeds. If collection sites are remote, it may be possible to identify and tag female plants a year in advance and estimate seed maturation date by observing catkin development so that a well-timed collection trip will yield ripe catkins the following year. Seeds can be cleaned and seedlings grown as described below. Seedlings generally grow the first year in SC-10s and are transplanted into 1GTPs during winter or spring. The plants can be tagged for gender after catkins appear which can be as early as the second year for early maturing species (for example, S. *bebbiana, S. irrorata, S. scouleriana*). Once the sex is know, plants can be moved to the seed orchard as described above.

Other Considerations That May Affect Riparian Planting Stock Production

The difficulties encountered in getting an accurate species identification for *Salix* species may complicate restoration activities; however, the lack of positive identification should not necessarily stop propagation endeavors. In addition, the stock size for outplanting will greatly influence the lead time needed to produce plant materials for a riparian restoration project.

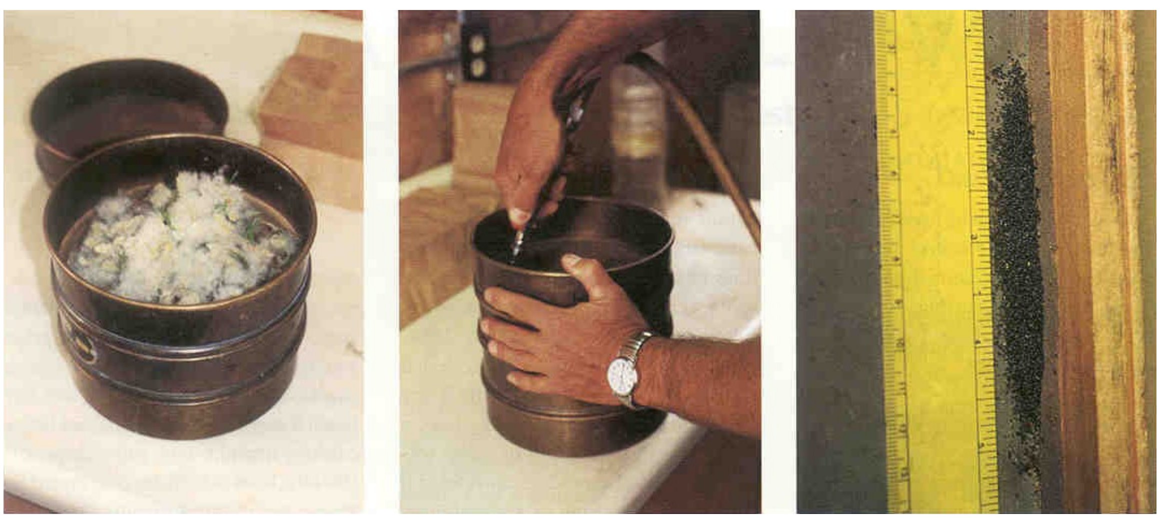

Figure 3: Three soil sieves are needed to clean seeds. The bottom sieve is where the seeds collect. Cotton and seeds are placed in the middle sieve. The top sieve holds the cotton from blowing out when ta stream of compressed air is blown across it. The cotton remains in the middle sieve and clean seeds are deposited on the bottom.

Positive species identification is obviously preferred for any propagation activity. A case can be made, however, that because of the difficulty in willow species identification an alternative approach may be acceptable if: 1) the willows are determined to be native or any exotic willows can be readily identified and disregarded; 2) the willows are collected from the watershed to be restored; 3) the growth characteristics of the willow species present in the watershed are appropriate for the restoration purpose and are consistent with the vast majority of .the future planting sites; and 4) if necessary, propagules can be collected and kept separate for each individual wild stock plant throughout the propagation process. This final recommendation will allow the seedlings of an individual species to be differentiated at outplanting in case more than 1 species has been harvested during propagule collection. Otherwise, vegetative characteristics may be the only key to separating species until catkins develop.

Standard Container Seedling Production Protocol

The most common container stock type we use for montane riparian restoration is 1GTP containers. This container size is generally adequate for acceptable rates of survival with little aftercare, except protection from cattle and elk. In lower elevation cottonwood forests, 1GTP stock can be used but typically requires supplemental watering for several years to become established. We use small volume "mini-plugs" to maximize greenhouse space for starting the crop, transplant up to SC-10 containers, and finish the crop cycle in 1GTP containers.

Seed Cleaning

Once seeds are harvested from wild stands or on-site seed Orchards, they can be cleaned using an air stream and soil screens similar to that described for *Populus* by Schreiner (1974). A compressed air source and a set of 3 soil screens in a series from top to bottom of 250 gm (# 60), 500 gm (# 35),125 gm (# 120) are employed; the dry catkins containing open capsules are placed between the 250 gm and 500 gm screens (Figure 3). A jet of compressed air is blown through the top screen in a swirling fashion; the seed is dislodged and sifts through to the 125 µm screen. The cotton and empty catkins remain on the 500 µm screen. Seeds can also be cleaned with vacuum systems (see Dawes 2003; Day and others 2003).

Seed Germination

At the Los Lunas Plant Materials Center in New Mexico, we germinate willow seeds within a few days of cleaning in "mini-plug" containers having 512 cavities each 14 x 14 x 29 mm (0.5 x 0.5 x 1.1 in [for short term growth–2 to 3 wk]) or 341 cavities each 19 x 19 x 63 mm (0.75 x 0.75 x 2.5 in [for longer term growth–4 to 6 wk]). We rely on mini-plugs because of space restrictions on our automated watering bench that precludes large-scale germination in larger containers. The germination medium is a standard sphagnum peat moss and perlite mix of fairly coarse texture. The coarse texture allows the small *Salix* seeds to infiltrate between the particles of peat moss, allowing optimum aeration, moisture, and light.

One difficult task is hand seeding. Precision is very difficult because willow seeds are very small (the largest being about 1 mm in length and 0.3 to 0.5 mm in width). Adding a diluent of similar size might be of some benefit in achieving more precise sowing by hand. The seeds are usually sufficiently clean that an automated seeder typically used for bedding plant seeds of similar shape and size would probably be effective if very large-scale seeding was envisioned.

Mini-plug Irrigation

The plug medium surface must be kept continuously moist; germination of willow seeds is often apparent after 1 d as noted by the swelling and separation of the cotyledons. Our greenhouse watering bench has mini-sprinklers and automatically waters plug trays once a day (Figure 4). The bench is covered with a copper-coated fabric (Texel Tex-R® Forestry Fabric, Texel Inc, Quebec, Canada) to reduce root egress from the plug cells; this fabric covers a filter fabric (Dewitt soil separator fabric) which acts to pull excess water out of plug cells via capillary water movement. Soluble fertilizer is applied once or twice a week at a rate of 200 mg/l (ppm) nitrogen (20N:OP_2O_5:20K_2O Peat Lite Special; Peters Professional, Scott's Company, Marysville, Ohio). Ideally, the plugs are transplanted as soon as the root sys- tem is sufficient to keep the soil plug intact (3 to 6 wk depending on species and plug size).

Transplanting into SC-10 Containers

Our medium is a mix of 2 parts Sun- shine Mix#l or#2 (Sun Gro Horticulture, Bellevue, Washington) with 1 part perlite (v:v) that has 2.7 kg (6 lb) of CRF incorporated per 0.765 nl3 (1 yd^3) of medium. For plants started in the greenhouse during spring, 5- to 6-month release CRF is used, but for summer grown material 3- to 4- month release CRF is incorporated.

Filled SC-1O containers are dibbled to provide a hole for the mini-plug seedling. Thinning seedlings is often required and can be completed as the mini-plugs are transplanted into the SC-10 containers if seedlings are large enough to make clipping feasible. Otherwise, thinning is accomplished after some growth has occurred in the SC-10 containers. The mini-plug seedling root ball is removed using a flat powder spatula having a blade about 6 mm (0.25 in) wide and 30 mm (1.2 in) long attached to a handle. The blade is plunged along the side of root ball and the seedling plug is levered out of the cell. The plug is dropped into the dibbled hole and the medium is pressed around the root ball with fingers. Top watering firms and fills any voids around the plug.

Figure 4: Willow seedlings grown in mini-plugs prior to being transplanted into SC-10 containers.

Transplanting into Treepots™

Transplanting into 1GTPs usually occurs in the late summer of the first year or spring of the second year. The containers are filled with an aged bark:pumice:peat medium (55:35:10; v:v:v) and dibbled with a SC-10-size planting dibble. CRF is top-dressed at planting or soon thereafter. For pots transplanted in late spring, a 5- to 6- month release CRF is used at a rate of 15 g (0.5 oz) per pot. Seedlings transplanted later in the summer receive a similar rate of 3- to 4-month release CRF. While the plants are establishing themselves in the larger container, irrigation is usually applied 3 times per week. Plants are typically grown without shade. Watering frequency during the rapid growth phase is every day for large riparian plants with substantial leaf areas.

Seedling Growth Rates For Several Willow Species

Examples of height and root collar diameter (caliper) growth for several willow species grown in SC-10s with moderate CRF rates are described below as well as for *Salix exigua* (Nutt.) in larger intermediate containers with high CRF rates. The growth enhancement provided by larger containers with high nutrient levels has been confirmed during the 2003 production season for other species including *S. irrorata* and *S. bebbiana*. One aspect of this willow seedling growth data requires explanation–for some species, seeds from stock plants of montane species grown in the desert environment of the Los Lunas Plant Materials Center (elevation 1463 m [4800 ft]) have been used. It appears, based on the range of willow seed dispersal dates presented by Zasada and others (2000), that seeds are generally produced in our seed orchard at least I mo earlier than would be expected from wild collections of montane willows. An example of a typical SC-10 and IGTP are provided in Figure 5.

Salix irrorata

Male and female cuttings of *S. irrorata* were collected from the Wilderness District of the Gila National Forest in southwestern New Mexico and rooted at the Los Lunas Plant Materials Center nursery. After 1 y, stock plants growing in IGTP containers were tagged by sex and then transplanted into a seed orchard established in organic rich nursery beds. After 4 y, stock plants were 7 m tall. Seedlings (sown in late April–early May) growing in SC-10 containers for 1 growing season averaged 62 cm (24 in) in height and 5 mm (0.2 in) in caliper measured at the top of the container. After transplanting and growing in 1GTPs for another year, plants averaged 2.6 m (8.5 ft) in height and 14 mm (0.5.5 in) of caliper.

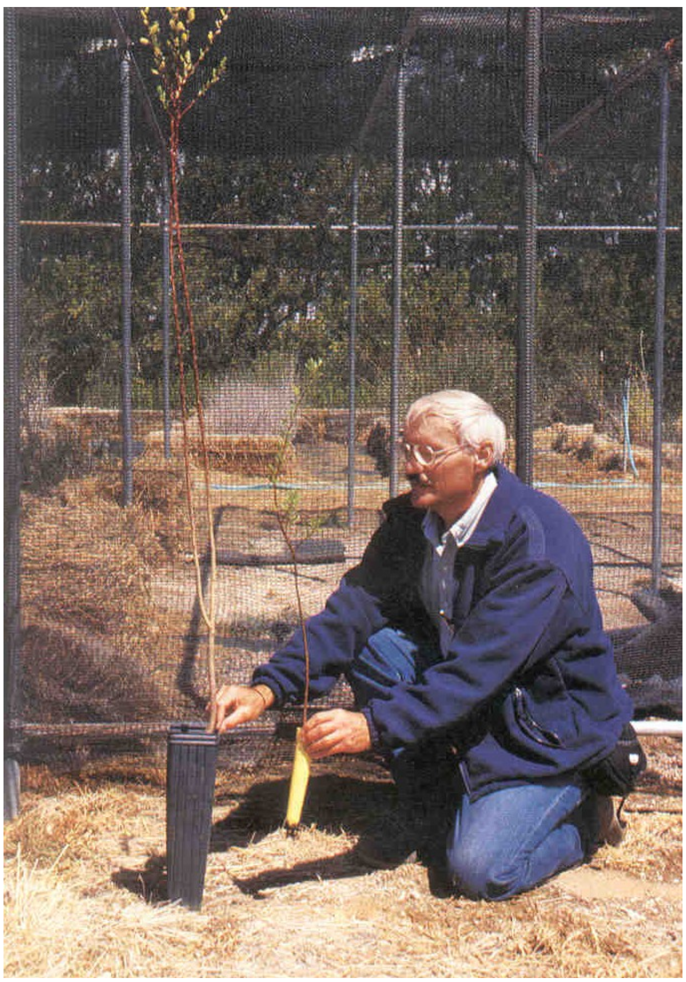

Figure 5: A typical seedling of *S. irrorota* growing in 1GTP (left) and SC-10 (right) after 2 and 1 growing seasons, respectively.

Salix bebbiana

In March 2001, USDA Forest Service personnel collected *S. bebbiana* cuttings from 2 stands at approximately 2400 m (7875 ft) elevation, and in June they collected seeds from a wild stand (2700 m [8860 ft]) on the Apache-Sitgreaves National Forest in east central Arizona. The cuttings were stuck into 1GTP and the following year (2002) they produced seeds. Seedlings were grown I1y in SC-10s and transplanted the following year into 1GTPS. Mean heights of 0.5 and 1.6 m (20 in and 5.2 ft) and mean calipers of 4.4 and 13 mm (0.17 and 0.51 in) were achieved after 1 and 2 growing seasons for the 2001 (sown mid June) and 2002 (sown early May) seedling sources, respectively.

Salix scouleriana

Cuttings for *S. scouleriana* stock plants were collected from 1 male and 1 female plant at an elevation of 2900 m (9570 ft) within the Carson National Forest in north-central New Mexico. These cuttings produced seeds, and the resulting full sib seedlings are maintained in large pots as seed sources. These 2-y-old seedling stock plants yielded seeds in early May and the resulting seedlings, grown in SC-10s, had a mean height and caliper of 28 cm (11 in) and 3.5 mm (0.14 in), respectively, after one growing season.

Salix exigua

Seeds of coyote willow (*Salix exigua* Nutt.) were collected in early June from an individual female thicket in the Middle Rio Grande Valley. The mini-plug seedlings were transplanted into SC-10 containers with either a moderate (3.5 kg/m^3 [6 lb/yd^3]) or high (7.1 kg/m^3 [12 lb/yd^3]) dose of incorporated CRF (3- to 4-mo release). Additional seedlings were transplanted at the same time into D16 (262 ml [16 in^3]) and D40 (656 ml [40 in^3]) Deepot™ (Stuewe and Sons Inc) containers containing the same soil-less mix with the high dose of CRF.

Relative to seedlings grown in SC-10 containers with moderate nutrient levels, mean height growth was increased 29%, 46%, and 93% for the SC-10, D16, and D40 seedlings with high nutrient levels. Similarly, increases in mean caliper of 15%, 51%, and 78% were noted for the SC-10, D16, and D40 seedlings with high nutrient levels.

Salix arizonica Dorn

Arizona willow is classified as a sensitive species by the USDA Forest Service, as a highly safeguarded species by the Arizona Native Plant Law, and has a global rank of rather rare (G3) and state rank of rare (ARPC, undated). USDA Forest Service personnel collected seeds of *S. arizonica* in early July 2002 from 2 previously identified female plants on the Apache-Sitgreaves National Forest. After 8 wk growth in SC-10s, the mean heights and calipers were 11 to 15 cm (4 to 6 in) and 2.2 to 2.3 mm (0.1 in), respectively.

More Information

A more detailed description of techniques we use for riparian restoration, including nursery production of other containerized species, field production of pole cuttings, and descriptions of planting projects in the southwestern US can be found in Dreesen and others (2002) available online at URL http://www.rngr.net/Nurseries/ Publications/Proceedings/2001/dreesen.pdf.

Summary

The rapid growth rate of *Salix* seedlings and their almost immediate germination are appreciable advantages for seed propagation. The small seed size and the potential difficulties in collecting seeds from wild stands are among the problems that should be considered before initiating *Salix* seedling propagation. The rapid transition from juvenile to reproductive phase for some willow species offers benefits in establishing seed stock plants with considerable genetic diversity. Large planting stock with enhanced probability of establishment in disturbed riparian areas can be produced in 2 growing seasons.

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Sex and the Single Salix: Considerations for Riparian Restoration[1]

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Study Number: NMPMC-T-0501-OT

Abstract

Most restoration projects strive to create a sustainable plant community but exclusive use of vegetatively propagated material may be preventing this goal. The dioecious willows and cottonwoods of the Salicaceae are widely used in riparian restoration projects. Hardwood cuttings have traditionally been used to propagate these species in nurseries, and live stakes, branched cuttings, and poles are also used in bioengineering structures for bank stabilization. Woody cuttings are collected either from the project site or from stooling beds in nurseries during the winter dormant period. Unfortunately, little attention has been given to the sex of the donor plants. The potential problem is that a proper mixture of male and female plants may not be present in the hardwood cuttings or rooted cuttings destined for the restoration site–in the worst case they may be entirely 1 sex or the other. Fortunately, it is relatively easy to distinguish male and female plants. Collecting cuttings from many different plants and from a known ratio of males and females will ensure that the resultant plants will be able to produce viable seeds and achieve the ultimate goal of a sustainable plant community.

Key Words: Salicaceae, *Populus*, seed collection, seed propagation

Nomenclature: IT IS (2002)

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Introduction

The Salicaceae consists of hundreds of species of woody trees, shrubs, and subshrubs but contains only 2 genera: the willows (*Salix* spp. L.) (Zasada and others 2003) and the poplars, cottonwoods, and aspens (*Populus* spp. L.) (Wycoff and Zasada 2003). This plant family is noteworthy for several reasons: 1) individual plants are dioecious (each plant is either male or female)–rarely are plants both (hermaphroditic) (Rowland and others 2002; Zasada and others 2003); 2) members of the Salicaceae are keystone species in many riparian plant communities; and 3) they are commonly propagated by cuttings rather than seeds. Between 300 and 500 species of *Salix* and 36 species of *Populus* exist, with centers of species diversity being in the north temperate and subarctic regions of the world.

A rooted cutting of *Salix drummondiana* Barratt ex-Hook (Salicaceae).

Demand for willow and cottonwood plant materials has been increasing greatly in the last decade because of an increased interest in riparian restoration. A wide variety of plant materials of *Salix* and *Populus* are being utilized (Figure 1), and most of these use hardwood cuttings as propagules. In the western US, we use a large range of sizes of hardwood cuttings for stabilizing and revegetating stream banks (Table 1). Note that five stakes are stuck directly in stream banks, and the branched cuttings used in bioengineering structures like brush mattresses, fascines, and vertical bundles are expected to root, stabilize soil, and eventually revegetate the site (Dreesen and others 2002; Hoag and Landis 2002). This is vegetative propagation, and like all forms of vegetative propagation, has serious consequences.

The Problem

The ultimate objective of any restoration project is to produce a plant community with the greatest possible genetic diversity, and one that is also self-sustaining. Our concern is that all of the above uses of willow and poplar involve cuttings and therefore vegetative propagation (see Live Stakes, An Opportunity on Page 27). The Salicaceae are ideal for cuttings because, with the exception of quaking aspen (*Populus tremuloides* Michx.) and Scouler willow (*Salix scoulerana* Barratt Ex Hook.) in the northern Rocky Mountains (Edson and others 1995), they root very easily. Sexual propagation is preferred, however, in restoration projects because seeds contain a mixture of genetic characteristics so that offspring will consist of both male and female plants. In contrast, vegetative propagation produces exact clones of the mother plant. This is of particular concern with dioecious plants, such as *Salix* and *Populus*, because all the progeny produced by vegetative propagation will have the same sex as their parent (Figure 2). If care is not taken to collect cuttings from a broad area, genetic diversity may also suffer.

Most restorationists and nursery workers collect dormant cuttings of willow and cottonwood without any consideration to the sex of the parent plant. In nature, these species often reproduce naturally from root sprouts or buried branches and, as a result, adjacent plants on the project site may be from the same done. Branches often break off parent plants during floods, become buried farther downstream, and root into new plants. If few genetically different plants are growing in an area to start with, perhaps the result of grazing, flood control, agricultural practices, or harvesting (Karrenberg and others 2002), all the willows or cottonwood plants in a riparian community can be from only a few parents or even a single parent. This was found to be the case with both lanceleaf cottonwood (*Populus x acuminata* Rydb. pro sp.) and yellow willow (*Salix lutea* Nutt.) on the Hopi Reservation in northeastern Arizona. Genetic testing revealed that all the plants at the project site were dones of the same individual. This illustrates that natural asexual reproduction tends to prevail in areas where secondary succession occurs. Along major rivers, however, where periodic flooding occurs and wipes out the existing vegetation, primary succession prevails and *Salix* and *Populus* populations are usually of seedling origin.

T'he unisex problem becomes even worse when willow and cottonwood cuttings are brought back to the nursery and used to start stooling beds. Because cuttings will be collected from these beds for many years, ignoring the sex of donor plants win seriously bias the sexual composition of the cuttings. Walk through the stooling beds in your local nursery next spring when the willows are flowering and you might be surprised.

In summary, if care is not taken to ensure that a balanced mix of male and female plants are used for collecting cuttings, then the resultant plant materials will contain a disproportionate ratio of

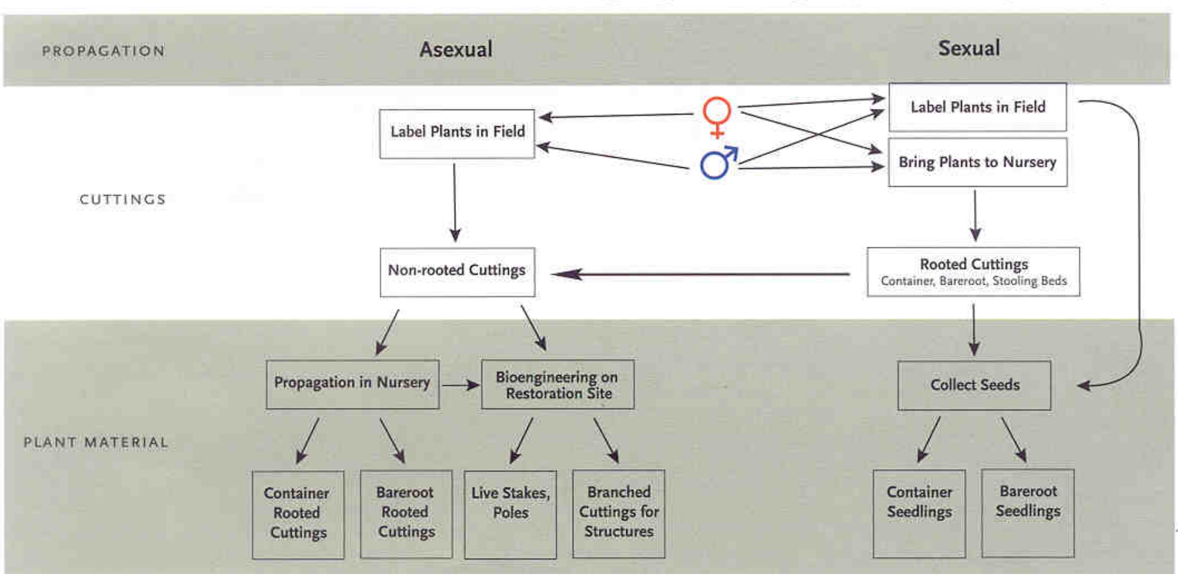


Figure 1: A wide variety of plant materials of willows and cottonwoods can be produced by asexual and sexual propagation. We recommend sexual propagation whenever possible to enhance genetic and sexual diversity on the outplanting site.

males and females. When large numbers of these same plants are used in riparian restoration projects, the long-term sustainability of the plant community will be jeopardized.

Table 1: A wide range of hardwood cuttings of willows and cottonwoods are used in riparian restoration

Type of Cuttings	Length (metric [English])	Use of cuttings
Microcuttings	5 to 10 cm (2 to 4 in)	Nursery propagation
Live stakes	30 to 45 cm (12 to 16 in)	Direct sticking on site
Branched cuttings (whips)	0.6 to 1.8 m (2 to 6 ft)	Bioengineering structures on site
Poles	3.6 to 4.9 m (12 to 16 ft)	Outplanted on site

Solutions

Because sexual and genetic diversity are critical in ecological restoration, the sex of donor plants should be identified in the field and sexual propagation should be used whenever possible. Unfortunately, a biochemical or genetic test to distinguish the sex of a donor plant is unavailable (Zasada and others 2003). Therefore, only field solutions are possible.

Identify the Sex of Parent Plants on Project Sites

By marking known clones of each sex in advance, cuttings or seeds of both sexes can be collected (Figure 1). It is simplest to determine the sex of willow and cottonwood plants when they are flowering. Depending on species, willow catkins may appear before (precocious), during (coetanous), or after (scrotinous) new leaves appear in spring. This timing mechanism, along with habitat and elevation, discourages hybridization between species-natural hybrids have only been observed in small areas of overlap between closely related species that are usually separated by elevational distributions (Argus 1964; Argus 1973; Dorri 1974; Brunsfeld and Johnson 1985). Identifying anthers in male catkins (Figure 3A) and pistils in females (Figure 3B) is easy. Verifying the sex of the parent plants is also easy when they are producing characteristic capsules and cotton (Figure 3C).

During the winter dormant season, it is possible to identify the sex of dormant willows and cottonwoods by examining the size and location of floral buds, which are typically found in the upper branches just below the terminal vegetative bud. We have had good luck sexing cottonwood trees in the field using a pole pruner to collect branch tips from upper portions of the crown (Figure 4A), and examining the floral buds with a razor blade and 10X hand lens (Figure 4B). Male buds are typically larger than female buds and the floral structure can also be checked by slicing buds with a razor blade (Figure 4C and 4D). Willows have much smaller buds, however, and so it is better to examine the cut buds under a dissecting scope. Once an individual plant is sexed, cuttings are collected, kept cool and moist in white plastic bags, and labeled. In keeping with tradition, we use pink flagging labels for female cuttings and blue for males.

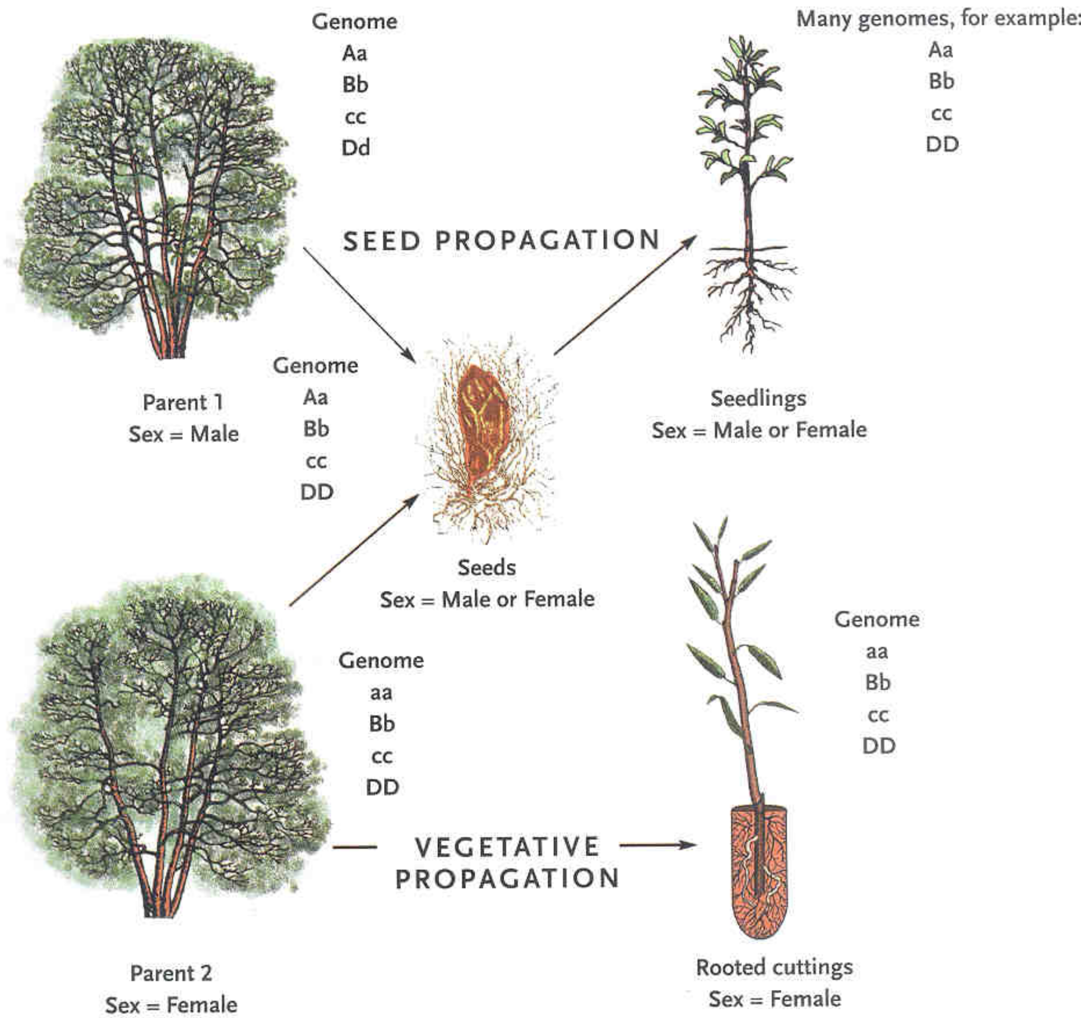


Figure 2: Plants of the family *Salicaceae* are unisexual. This creates challenges for nursery managers and restorationists because using hardwood cuttings, the traditional means of propagation, produce individuals of the same genetic makeup and sex.

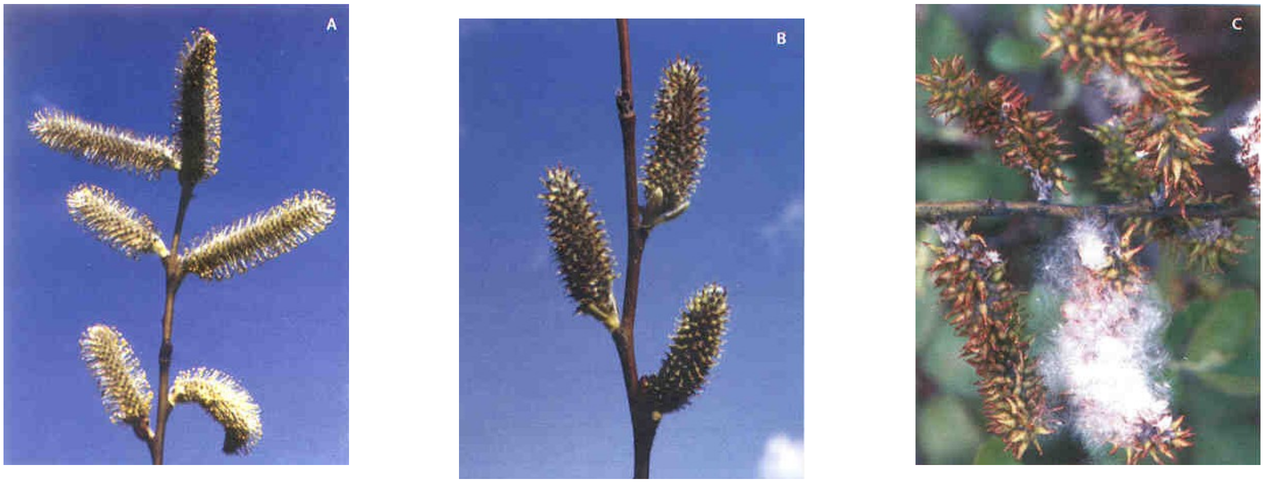


Figure 3: The sex of willows and cottonwoods can easily be determined when the plants are in flower or fruiting (A = willow male, B = willow female, C = willow fruit).

Collecting Propagules

Labeling plants of known sex also makes it easy to come back and collect seeds from females. It is also important to identify the species, especially in the willows. Cottonwood flowers in spring (Wycoff and Zasada 2003) but willows can be divided into species producing seeds in the spring or summer and those that disperse seeds in fall (Zasada and others 2003). Seeds can be processed and sown in either bareroot beds or containers (see Dawes 2003; Day and others 2003; Dreesen 2003). We have found it better to sow seeds of spring and summer flowering willows immediately but seeds from fall flowering willows have a cold dormancy requirement that may require cold-moist stratification (Zasada and others 2003).

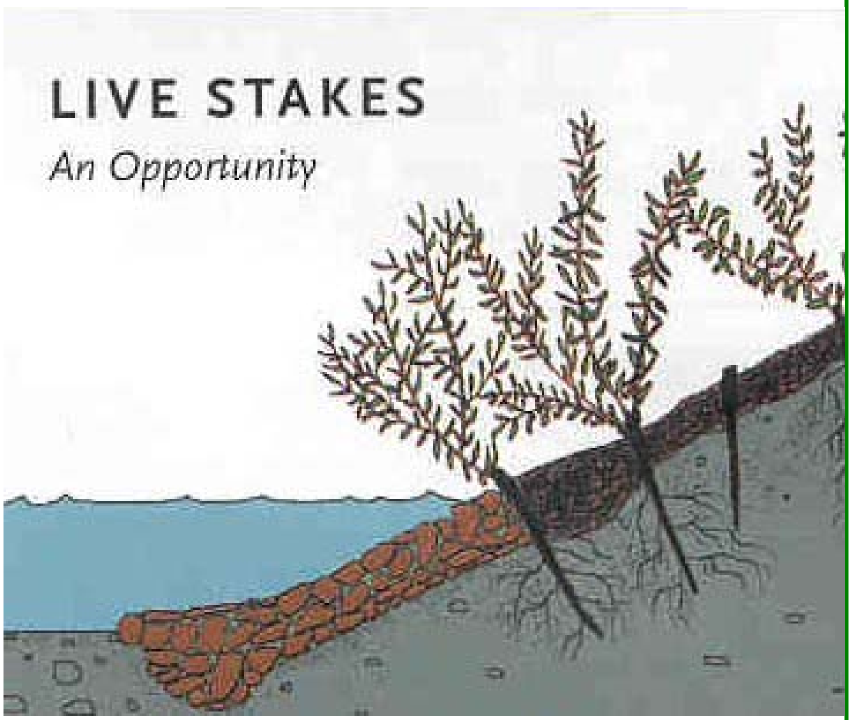
If you are unable to make frequent visits to the restoration site when seeds are maturing, another option is to bring stem cuttings of known male and female plants back to the nursery and force them to produce seeds (Figure 1). These cuttings should be collected during the winter dormant season when rooting success is highest and floral buds are completely formed. The trick is to be able to distinguish male and female plants at this time, and to collect mature cuttings with floral buds.

Forcing Seed Production in the Nursery

Branches with floral buds can be placed in buckets of water and incubated in a greenhouse until they flower. The water should be changed 2 to 3 times per week and with each change the ends of the branches should be recut to improve water uptake. Flowering usually takes place in 2 to 4 wk and then pollination can be induced (Wycoff and Zasada 2003). *Populus* species are wind pollinated so good air movement will result in pollination, but willows require insects to pollinate flowers–therefore insects must have access to willow flowers or flowers must be pollinated by hand.

Another more long-term option is to root branch cuttings in containers being careful to maintain sexual identity, and then mix male and female plants in the growing area to facilitate fertilization. This procedure also allows mixing of plants from across the project area, ensuring a better genetic mixing than would occur naturally. Many willows are sexually precocious and will produce flowers that same season, and both willows and cottonwoods (if collected from mature branches) should flower the following year. The timing of pollen release and pistil receptivity may vary considerably among male and female cutting collections which emphasizes the need for sampling sufficient numbers of individuals to maximize the period of flowering and the chances of pollination. Because plants are growing in close proximity, the percentage of seed set is high and quality seeds can be collected a month or so after flowering.

To ensure good seed quality, collect female capsules just before they open (Figure 3C) and place them in a brown paper bag to afterripen. When the cotton is just emerging from the capsules, seeds can be separated by using screens and compressed air. Cottonwood seeds can be processed by hammer-milling the capsules and separating the seeds with screens at low air flow. The exact procedure, including screen sizes, is given in Dreesen and others (2002), Wycoff and Zasada (2003), and Zasada and others (2003).



CUTTINGS USED FOR BIOENGINEERING ARE A FORM OF VEGETATIVE PROPAGATION: Depending on the size of the project, hundreds to tens-of-thousands of nonrooted willow cuttings can be used for live stakes or branched cuttings for bioengineering structures. Besides providing stability, these cuttings sprout and become pioneer plants. If the sex of the donor willows is not considered during cutting collection, the sexual diversity of the plant community can be seriously compromised.

Rooting and establishing mature male and female willows and cottonwood plants in the nursery allows a good mixing of genotypes and produces seeds of greater genetic diversity. We have had some success with producing viable willow seeds the first season but better flowering and seed production occurs the second year. A typical propagation protocol schedule for willow seedlings grown from seeds at the Los Lunas Plant Materials Center in New Mexico is shown in Figure 5. If the dormant hardwood cuttings are collected during winter, they can be stuck in the nursery the following spring. The plants will flower the first or second season and seeds can be collected and processed. By immediately sowing, shippable seedlings can be ready by the third or fourth year, depending on the container and desired target seedling size.

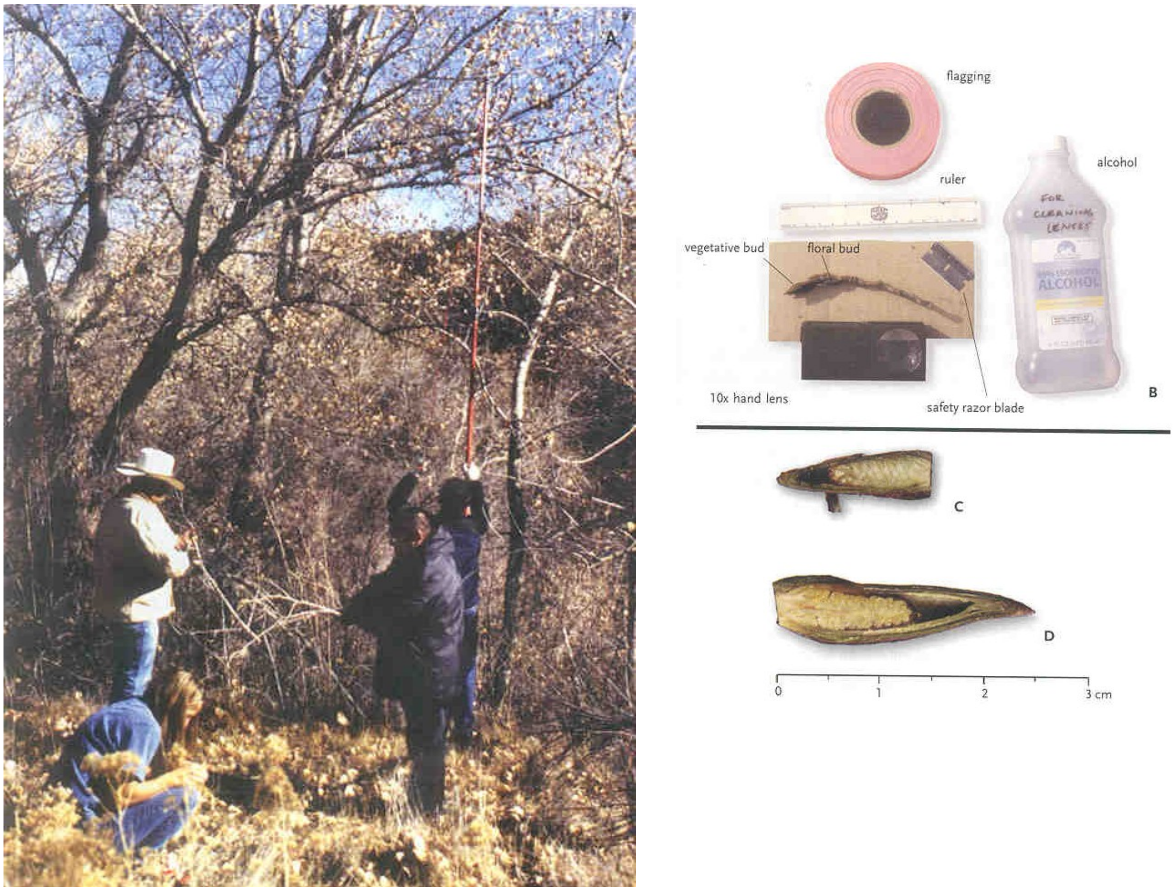


Figure 4: Dormant cottonwood trees can be 'sexed' by clipping branches from the upper crown with pole pruners (A) bisecting the floral buds and examining them with a hand lens. Floral buds are always located laterally on the stem below a terminal vegetative bud (B), and with a few supplies, can be easily sampled and identified. Female buds are smaller and the round pistils can be clearly seen (C), whereas male buds are larger and distinguished by the presence of the pollen sacs (D).

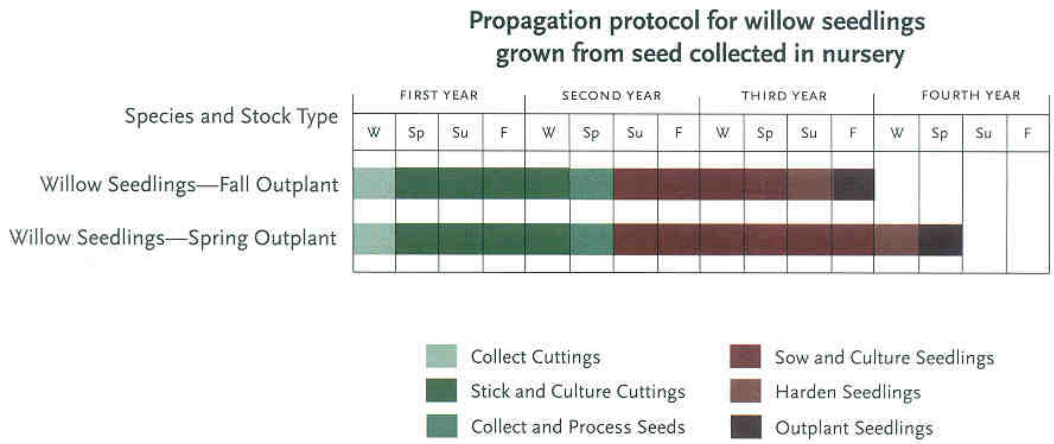


Figure 5: Seedlings of willow and cottonwood can be produced in 3 to 4 y, depending on how soon seed can be produced and the desired stock size.

Summary

The dioecious nature of the Salicaceac requires that special measures must be taken to ensure that genetic and sexual diversity is maintained during propagation. The critical thing is to identify the sex of willows and cottonwoods when collecting cuttings in the field. Then, a sexually and genetically diverse mixture of cuttings can be obtained for bioengineering structures, direct sticking, or for establishing stooling beds in the nursery. Seed propagation should be encouraged whenever possible. Seeds can be collected from the project site, or it is relatively easy to force seed production from rooted cuttings in the nursery. Using these procedures, one can collect cuttings, force seeds, and grow genetically and sexually diverse willow and cottonwood seedlings in as little as 3 to 4 y.

Acknowledgment

Thanks to Tara Luna for her expertise in identifying willows in the field and comments on earlier drafts.

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Tumbling For Seed Cleaning And Conditioning[1]

By: David Dreesen[2]

Study Number: NMPMC-T-0501-OT

ABSTRACT

Small rock tumblers can be used to clean and condition seeds both in an aqueous and a dry mode. During the process, grit and gravel remove fruit pulp and abrade seed coats. Wet tumbling of seed aids imbibition, leaches water-soluble germination inhibitors, and may partially substitute for cold stratification for some shrub seed lots.

Key Words:

Oleaceae, *Forestiera pubescens* var. *pubescens*, New Mexico olive, Plantanaceae, *Platanus wrightii*, Arizona sycamore, Grossulariaceae, *Ribes aureum, Ribes cereum,* Solanaceae, *Lycium torreyii*, wolfberry, Cornaceae, *Cornus sericea* ssp. *sericea*, redosier dogwood

Nomenclature:

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Introduction

At the Los Lunas Plant Materials Center in New Mexico, we use small, hobby-size rock tumblers to accomplish a number of seed cleaning and seed conditioning treatments. The principal application of the tumbler has been maceration of dried or hydrated fruit pulp. We commonly use it to remove pulp from dried New Mexico olive (*Forestiera pubescens* Nutt. var. *pubescens* [Oleaceae]) fruits. The fruits collected in late summer or fall after the pulp has dehydrate and adheres tenaciously to seeds. A wet tumbling procedure employing pea gravel/crushed stone and water in a rubber lined tumbler vessel allows the rehydration of the pulp an slow abrasion of pulp from seeds. The amount of water is minimized so that the gravel and fruit makes a slurry. This method is not quick, but the tumbler can be run overnight and check the following day. After a course of tumbling, the contents dumped into a sieve and the pulp is washed off, leaving clean seeds. The tumbling process is repeated until clean seeds achieved (Figure 1).

Figure 1: The pulp of naturally dehydrated fruits (top) of New Mexico olive can be removed using a rock tumbler, leaving extremely clean seeds (bottom).

Another cleaning application involves removal of fine hairs attached to achenes of Arizona sycamore (*Platanus wrightii* S. Wats. [Platanaceae]). The dry fruiting heads are crushed under water to partially liberate the achenes while preventing and fine hairs from becoming airborne (Figure 2). A slurry achenes with pea gravel is tumbled and the hairs detach time and can be separated using sieves and strong sprays of water. In addition, the wet tumbling thoroughly imbibes seeds and may leach out water soluble germination inhibitors. After cleaning and imbibition, seeds are typically cold stratified.

Dry tumbling to scarify legume seeds has been investigated, (Bonner and others 1974; Dreesen and Harrington 1997). The rationale for dry tumbling is to avoid seed destruction that can readily occur with sulfuric acid, boiling water, and high energy impact mechanical scarification treatments. Dry tumbling is a slow process taking several days to a week, but we often use it when we have small seed lots we do not want to risk with other scarification treatments. The procedure uses carborundum grit (sold by rock tumbler dealers), pea gravel, and seeds. After tumbling, scarified seeds are separated from the grit and gravel with sieves. The grit can also be reused by washing the seed coat debris through a fine sieve or by floating off the debris and then drying the grit. Different size grits are available and we typically use fairly coarse material. Coarse grit size is still much smaller than most legume seeds, allowing the easy sieve separation of grit, seeds, and gravel.

Figure 2: At the Los Lunas Plant Materials Center, dry fruiting heads of Arizona sycamore, seen lower left, are crushed under water in a large pan. The hairs agglomerate into balls (gray sieve in foreground). A slurry of achenes and pea gravel are tumbled in the rock tumbler to dislodge the hairs. Finally, the achenes, hairs, and pea gravel are separated with soil sieves with the cleaned achenes visible in the brass sieve (background).

Wet tumbling can be used for scarification if an abrasive (typically pea gravel) is incorporated in the seed and water slurry (Dreesen and others 2002). The force imparted to the grit by the tumbling gravel facilitates abrasion. Although this treatment method may result in some seed coat degradation, other effects may be more important, such as assuring com- plete imbibition in well-aerated water and the leaching of water soluble germination inhibitors in the seed coat. A typical treatment would involve wet tumbling for several days to a week with daily changes of water.

For a few species, wet tumbling may partially substitute for a cold stratification requirement. Two currant species (*Ribes aureum* Pursh and *R. cereum* Dougl. [Grossulariaceael]) and wolfberry (*Lycium torrey*ii Gray [Solanaceae]) generally require 2 to 3 m of cold stratification to achieve acceptable germination. Wet tumbling followed by 1 to 2 wk of storage in a warm moist environment has resulted in germination without cold stratification. The dry seeds of another important riparian species, redosier dogwood (*Cornus sericea* L. ssp. *sericea* [Cornaceae]), generally require 1 h scarification in concentrated sulfuric acid and then 2 to 3 mo of cold stratification for acceptable germination. Using fresh fruit with hydrated pulp, rapid germination has been achieved by wet tumbling the fruit with 1 to 2 cm (0.5 to 0.75 in) gravel. Most of the pulp is removed in the first day of tumbling and separated by screening and float/sink manipulations in water. After pulp removal, seeds are wet tumbled for several more days with daily water changes. The imbibed seed is then stored in a warm moist environment; germination starts in about 7 to 10 d and continues for several weeks. Although a limited number of species have been tested with wet tumbling for seed conditioning, additional species may benefit from this treatment.

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Sulfuric Acid Scarification Of Wax Currant Seeds From New Mexico[1]

By: Lee S Rosner[2], John T. Harrington,[3] David R. Dreesen[4], and Leigh Murray[5]

Study Number: NMPMC-T-0501-OT

Abstract

The germination response of six New Mexico sources of wax currant (*Ribes cereuum* Dougi. [Grossulariaceael) to combinations of 0 to 120 d cold stratification and 0 to 8 min of acid scarification varied widely among seedlots. For most seedlots, cold stratification was more effective than scarification in improving germination, and scarification improved germination only at low, ineffective levels of cold stratification. For 3 of 6 seedlots, maximal germination was achieved without scarification. For the remaining 3 seedlots, optional scarification duration varied. Variability in sensitivity to acid scarification is discussed in terms of environmentally induced effects on seed coat structure and physiology.

Key Words: cold stratification variability, dormancy

Nomenclature: IT IS (2001)

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Introduction

Wax currant (*Ribes cereum* Dougl. [Grossulariaceae]) is a shrub species found throughout western North America including New Mexico. Wax currant occurs on dry slopes, ridges, and plains within numerous habitat types and plant communities (Vines 1960; Marshall and Winkler 1995). This species grows on diverse soil types and occurs across a range of temperatures and precipitation levels (Marshall and Winkler 1995). Wax currant provides browse for deer when better browse is not available, and fruits are eaten by numerous bird species (Marshall and Winkler 1995). Wax currant is valued for use in the reclamation of disturbed lands.

Table 1: Seedlots used in wax currant germination studies

Seedlot	Latitude	Location in New Mexico	Elevation m (ft)	Collection data (1997)
Capulin	36° 42' N	Questa	2987 (9800)	10 Aug
Raspberry Ridge	36° 42' N	Questa	2987 (9800)	12 Aug
Pinon Knob	36° 42' N	Questa	2986 (9500)	21 Aug
Mahogany Hill	36° 42' N	Questa	2774 (9100)	13 Aug
Rociada	35° 50' N	Rociada	2377 (7800)	17 Aug
Gila	34° 06' N	Gial National Forest	2499 (8200)	21 Aug

The primary seed dormancy mechanism in *Ribes* species is embryo dormancy, but seed coat dormancy controlled by growth inhibitors and/or an impermeable seed coat is suspected to occur as well (Pfister 1974; Goodwin and Hummer 1993). Cold stratification for 60 to 300 d has been used to overcome embryo dormancy for most *Ribes* species (Fivaz 1931; Quick 1936; Heit 1971, Pfister 1974; Young and Young 1992; Goodwin and Hummer 1993). Among New Mexico seedlots of wax currant, the cold stratification requirement ranges from 120 d or more for northern seedlots, to none for at least one seedlot in the southern third of the state (Rosner and others 2001). Others have also observed variability in seed dormancy level between and within seedlots in *Ribes* (Pfister 1974; Young and Young 1992).

Photo by John T. Harrington

Acid scarification using various concentrations of sulfuric acid has broken seed coat dormancy in some *Ribes* species. A 5-min soak in 50% sulfuric acid improved germination of European black currant (*Ribes nigrum* L.) (Adam and Wilson 1967). Germination of Appalachian gooseberry (*Ribes rotundifolium* Michx.) was improved by a 35-min soak in "commercial" sulfuric acid (Fivaz 1931). Five-min soaks in 2% to 10% sulfuric acid solution improved germination of prickly currant (*Ribes lacustre* [Pers.] Poir.) and sticky currant (*Ribes viscosissimum* Pursh) (Pfister 1974). There is a lack of published literature documenting the use of acid scarification as a seed treatment for wax currant.

For many native shrub species, propagation techniques are not well researched, resulting in increased production costs (Dreesen and Harrington 1997). In reclamation, locally adapted seedlots are usually preferred, but seed crops are often limited, and the need to maximize germination is paramount. For wax currant, the combination of acid scarification and cold stratification may result in higher germination than cold stratification alone. The purpose of this research was to evaluate the efficacy of sulfuric acid scarification and variability in treatment response among wax currant seedlots encompassing both a range of latitudes throughout New Mexico and a range of elevations at one location in northern New Mexico.

Materials And Methods

Seeds were collected 10 August 1997 through 21 August 1997 at six locations throughout New Mexico (Table 1). Seeds were collected at varying heights within the canopy of each plant and from a minimum of 5 plants at each location. Seedlot locations were selected to encompass both a range of latitudes within New Mexico and a range of elevations at Molycorp Mine in Questa, New Mexico. Before cleaning, seeds were soaked overnight in tap water (seeds that floated were discarded), allowed to ferment for 48 h, mashed, and dried. Dried fruits were processed in a rubbing box, and a Dakota blower was used to separate seeds from pulp. Cleaned seeds were stored at 5° C (41º F) until use.

This study utilized a completely randomized design with a factorial treatment structure. Factors were seedlot, scarification treatment, and cold stratification duration. Seeds from 6 seedlots underwent acid scarification in concentrated sulfuric acid for durations of 0, 2, 4, or 8 min followed by cold stratification for 0, 60, 90, or 120 d. Germination data were analyzed as a 6 (seedlot) by 4 (cold stratification) by 4 (scarification) factorial and then separately by seedlot. Two replications of 100 seeds were used to test each treatment combination.

Scarification treatments were conducted using concentrated sulfuric acid (Reagent ACS, 95.0-98.0%, VWR Scientific Products, West Chester, Pennsylvania). Each seed sample (100 seeds) undergoing scarification was placed in 10 ml acid, stirred vigorously for 30 s to disperse the seeds, and then allowed to soak in the acid for the remainder of the treatment duration (2, 4, or 8 min). Following treatment the seeds were removed from the acid and thoroughly rinsed under running tap water for 1 min.

Seeds were placed between 9.0-cm (3.5-in) filter papers (VWR Qualitative Grade #3) moistened with distilled water for cold stratification treatments. Filter papers were placed in 100-mm Petri dishes sealed in 15 x 16 cm self-sealing poly bags within a walk-in cooler. Cooler temperatures fluctuated from an average daily low of -1.2° C (30° F) to an average daily high of 5.4° C (42° F). Seeds underwent cold stratification immediately following scarification. Scarification/cold stratification start dates were staggered so that all seeds completed cold stratification at the same time.

Seeds were maintained between filter papers in Petri dishes within poly bags for germination testing. Petri dishes in poly bags were placed directly on greenhouse benches under natural light (filtered through shade cloth) with fluctuating temperatures. A 30-cm (1-ft) border on all sides of each bench was left empty in order to minimize temperature differences between samples. The greenhouse thermostat was set to maintain daytime highs near 30° C (86° F) and nighttime lows near 15° C (59° F). Daytime high temperatures averaged 34° C (93° F) +/- 0.5°C (0.9° F) and nighttime low temperatures averaged 15° C (59º F) +/- 0.3° C (0.5° F) during the experiment. Germination testing took place from 14 May 1999 through 11 June 1999.

Germinated seeds were counted and removed when samples were taken out of cold stratification and after 7, 14, 21, and 28 d of incubation. Filter papers were remoistened as needed. Seeds were considered germinated if the radicle was visible to the naked eye. Fungal contamination of petri dishes caused some problems. Seeds covered in mycelium, discolored, softened, or oozing were removed from the petri dish and counted as rotten.

Categorical analysis (SAS PROC CATMOD) was used to determine treatment differences in total germination using a factorial treatment structure (SAS Institute 1989; Stokes and others 1995). Traditionally, analysis of variance (ANOVA) has been used to analyze germination data. The ANOVA assumes continuous, normally distributed data with equal variances, but germination percentage data has unequal variances between treatments and is frequently skewed and, therefore, non-normal. Usually percentage data are arcsine transformed to achieve normality and then analyzed by ANOVA. Categorical analysis eliminates the need for data to be transformed. The procedure is a generalization of the chi-square (X^2) test of homogeneity, using the "logit"-the natural log of the ratio of germinated to non-germinated seeds-as the response (Grizzle and others 1969). Generalized least squares were used to calculate X^2 test statistics. Observed significance levels less than a=0.05 were considered significant. Percentages and standard errors were calculated for main effects and interactions. Approximate pairwise Z statistics were used to conduct pairwise comparisons of main treatment effects using a conservative alpha value of 0.05 divided by the number of comparisons. Due to a highly significant 3-factor interaction, main effects and all 2-factor interactions except cold stratification by acid scarification are not discussed here. This interaction is presented because growers will not be using the seedlots tested in this study, and it may be useful to understand how cold stratification and acid scarification interact averaged across multiple seedlots.

Results

Cold stratification, seedlot, acid scarification, and all interactions of these factors impacted germination (Table 2). Germination response to combinations of cold stratification and acid scarification treatments varied by seedlot (Figure 1). For all seedlots except the southernmost (Gila) and the highest elevation Questa seedlot (Capulin), cold stratification was a more robust treatment than acid scarification-the simple effect of cold stratification improved germination more than the simple effect of acid scarification for those seedlots. For the Gila seedlot, however, scarification improved germination more consistently than cold stratification, whereas for the Capulin seedlot, which appeared to have the lowest overall quality, the combination of cold stratification and acid scarification treatments resulted in threefold improvement in germination over the best level of either treatment alone. Interestingly, the seedlot with the best cold stratification-only germination (Raspberry Ridge) was most negatively affected by acid scarification treatments, while the seedlot with the lowest cold stratification-only germination (Capulin) was most positively affected.

The effect of scarification varied widely among cold stratification durations for all but the Capulin seedlot, for which germination improved with increasing acid soak duration at all cold stratification levels. For the remaining seedlots, acid scarification tended to improve germination only at low, less effective levels of cold stratification. Averaged over all seedlots, 2- or 4-min acid scarification treatments improved germination in combination with 0- or 60-day cold stratification treatments, but all acid scarification durations reduced germination for seeds undergoing 90 or 120 d of cold stratification (Figure 2). As a result of this interaction, for 3 of 6 seedlots (Raspberry Ridge, Pinon Knob, and Rociada), maximal germination could be achieved without the use of acid scarification (Figure 1). For those 3 seedlots, no treatment combination resulted in better germination than cold stratification for 120 d alone. For the remaining 3 seedlots, acid scarification was necessary to achieve maximal germination, but the optimal treatment duration varied.

Table 2: Categorical analysis of variance table for wax current germination response to stratification, seedlot, and acid stratification.

Component	DF	Chi-square	Observed Significance level
Stratification	3	774	<0.001
Lot (L)	5	1010	<0.001
Acid scarification (A)	3	24	<0.001
S x L	15	570	<0.001
S x A	9	138	<0.001
L x A	15	251	<0.001
S x L x A	45	257	<0.001

The percentage of seeds rotting during the course of cold stratification and germination testing (based on the total number of seeds) increased sharply with increasing duration of acid soak, for both pooled seedlots and by seedlot (Figure 3). The differences among seedlots in percentage of rotting seeds corresponded to differences in acid scarification treatment efficacy. The 2 seedlots with the highest percentages of rotting seeds at all treatment levels (Raspberry Ridge and Pinon Knob) were 2 of the 3 seedlots that did not benefit from acid scarification. In contrast, 3 of the 4 seedlots with the lowest percentages of rotting seeds (Capulin, Mahogany Hill, and Gila) had optimal treatment combinations involving some level of acid scarification. It should be noted that seeds must be filled in order to rot, but seed fill was not measured. The percentage of filled seeds may have varied among seedlots, and some of the observed differences in rotting may have been influenced by differences in seed fill.

Discussion

Variability in acid scarification requirement among seedlots has been found to occur in numerous species including California redbud (*Cercis canadensis* var. *texensis* [S. Wats.] M. Hopkins [Fabaceae]) (Heit 1967), honeylocust (*Gleditsia triacanthos* L. [Fabaceae]) (Bonner and others 1974), and cotoneaster species (*Cotoneaster* Medilc [Rosaceae]) (Slabaugh 1974). This variability occurs to such an extent that Heit (1967) and Bonner (2001) recommend testing each seedlot of species requiring acid scarification to determine the optimum duration of treatment. Seed source has been ascribed as a major source of this variability (Heit 1967; Bonner 2001). A good example of source variability is Kentucky coffeetree (*Gymnocladus dioicus* [L.] K. Koch [Fabaceae]), where acid scarification improved germination of seeds collected in Ohio and Illinois, but not in Minnesota (Frett and Dirr 1979; Ball and Kisor 1985). For wax currant in the present study, the effect of sulfuric acid scarification on germination varied widely among seedlots, but this variability conformed to no latitudinal or elevational pattern. In fact, Capulin and Raspberry Ridge seedlots occur at similar elevations within a mile of each other, yet response to acid scarification was nearly opposite; increasing acid soak duration increased Capulin germination, whereas all levels of acid soak, when combined with cold stratification, reduced Raspberry Ridge germination.

This differential response to acid scarification among proximal seed sources may stem both from genetic and environmental differences between these populations. The extent of the contribution of each factor, however, is generally difficult to determine (Anderson and Milberg 1998). Environmental factors during seed maturation have been shown to affect depth of dormancy (Gutterman 1992), seed coat thickness (Pourrat and Jacques 1975), seed coat permeability (Gutterman and Evanari 1972), seed coat thickness and germination-inhibiting polyphenol content (Dorne 1981), and hardness of the seed coat and endosperm (Juntilla 1973). Microclimatic factors such as aspect, slope, vegetative cover, and edaphic conditions can affect temperature, light quality, moisture, wind exposure, and nutrient availability. Anderson and Milberg (1998) suggest that even seeds collected from plants growing side by side may have been subject to different weather conditions during maturation due to small differences in development time, and that water and nutrient status can vary within small areas. Differential response to acid scarification among seed sources in the present study may have been mediated by microclimatic differences, and variability among proximal sources is not surprising.

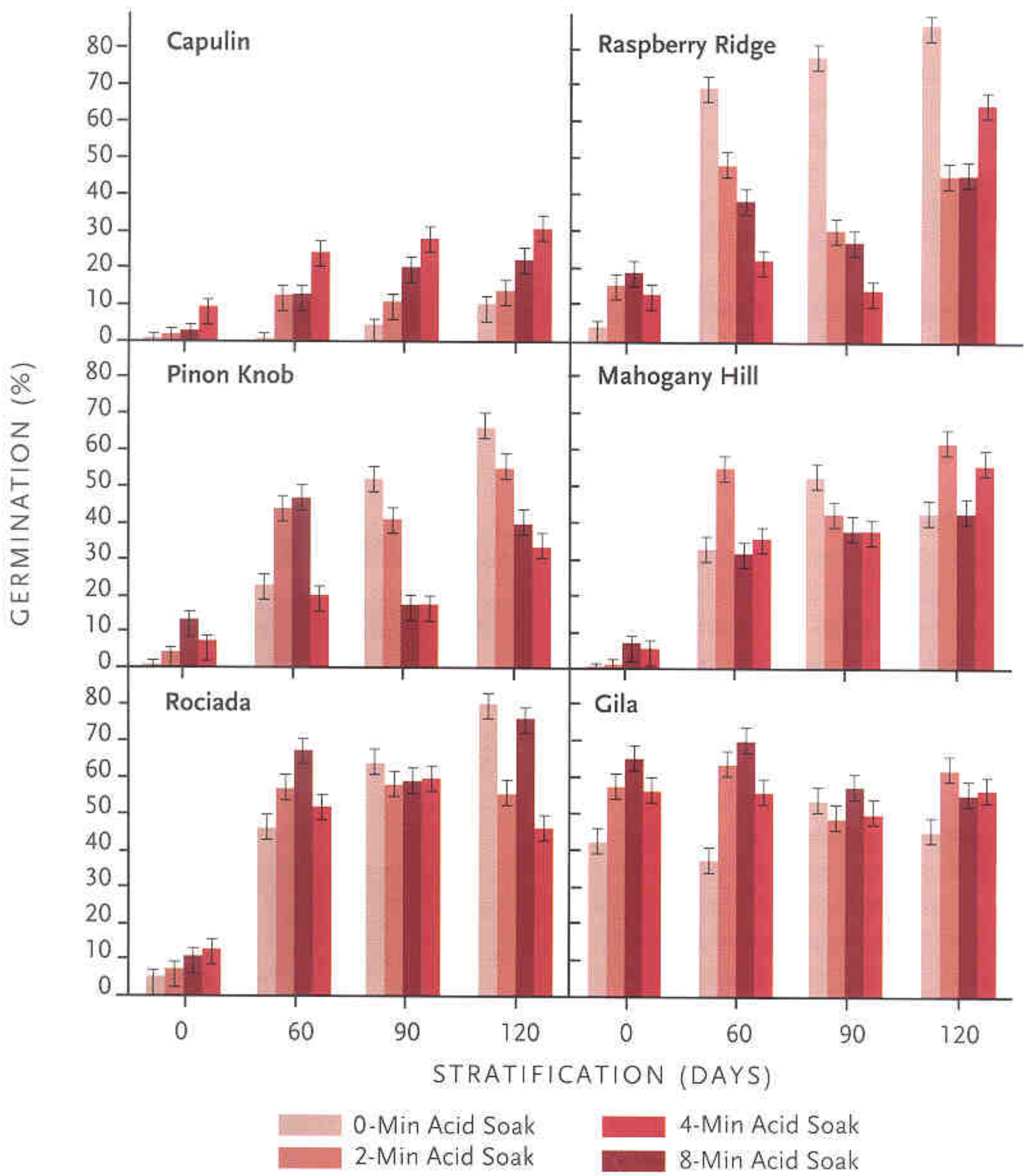

Figure 1: The effect of interaction between acid scarification duration, stratification length, and seedlot on wax currant germination.

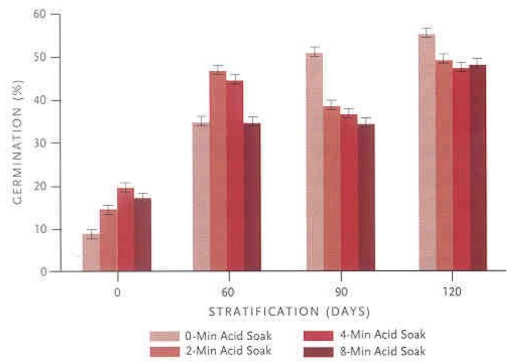

Figure 2: The effect of interaction between acid scarification duration and stratification length on wax current germination.

Seeds damaged or weakened by excessive treatment lose their ability to resist pathogenic deterioration (Murdock and Ellis 1992). For the Raspberry Ridge seedlot, a high percentage of seeds rotted following even the shortest duration of acid soak, indicating that sulfuric acid damaged seeds at all treatment levels. Although the Capulin seedlot responded positively to acid scarification, 10% to 20% of scarified seeds rotted following treatment, depending on treatment level. This occurrence indicates a high degree of within-seedlot variability in seed coat dormancy and a paradox inherent in all scarification treatments; treatments thorough enough to improve germinability for some seeds maybe damaging to other seeds within the lot (Young and others 1984). In some cases, weaker solutions and longer incubation durations may reduce the risk of damaging seeds without loss of treatment efficacy (Young and others 1984).

Conclusions

Our results suggest germination in New Mexico seedlots of wax currant is improved by 120 d of cold stratification, but response to acid scarification is variable. For most seedlots, cold stratification for 120 d results in good germination. Further increases in germination can be realized through the use of treatments targeting seed coat dormancy mechanisms, but sulfuric acid may be too reactive to be an effective agent. Better understanding of the mechanisms imposing seed coat dormancy in this species may lead to the development of more effective seed treatments.

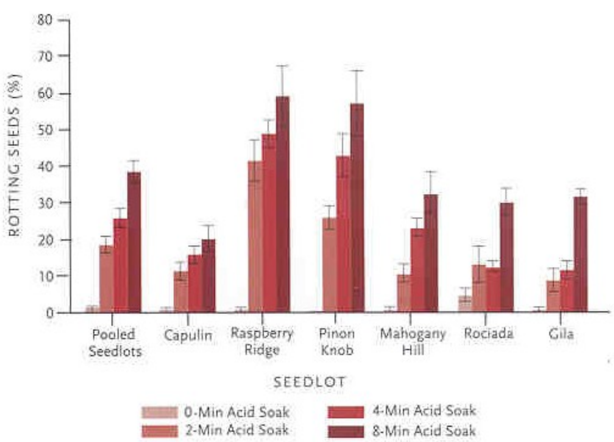

Figure 3: Effect of interaction between acid scarification duration on percentage of wax currant seeds rotting during the course of stratification and germination testing for pooled seedlots and by seedlot.

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Blue Grama Variety Trial

By: LLPMC Staff[1]

Study Number: NMPMC-T-0401-RA

High-elevation grazing competition between elk and livestock has become a concern for landowner Carl Smith. Elk have been grazing on his forage pasture during the spring, decreasing the available forage for livestock during the summer-grazing season. The elk herd in the area eats the cool-season grass forage prior to the introduction of livestock in the summer months. Without the cool-season species forage, and because of the low production rate of warm-season, indigenous forage grass species, the livestock end up with an insufficient amount of feed during the summer grazing period.

To attempt to solve this problem, the NRCS Field Office in Espanola, New Mexico and the Los Lunas Plant Materials Center (LLPMC) are establishing a trial planting of improved varieties of blue grama. Blue grama is a component of the warm-season range species indigenous to the ranch. The native blue grama exhibits low forage production and does not contribute much to the total forage production of this rangeland. Improved varieties of blue grama could provide a greater forage potential at this elevation (8200 feet).

On July 27, 2004, the LLPMC installed four varieties of blue grama on Mr. Smith's ranch: Hachita, Lovington, Alma and Bad River Ecotype. Hachita, Alma and Lovington are improved blue grama varieties developed by the LLPMC. Bad River Ecotype is an ecotype release from the Bismarck Plant Materials Center (PMC) in North Dakota. Including the Bad River Ecotype in the trial planting allows the opportunity to evaluate an accession from a northern climate. The new trial planting covers .10 acres in 16 replicated plots. The seed was installed using a plot drill.

The seeding was evaluated on 10/01/2004. None of the blue grama seed had germinated. The July 2004 planting may have been too late in the season for germination to occur at this elevation. In 2005, a new trial planting of the same four varieties will be installed but at an earlier date.

Another evaluation of the 2004 planting is scheduled for 2005.

[1] David Dreesen, Gregory Fenchel, Danny Goodson, and Keith White

Blunt Panic (*Panicum obtusum*)

By: LLPMC Staff[1]

Study Number: NMPMC-P-9901-RA

Blunt Panic (commonly called vine mesquite in New Mexico) is a native, stoloniferous, perennial, warm-season grass. It is typically found in sandy or gravelly soil, and chiefly in moist sites along stream and ditch banks. It is fair-to-good forage for livestock and wildlife, and it can withstand heavy grazing. Because of its stoloniferous habit, Blunt panic often grows in dense stands and may be used to stabilize washes and prevent soil erosion. It is in high demand in New Mexico for use in riparian restoration grass seedings. However, it is not currently in commercial production.

Blunt panic seed typically has a low germination rate, mainly due to a low percentage 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.

Blunt panic bulk seed collections were made from 80 collections throughout New Mexico. In 1983, seedlings were transplanted to the field into non-replicated accession rows. Plots were two 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 80 accessions.

The previous plant breeder selected the accessions that displayed the best seed fill and germination rates (40–60 percent). These accessions are listed in the following table:

Accession	Origin (NM County)
9027854	Socorro
9029111	Sandoval
399274	?
9003860	?
9023213	Valencia
9027836	Colfax
9027930	Rio Arriba
9023296	Union
9029719	Union
9003848	?

[1] David Dreesen, Gregory Fenchel, Danny Goodson, and Keith White

Seed from the selected accessions was taken to the Tucson Plant Materials Center where the plant breeder will continue the development of a commercial release with an improved seed germination rate.

The original ¼-acre planting of the 80 accessions is still alive and growing vigorously. The ten selections that were made were not randomly located throughout the planting as one would expect. All but two accessions were located only on the outside rows of the planting. These outside rows generally receive slightly more water due to a border affect, and this can significantly improve seed fill and germination rate if plants are moisture stressed. Subsequently, the planting has been heavily irrigated and fertilized in 2004 to encourage maximum seed production. Seed will be bulk harvested and tested for germination rate. If seed fill and germination rate is satisfactory (above 50%), the seed will be used to establish a new seed production field. This is necessary because there is such a high, local demand for this commonly occurring species. This seed will be provided to interested growers as a selected plant material release.

If the seed germination rate is poor after bulking all the lots, we will increase the two accessions through vegetative means that performed well in the interior of the planting. This seed will be planted in a new, isolated planting and will be measured for seed fill and germination rate.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the fields clean and promote vigorous growing of the planting.

Vine Mesquite IEP Field 13

Action	2004 Date
Irrigation 3" water application	5/24, 6/21, 7/9, 7/21, 9/1
Herbicide Pre-emergent	 3/31
Fertilizer 160 pounds Nitrogen 40 pounds Phosphorus	2004
Harvest (combine)	10/12
Baled	10/29

Giant Sacaton (*Sporobolus wrightii*)

By: LLPMC Staff[1]

Study Number: NMPMC-P-8401-CP

Giant sacaton is a native, robust, perennial warm-season bunchgrass. It is found 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 sacaton may reach heights exceeding 3 m. The mature plants range in height from 1–4 m. Based upon its density and height, it has the potential as a windbreak plant for irrigated cropland.

Seed collections of Giant sacaton were taken from 37 locations throughout New Mexico. These collections were used to establish non-replicated, accession rows that consisted of 520 plants in a field at the Los Lunas Plant Materials Center. Based on a visual evaluation of vigor and height, ten superior plants were selected. Each selected superior plant came from a separate accession to maintain a diverse population. From these ten plants, one super selection was made. A hybrid, cross-planting was established as an attempt to improve the height of the progeny.

In 1992, colonel shoots of each selected plant were planted into a hybrid, seed-production block with the super plant as the male pollinator. In 1995, seed was hand-harvested from each female parent. In 1996, this seed was used to establish an evaluation planting that contained both 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 eight months in an attempt to equalize carbohydrate reserves in the seed derived plants and the clones. The planting design was an 8-replicated, split-plot, randomized block design. Each replication consists of 20 plants spaced on 10-ft. centers. A plot consists of a parent and the progeny plant.

The planting is mowed in the winter to remove plant liter from the previous year. By the end of the third growing season, the leaf blades of most plants had approached 3 m in height. When the plants are flowering they may approach 4 m.

In August 2002, the planting was evaluated for leaf height, basal width, and appearance. A separate, paired, T-test statistical analysis was performed on each replication comparing the height of each parent to its progeny. The progeny and parent plants were not significantly different in height (alpha .05). However, there appears to be a difference in leaf blade width, color, and uprightness between the parents and progeny plants. The cloned parent plants remain identical to their source where the progeny plants seem to have random variation. The planting will be evaluated again in 2005.

[1] David Dreesen, Gregory Fenchel, Danny Goodson, and Keith White

2004 Treatment and Harvest

Field maintenance for the parent and parent and progeny test plantings consisted of the following.

Weed control was performed throughout the growing season to keep the fields clean and promote vigorous growth of the plantings.

Action	**Date**
Irrigation 3” water applications	3/18, 6/14, 7/15, 8/11, 9/15
Fertilizer 90 pounds Nitrogen 60 pounds Nitrogen Phosphorus 20 pounds Potassium	 5/13, 5/17, 8/11 5/13, 8/11 5/13
Harvest completed (Field 10 only)*	9/29 – 10/7/2004
Swathed	1/16
Baled	12/28

New Mexico Feathergrass (*Hesperostipa neomexicana*) and Needleandthread (*Hesperostipa comata*)

By: LLPMC Staff[1]

Study Number: NMPMC-P-9504-CR

New Mexico feathergrass and needleandthread are native, perennial, cool-season grasses that are tolerant to only 8–10 inches of annual precipitation. They provide fair-to-good forage for livestock and wildlife. However, their flower has long awns, and it may prove injurious to livestock. Both are commonly found on calcareous and sandy soils. The breeding system of needleandthread is self-pollination. New Mexico feathergrass also appears to be primarily self-pollinating.

Seed from six New Mexico feathergrass and 61 needleandthread accessions were obtained from bulk seed collections throughout New Mexico, Arizona, and Montana. In 1985, these bulk collections were established in a field at the LLPMC and into non-replicated accession plots. The plots consisted of two rows of 14 plants each. Fifteen needleandthread accessions and three New Mexico feathergrass accessions were selected based on survival, foliage height, basal width and visual vigor. Seed was bulk harvested from all plants of the selected accessions.

In 1994, a replicated entry evaluation of the selected accessions was established at two sites at the LLPMC. The experimental units consisted of a plot containing two plants. The experiment at both sites was conducted in a randomized complete block with nine replications. Site #1 had salinity levels ranging from 3.3 to 4.5 mmhos, cm^{-1}, and Site #2 ranged from 0.42 to 0.44 mmhos, cm^{-1}. In 1996, Site #1 was abandoned because the site was weedy, and a majority of the plants had died possibly due to the high soil salinity. Site #2 did well and contains healthy plants.

In 2005, superior plants will be selected from the 18 remaining accessions. Plants from both species will be selected, vegetatively increased, and planted into two separate seed increase fields for continued testing. This testing will include off-center plantings.

2004 Treatment and Harvest

Weed control was performed throughout growing season to keep the field clean and to promote vigorous growth of the planting. No evaluations were made in 2004.

Action	2004 Date
Irrigations 3” water application	1/8, 3/30, 4/29, 5/18, 7/8, 9/1, 10/5
Herbicide	
Pre-emergent	3/11
Fertilizer	
50 pounds Nitrogen	4/22, 8/11
20 pounds Phosphorous	4/22/2004
20 pounds Potassium	4/22/2004
Baled	6/24

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Prairie Junegrass (*Koeleria macrantha*)

*By:*LLPMC Staff[1]

Study 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 6,000 and 11,000 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 within a population will increase 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 two 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 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 same ploidy level.

Table 1: 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	-	-

In 1989, polycross blocks were established for the early-maturing and late-maturing accessions. Plants for both types of polycross blocks were derived from the original collections.

In 1997, the polycross block for the late-maturing accessions did not perform as expected, and was abandoned. In 1998, superior plants were selected from the early-maturing polycross block established in 1989. Seed was collected from these plants, and clones were established from the parents.

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In 1999, an evaluation planting was established to compare the parents to the progeny. This planting is replicated six times and is a latin square design. These accessions were visually evaluated for forage and seed yield in 2003 and 2004. The progeny appear to be breeding true to the parents for there was no visual difference. Subsequently the planting will be used for seed production to support further field testing that will compare the performance of this material to other available commercial sources. The range of adaptability of this germplasm will be determined during field testing, and if it displays superior performance, the germplasm will be released to the commercial seed industry.

2004 Treatment and Harvest

Field maintenance included the following:

- Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.
- This planting was not evaluated in 2004. Evaluations will be completed in 2005 to work towards a possible release of this species.

Action	**2004 Date**
Irrigation 3" application	1/7, 3/22, 4/29, 5/14, 5/26, 6/17, 7/9, 7/20, 8/16, 9/06
Herbicide Pre-emergent	 3/3
Fertilizer 80 pounds Nitrogen 60 pounds Phosphorous 20 pounds Potassium	 4/22, 7/7, 9/16 4/22, 7/7 4/288

Evaluation of Giant Sacaton For Use In Field Windstrip Plantings

By: Danny Goodson[1]

Study Number: NMPMC-P-9801-CP

NRCS Field Offices continue to be very interested in using the giant sacation species for windstrip plantings. In 2004, the Los Lunas Plant Materials Center (LLPMC) provided giant sacation transplants to the field offices in Clayton, Estancia, and Grants, NM, and to the Navajo Reservation in McKinley County and Isleta Reservation in Valencia County, New Mexico. Distribution of these plant materials continues to promote the utility of this species for use as a windstrip, and it additionally defines its range of adaptability.

Rancho La Frontera

The Rancho La Frontera has had two, separate giant sactaon windstrip plantings. The first was installed in 1999-2000, and the second was installed in 2001. Both of these plantings were evaluated in 2004. All of the plants in the 1999-2000 windstrip planting appear to be vigorous and have produced seed heads. These plants average 8 feet in height and 40 inches in width. The 2001 windstrip planting also appears healthy, and the surviving plants are vigorous and have produced seed heads. These plants averaged 7 ½ feet in height and 38 inches in width. The plants that originally died in the 2001 planting have been replaced with new transplants which appear to be healthy.

An evaluation is scheduled for 2005.

Tucumcari Windstrip Planting

The giant sacaton planting at the Tucumcari outdoor classroom appears to be healthy; all of the plants are vigorous and have produced seed heads in 2004. The plants have averaged 4 feet in height and 30 inches in width. These plants are not receiving any additional watering; they have done well with just rainfall moisture. The plants do receive runoff from an adjacent paved road and parking lot during rainfall events. Additional plants maybe installed in 2005 to expand the windstrip area.

An evaluation is scheduled for 2005.

Bernard Lujan - lsleta Reservation

This giant sacaton windstrip was installed in July 2004 on the Bernard Lujan Farm in Isleta, New Mexico. This windstrip will provide protection during the windy season for Mr. Lujan's homestead. The planting consists of a single row of giant sacaton planted 5 feet apart; it is located on the west side of the homestead next to an irrigated alfalfa field. The giant sacaton transplants used in the windstrip were grown at the LLPMC. This planting is part of the adaptability trial of this native grass species for use in windstrips and will enable us to evaluate giant sacaton as a windstrip species in this area of New Mexico. The planting showed a 100 percent survival rate at the October 2004 evaluation. The plants had averaged 12 inches in height and 10 inches in width.

An evaluation is scheduled for 2005.

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Schwebach Farm

This giant sacaton windstrip planting is located in McIntosh, New Mexico. The planting was installed in August of 2004 using transplants grown at the LLPMC. The windstrip was installed along the west side of a farm road adjacent to irrigated cropland. The planting will protect cropland from wind erosion during the windy season (February–May). The planting will be irrigated using water from an existing underground irrigation pipeline. Plants were planted in two staggered rows and spaced 6-feet apart. At the October 2004 evaluation, the plants had averaged 10 inches in height and 6 inches in width. The current survival rate is 100 percent. The plants appear to be healthy and vigorous, and they have received abundant moisture due to heavy rains in the area. This planting will help us to evaluate the suitability for this species to be used as a windstrip in this part of New Mexico.

An evaluation is scheduled for 2005.

Turner Ranch

This giant sacaton windstrip planting is located on the Turner ranch approximately 15 miles northwest of Deming, New Mexico. The planting was installed in July 2002 using transplants grown at the LLPMC. The windstrip is adjacent to irrigated cropland and will provide wind erosion protection for the cropland during the windy season (February–May). This planting will provide evaluation data on the suitability of giant sacaton as a windstrip species in this part of New Mexico. The planting was evaluated in November of 2004 for survival and growth. The plants had averaged 7 feet in height and 38 inches in width, and all of the plants had produced seed heads. No plants have been lost since the 2003 evaluation. The plants appeared to be healthy, vigorous, and well established.

An evaluation is scheduled for 2005.

Keeler Farm

This giant sacaton windstrip planting is located in Deming, New Mexico on Keeler Farms. The planting was installed in July 2002 using transplants grown at the LLPMC. The windstrip is located on the west side of an irrigated field and will protect the cropland from wind erosion during the windy season (February - May). The planting will provide evaluation data on giant sacaton for use in windstrips in this part of New Mexico. The planting was evaluated in November of 2004 for survival and growth. The plants had averaged 7 feet in height and 38 inches in width, and all of the plants had produced seed heads. Survival has remained constant since the last evaluation, and all of the plants appear to be healthy and vigorous. However, this planting does have a serious weed problem. African rue is growing in the windstrip and must be controlled to prevent damage to the planting, and also to keep it from spreading to the adjacent cropland. Mr. Keeler is aware of this problem and has initiated a chemical control program.

An evaluation is scheduled in 2005.

Field Maintenance at the Los Lunas Plant Materials Center

By: Danny Goodson[1]

Alkali Muhly

Study Number: **NMPMC-P-8301-RA**

Introduction

This accession of alkali muhly is in the process of being released as Westwater germplasm from the LLPMC. Alkali muhly, sometimes known as scratchgrass, is a common riparian grass species found throughout the U.S. except for the Southeast. Alkali muhly is a native, warm-season, perennial sod grass, which has a prostrate or an erect growth form. Alkali muhly is an excellent soil stabilizer because it is strongly rhizomatous and grows in moist-to-wet, sand-to-clay and neutral-to-alkali soils.

Westwater germplasm alkali muhly was first collected in 1993 near Westwater Spring in San Juan County located in northwestern New Mexico. This site is 5,200 feet in elevation, receives about 7 inches of annual precipitation, and is in the USDA plant hardiness zone 6. The Westwater germplasm release will be beneficial in the restoration of riparian sites along drainages located in the LLPMC service area. Alkali muhly will be one of the plant materials used to control the introduction or reintroduction of invasive species along riparian corridors.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action	**2004 Date**
Irrigation 3” application	5/18, 6/17, 7/8, 9/1, 10/5
Field burned	3/22
Herbicide[2] Pre-emergent	3/31
Fertilizer 165 pounds Nitrogen 60 pounds Phosphorus 20 pounds Potassium	2004
Harvest Completed	8/30

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[2] This species is not tolerant to 2,4-D types of herbicide. Severe die-back of foliage has been observed after applying this herbicidal group.

National Arboretum Americal Elm Selections

Study Number: **NMPMC-F-0201-OT**

Introduction

Two varieties of American elm were obtained from the National Arboretum in the spring of 2002. The National Arboretum shipped three rooted plants of two varieties, Valley Forge and New Hannony to the LLPMC for evaluation in our hardiness zone. On August 15, 2002, the six trees were transplanted into Field 26S on the LLPMC.

The elm selections have a 100 % survival rate, and the amount of growth is fair but appears to be limited by our climate. The New Hannony selection averaged 42 inches and the Valley Forge plants averaged 75 inches in total height. Both elm selections had good foliage color, but very few new branches were produced in 2004. It is too early in the growth of both selections to make a judgment on how this species will perform here in Los Lunas.

The planting will be evaluated for growth and survival in 2005.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action	**2004 Date**
Irrigation 3” application	3/23, 4/30, 5/24, 6/10, 6/18, 6/25, 7/20 8/16, 9/1, 9/16, 10/19
Herbicide Pre-emergent	 3/11
Fertilizer 80 pounds Nitrogen 60 pounds Phosphorus 20 pounds Potassium	2004

Autumn Amber

Study Number: **NMPMC-P-9803-UR**

Introduction

Evaluation of propagation techniques will be performed in 2005 as required.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action	**2004 Date**
Irrigation 3” application	3/23, 4/30, 5/24, 6/23, 7/23, 8/24, 10/19

Hope Desert Willow Stock Plant Production

Study Number: NMPMC-P-0102-UR

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Seed was not harvested in 2004 from this planting.

Action	2004 Date
Irrigation 3” application	3/22, 4/30, 5/28, 6/18, 7/9, 7/22, 8/16, 9/24, 10/29
Herbicide Pre-emergent	 3/11
Fertilizer 50 pounds Nitrogen 20 pounds Phosphorous 20 pounds Potassium	 2004

Regal Desert Willow Stock Plant Production

Study Number: **NMPMC-P-0101-UR**

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Seed was not harvested in 2004 from this planting.

Action	2004 Date
Irrigation 3” application	3/22, 4/20, 5/28, 6/18, 7/9, 7/23, 8/16, 9/24, 10/29
Herbicide Pre-emergent	 3/11
Fertilizer 50 pounds Nitrogen 20 pounds Phosphorous 20 pounds Potassium	2004

Species from Four Corners Region

Study Number: **NMPMC-P-9505-CR**

Introduction

The plantings of different species collected in the Four Corners region of New Mexico were not evaluated in 2004.

Evaluations will be completed in 2005 to work towards a possible release of selected species.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the fields clean and promote vigorous growth of the plantings.

Action	2004 Date
Shrub collections	
Irrigations 3" water application	5/3
Desert needlegrass and Slender wheatgrass	
Irrigations 3" water application	5/3, 5/25, 10/8
Herbicide	
2,4-D	4/23, 7/9
Fertilizer,	
10 pounds Nitrogen	2004
20 pounds Phosphorus	
20 pounds Potassium	
Mexican whitesage, Buckwheat and White prairieclover	
Irrigation 3" water application	5/3
Muttongrass	
Irrigation 3" water application	5/3, 5/25
Herbicide	
2,4-D	4/23

Little Bluestem Initial Evaluation Planting

Study Number: **NMPMC-P-9101-RA**

Introduction

In 2004, this planting was not evaluated. Evaluations will be completed in 2005 to work towards a possible release of this species.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

There was no seed harvested in 2004.

Action	2004 Date
Irrigation 3" application	5/26, 6/23, 7/23, 8/31, 9/28
Herbicide	
Pre-emergent	3/9
2,4-D	7/8
Fertilizer	2004
90 pounds Nitrogen	
20 pounds Phosphorus	
20 pounds Potassium	
Mow	1/8/2004

Mexican Whitesage

Study Number: **NMPMC-9801-WL**

Introduction

This Mexican Whitesage collection is being evaluated for its potential as a variety release.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

The plants produced seed in 2004, but no harvest was attempted. Seed harvest will be completed in 2005.

Action	**2004 Date**
Irrigation (3” application)	4/30, 6/18, 9/16
Fertilizer 40 pounds Nitrogen	2004
Mow	1/2

Sandhill Muhly

Study Number: **NMPMC-P-9601**

Introduction

This collection of Sandhill muhly is being evaluated for its potential as a variety release.

Evaluation of this collection of Sandhill muhly will be completed in 2005.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action	**2004 Date**
Irrigation (3” applications)	
Herbicide Pre-emergent	 3/3/2004
Fertilizer 130 pounds Nitrogen 60 pounds Phosphorous 20 pounds Potassium	2004

Single Leaf Ash and Fragrant Ash

Study Number: **NMPMC-P-9804-UR**

Introduction

Evaluation of the accessions will continue in 2005 for possible release.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action	2004 Date
Irrigation 3” application	3/22, 4/30, 5/28, 6/18, 7/9, 7/23, 8/16, 9/24, 10/19
Pre-emergent herbicide	5/16/2004
Fertilizer 40 pounds Nitrogen 40 pounds Phosphorous	2004

IE Tobosa Planting

Study Number: **NMPMC-P-8301-RA**

Introduction

Five culms from six accessions, 9009424, 9009413, 9009414, 9009419, 9009418 and 9009420 were taken from plants in the initial evaluation planting in Field 6 of the LLPMC on 4/13/2004. The culms were placed in one gallon pots and put in the LLPMC greenhouse. On 10/20/2004, the one-gallon transplants were planted into Field 7. In 2005, five more culms of the six superior accessions will be dug from the IEP in Field 6 and placed in pots to provide 10 plants per accession in the advanced planting of tobosa in Field 7. This advanced planting then will be evaluated to determine if a plant materials release of tobosa can be justified.

Evaluation of the accessions will continue in 2005 for possible release.

2004 Treatment and Harvest

Weed control was performed throughout the growing season to keep the field clean and promote vigorous growth of the planting.

Action – Field 6	2004 Date
Irrigation 3” application	6/16, 7/17
Herbicide 2,4-D	 4/23, 7/8
Fertilizer 40 pounds Nitrogen 40 pounds Phosphorous	2004
Action – Field 7	**2004 Date**
Culms potted	4/13
Transplanting to Field 7	10/20
Irrigation 3” application	10/22, 10/28, 11/12

Los Lunas Habitat Restoration Project

By: LLPMC Staff[1]

Study Number: NMPMC-T-0502-RI

Abstract

Due to the construction of silvery minnow egg retention ponds, the Los Lunas Plant Materials Center (LLPMC) was contracted to restore 1.2 miles of the Rio Grande river bank in Los Lunas, New Mexico. The LLPMC planted native vegetation on approximately 16 acres of a disturbed area of the bosque. The LLPMC implemented planting techniques that involved getting the plants' roots or the cut end of the pole cuttings into the soil where subsurface water is naturally present. This technique takes advantage of natural irrigation.

Currently, most of the plants are healthy even though they have not received any supplemental irrigation. However, the plantings were inundated for 50 or more continuous days in May, June and July 2005, killing many of the transplants and pole cuttings. The rate of survival was affected by plant species and container type.

The plantings included four acres of grass and penstemon seeding, 1200 transplants of three shrub species grown in tall pots, 100 New Mexico olive transplants grown in tree pots, 780 cottonwoods pole cuttings, and 865 black willow pole cuttings.

The survival rate of skunkbush sumac transplants grown in tall pots (8 %), New Mexico olive transplants grown in tree pots (14 %), and newly planted cottonwood pole cuttings (27%) were severely impacted by the 50 plus days of continuous inundation. The survival rate of transplants of wolfberry grown in tall pots (50%) was also reduced by the inundation. The wolfberry plants that were planted in low areas and were inundated for the longest period of time had typically died. However, survival of second-year planting of cottonwood pole cuttings (76%) and New Mexico olive grown in tall pots (93 %) was not affected by the 50 plus days of continuous inundation. Survival of the newly planted black willow pole cuttings (67%) did not seem to affected by inundation if they were planted in sandy top soils. When planted on sandy top soils, nearly 100 % of the plants survived. On clay top soils, most had died.

Moist soil along riparian areas in the arid southwest is very conducive to growing vegetation, including competitive weeds species. Once the soil of a riparian area is disturbed, it is common for annual and perennial weeds to establish quickly. New plantings and seedings will find it difficult to compete with fast-growing weeds for light, water, and nutrients. Applying a surface layer 4-6 inches of wood chips will reduce weed emergence and allow desired plants to grow. Surface mulch was not applied in this planting, and resulted in a continual application of weed control methods to protect the desired plants.

Currently, the four-acre seeding on the high-flow berm has not become established. It is competing with a dense population of annual weeds. The LLPMC will continue mowing this seeding to reduce the weed competition.

In addition, dense stands of salt cedar seedlings and salt cedar root sprouts are becoming established on the planting areas along the high-flow berm. These stands of salt cedar need to be

[1] David Dreesen, Gregory Fenchel, Danny Goodson, and Keith White

controlled while they are small and can be killed easily by herbicide applications. If the salt cedar stands are not controlled, they will be more competitive and reduce the density of the desired vegetation.

Introduction

The USDA-NRCS Los Lunas Plant Materials Center (LLPMC) participated in an interagency project designed to restore the hydrology of an area of the Rio Grande in Los Lunas to its natural condition where spring overbank flooding occurs. In an effort to protect the survival of the Silvery Minnow, egg retention ponds were constructed inside a 1.2 mile high flow channel on the river. In the process of building these structures, some of the native and non-native vegetation had to be cleared away. To restore this area to its natural vegetative state, the LLPMC implemented some unique planting methods which will require little or no irrigation. These planting methods were either developed or refined by the LLPMC, and they were used on this project to measure their effectiveness.

Developing a successful transplanting system that requires minimal follow-up irrigation is critical for bosque restoration in the droughty Southwest. These areas receive less than 10 inches of annual precipitation. The selection of tall pots (containers 30-inches in length and 4-inches in diameter) coupled with embedded irrigation tubes (40-inches in length and 1-inch in diameter) were tested at this site. Pole cuttings of cotton woods and western black willows were also tested. Both planting systems rely on getting roots or pole cuttings into the soil where subsurface water is present to provide the irrigation needs for the plants.

The participants in this project consisted of the Los Lunas Plant Materials Center (LLPMC), the Albuquerque District of the U.S. Army Corps of Engineers, the Albuquerque office of the U.S. Bureau of Reclamation (USBR), and the Middle Grande Conservancy District (MRGCD).

Background

In the area of the minnow ponds, the cottonwood gallery was destroyed in a wildfire in the spring of 2000. The scorched, 50-foot mature cottonwood trees appeared to be dead, but by late summer of 2000 they were starting to re-sprout at their base. In order to start the construction of the egg retention ponds in 2002, all of the wood debris had to be removed.

At the request of the LLPMC, the fine branches of the cottonwoods and small trees were chipped and transported to an off-site location. Traditionally the wood chips are used as a mulching layer and spread on the planting site, but the LLPMC thought it would be easier to establish cottonwood pole cuttings, shrub transplants, and grass seedings if the mineral soil was exposed and not covered by a layer of mulch. This would prove to be a costly mistake because of the prolific weed emergence as described in the results section of this document. The larger material, such as the main stems of the mature trees, were also removed and transported to an off-site location. Some standing dead trees were left intact to provide for woodpecker and raptor habitat.

Planting Preparation and Installation

The planting area consisted of two sites totaling approximately 16 acres and 1.2 miles in length (Figure 1). There are approximately eight acres along the MRGCD drain ditch road and approximately eight acres along the high-flow berm adjacent to the Rio Grande. The MRGCD requested us to leave a 30-foot open area along the berm for access to the site.

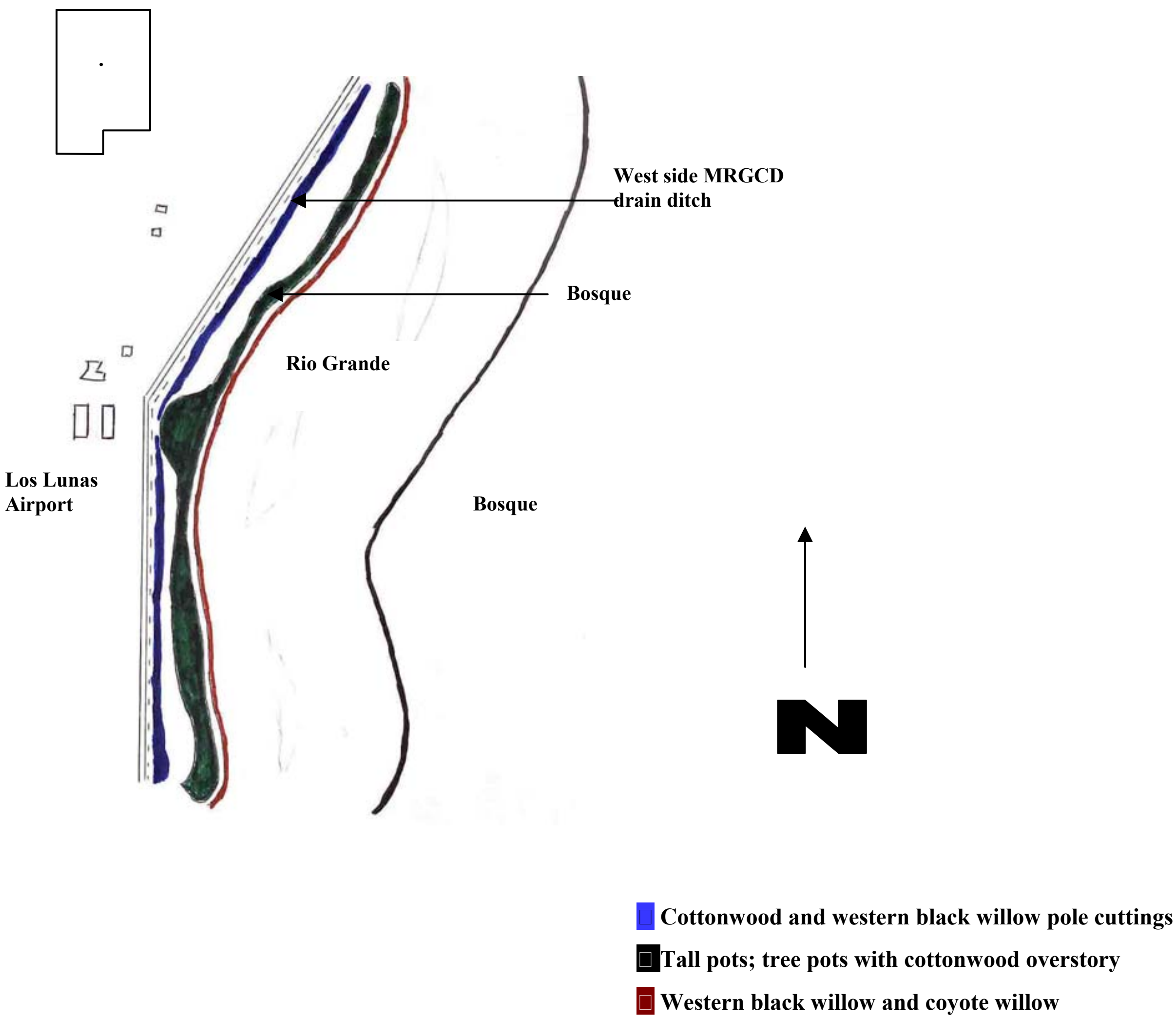

Figure 1: Map detail of the Los Lunas Habitat Restoration Project

April 2004

Location: North of the river access road between the existing bosque and the MRGCD drain ditch road.

The LLPMC staff planted 580 cottonwood (*Populus deltoides*) pole cuttings and 20 western black willow (*Salix gooddingii)* pole cuttings. The original source of the poles was taken from the Bosque del Apache Wildlife Refuge, but the poles that were cut and planted were grown and harvested from production fields at the LLPMC. We prepared the poles by pruning all but two or three terminal branches. The cut poles were then kept hydrated by placing their cut ends in water tanks until they could be planted.

The planting holes were dug using a 65-hp farm tractor with a front-end mounted auger that was 9-inches in diameter and 8-foot in length (see Figure 2). We planted the poles on 15–30 foot centers. After planting the poles we placed a poultry-wire tree guard (5-foot in height and 10-inches in diameter) around each pole to control beaver predation.

Figure 2: Planting cottonwood poles in April 2005

May 2004

By May of 2004, several mature cottonwoods had fallen over the access road that parallels the high-flow berm. The LLPMC staff used chain saws to cut up the debris, and then removed it from the planting site.

May, June, July 2004

Location: 1.2 mile high-flow berm along the river and the access road parallel to the high-flow berm (see map).

To prepare for the seeding, we sprayed this area once in May, once in June, and once in July with the herbicide glyphosate ('Rodeo') at the rate of 1-gallon per acre to control common annual weeds. The site was kept fairly clean with this treatment. To apply the herbicide, we used a 50-hp farm tractor outfitted with a power take off (PTO), 10 ft. boom spray system. The entire seeding area is approximately 4 acres in size.

Because the access road had been driven over regularly by vehicles resulting in compacted soil, we disked the access road that had been sprayed prior to the seeding.

August 2004

During the first week of August 2004, the prepared site was seeded by hand-broadcasting the seed. The seed then was incorporated into the soil by harrowing with a farm tractor which covered the seed with approximately ¼-inch of soil.

The seed mix was composed of sand dropseed (*Sporobolus cryptandrus*), Indian ricegrass (*Achnatherum hymenoides*), alkali sacaton (*Sporobolus airoides*), blue grama (*Bouteloua gracilis*), galleta (*Pleuraphis jamesii*), and narrowleaf penstemon (*Penstemon angustifolius)* (see Table 1).

Table 1: Seed mix for the Los Lunas Restoration Project

Common Name	Scientific Name	% Composition	Seeds/lb	Seeds /sq ft	PLS lbs/acre
Blue grama	*Bouteloua gracilis*	10	825,000	4	0.21
Galleta	*Pleuraphis jamesii*	20	470,000	8	0.74
Indian ricegrass	*Achnatherum hymenoides*	40	141,000	16	4.94
Alkali sacaton	*Sporobolus airoides*	15	1,758,000	6	0.15
Sand dropseed	*Sporobolus cryptandrus*	10	5,298,000	4	0.03
Narrowleaf penstemon	*Penstemon angustifolius*	5	313,000	2	0.28

September 2004, July and August 2005

The seeding was mowed with a brush hog once in September 2004, once in July 2005, and once again in August 2005 to control annual weeds (Figures 3 and 4).

Figure 3: The grass seeding on high flow berm before mowing in July 2005 (looking north). The weeds are mainly Russian thistle and Kochia.

Figure 4: The grass seeding on high-flow berm after mowing in July 2005 (looking south).

November 2004

To prepare the site for the containerized transplants, the soil surface of the planting area, located between the access road along the high flow-berm and the bosque, was scraped with the blade of a small dozer to remove the thick annual weed cover (mainly sunflowers and kochia with some approaching 12-foot in height). The weeds were piled outside the planting areas.

In mid-November, we planted 1,100 tall pots and 100 tree pots in the cleared areas:

- 700 New Mexico Olive (*Forestiera neomexicana*) tall pots
- 100 New Mexico olive tree pots
- 300 wolfberry (*Lycium torreyii*) tall pots
- 100 skunkbush sumac (*Rhus trilobata*) tall pots

The plants were planted to the depth of subsurface moisture, approximately 3- to 6-feet (Figure 5). Paired plantings of 100 New Mexico olive tall pot and 100 New Mexico olive tree pot transplants were planted within 8-feet from each other to test the effectiveness of the pot size on plant survival. An irrigation tube measuring 40-inches long and 1-inch in diameter was embedded with each transplant for future irrigation treatments. The lower ⅓ portion of the tube was perforated to enhance water dispersion in the root zone of each plant.

Figure 5: Planting New Mexico olive tall pot transplants with sub-irrigation tubes in November 2004.

February 2005 — The area between the MRGCD road on the west side of the river, and the bosque north of the pond access was mowed in preparation for the March 2005 planting of cottonwood pole cuttings.

March 2005

In early March, the area was planted with 300 cottonwood pole cuttings. The cuttings were planted on approximately 30–40 foot centers. Each pole had a poultry wire tree guard installed using the same methodology as previously discussed.

April 2005

Location: East side of the high-flow berm

To reduce stream flow velocity protecting the berm, we planted 845 western black willow and 1,425 coyote willow. So that the new planting would not have to be irrigated, both species were planted in 8-foot augured holes that reach subsurface moisture. The coyote willows were planted in group of four willows per hole, about 10 feet from the berm; no tree guards were installed. The western black willows were planted individually along the toe of the berm with tree guards. The areas that had been previously planted with tall pot containerized shrubs were sparsely planted with 110 cottonwood pole cuttings with tree guards to provide an overstory structural component.

Planting Maintenance

The areas planted in tall pot transplants and cottonwood pole cuttings near the river along the west side of the high-flow berm were spot treated once in April with a mixture containing a post-emergent and pre-emergent herbicide which were respectively 2% glyphosate (Roundup at 47.6 %) and 2% pendimethalin (Pendulum at 37.4 %).

In May 2005, only the post-emergent herbicide was applied. In both April and May, glyphosate (‘Pondmaster’) was applied around the edge of the pond to control mainly sunflower and kochia. By mid-May most of the treated areas were under water due to the rise in groundwater; a consequence of the extremely high flow of the Rio Grande. This high flow of water was due to twice the normal amount of snow-pack in the watershed compounded by extremely warm air temperatures. This area remained under water until mid-July.

When the soil surface dried out enough for a vehicle to enter the site (late July 2005), the perimeters of the tall pot transplants were sprayed with glyphosate (Roundup at 47.6%) to control annual weeds so plants could be located for irrigation and evaluated. Unfortunately, there was no control of annual weed emergence by the pendimethalin which had been previously sprayed. The chemical was probably diluted past the state of effectiveness by the long standing surface water.

As of August 26, 2005, there has been no irrigation treatments applied to any of the plantings. Subsurface moisture at this time was found to be approximately 18 inches below the surface.

The plantings were evaluated for survival August 22–23, 2005. Survival results for the treatments of the parried plot trial were analyzed using the SAS Statistical analysis procedure GLM (see Attachment A).

Results and Discussion

The construction of the silvery minnow egg retention ponds resulted in massive soil surface disturbance. With the mixing of subsurface and surface soil, new weed seed was positioned on the surface ready to germinate and establish with the addition of water. Because of the high flows of the Rio Grande, water was ponded on the soil surface for more than 50 days (Figure 6). In addition to providing anaerobic conditions for the planted shrubs and pole cuttings, a surplus supply of water was available for weeds to germinate, establish and grow. Consequently, during the entire period of this planting, the LLPMC has had to control weeds using both mechanical and chemical treatments. Otherwise the planting easily could fail because of the blanket shading and other impacts that would occur.

Figure 6: A typical inundated area of the planting with New Mexico olive tall pot transplants in the foreground in June of 2005.

Leaving a 4- to 6- inch chip layer on the soil surface would have reduced the continued need for weed control. A mulch layer similar to this was left where the mulch piles once stood and after two years it is still controlling weed emergence (Figure 7). These sites are highly productive because of the presence of surface water and need to be protected from annual and new perennial weed emergence once they are disturbed.

Figure 7: The second growing season for cottonwood pole cuttings planted at the side between the existing bosque and the MRGCD drain ditch road covered with a 4- to 6-inch surface mulch layer of wood chips. In the background where no surface mulching occurred, exists a dense ground cover of annual weeds in August 2005.

The berm grass and penstemon seeding began emerging in late August of 2004 after several rainstorms. Emerging seedlings of galleta and Indian ricegrass were the most common (Figure 8). Desert salt grass was also volunteering on the site. However, the seed bed was dominated by high densities of Russian thistle (*Salsola kali*) and kochia (*Kochia scoparia*) seedlings. Both plants are more competitive for light, water, and nutrients than grass seedlings. In retrospect, the site should have had weed control applied for at least two years prior to seeding to reduce this competition. As of August 2005, the berm is still dominated by weeds with some grass plants present. Unlike the other species seeded, New Indian ricegrass and penstemon seedlings will continue to emerge for the next two years.

Figure 8: Grass emergence on the berm seeding in September 2004. The grass in the foreground is desert saltgrass, other grasses are mainly galleta and Indian ricegrass.

Of the 600 pole cuttings planted in the April of 2004 (580 cottonwood and 20 western black willow), only 384 cottonwood and 17 western black willow were found, approximately 67 percent of the plants (Figure 9). The others are in a dense forest of 10–12 foot kochia, sunflowers, coyote willow and other vegetation. Of the plants that were located, the cottonwoods averaged 84 percent survival and the western black willow averaged 76 percent survival. The 50 days of inundation did not seem to have an effect on the survival of the poles that had already rooted one year earlier.

Figure 9: Cottowoods poles cuttings in their second year planted along the MRGCD drain ditch road in August 2005.

However, of the 410 cottonwood pole cuttings planted in March and April 2005, the survival rate averaged only 27 percent. The trees were affected by the 50 day plus inundation which occurred from May to July of 2005. The pole cuttings leafed out in May as they typically do, but they began to show signs of chlorosis by mid-June, and by July (Figure 10) they had dropped their leaves. Those plants that did survive were located on slightly higher ground within the planting. Similar survival results occurred on a new planting of cottonwood poles about 15 miles south of this planting. This similar planting was also inundated, and most of these pole cuttings also died except for those that were planted on higher ground.

Figure 10: In July 2005 three months after planting, these cottonwood pole cuttings had dropped their leaves and are probably dead.

Survival of the western black willow planted on the toe of the berm averaged 53 percent as a consequence of inundation (Figure 11). Those planted in sandy top soil seemed to have a higher survival rate (Figure 12). Their were areas within the planting that had 30 or more consecutive dead willows that seemed to correlate to clay soil surface texture which may provide less air for root respiration under saturated conditions. Traditionally, survival averages above 70 percent when conditions are ideal and the plants are not inundated. Survival of the coyote willow averaged about 75 percent even though they were planted in a slightly lower area than the western black willow (Figure 13). They appear to display a better tolerance to inundation than the western black willow. Some of the coyote willows were damaged by beaver. However the stems that were cut all had new growth. The western black willows with the beaver guards were left intact.

Figure 11: Western black willow pole cuttings planted on the toe of the high-flow berm are inundated in June 2005.

Figure 12: Western black willow pole cuttings five months after planting on sandy topsoil in August 2005.

Of the 700 New Mexico olive tall pot transplants, 609 plants were found. The plants averaged a 93% survival rate (Figure 14). The inundation did not have a significant impact on New Mexico olive tall pot survival. These plants can tolerate this extended period of inundation.

Figure 13: Coyote willow pole cuttings (center) four months after planting in the high-flow channel in August 2005.

Of the 100 skunkbush sumac that was planted, 90 plants were located. Skunkbush sumac tall pot transplants averaged an 8 percent survival. Every plant that was inundated for the extended period died. Only those plants that were planted on high ground survived.

Of the 300 wolfberry planted, 193 plants were located. Wolfberry tall pot transplants averaged a 51 percent survival. These plants were also impacted by inundation but not as severely as skunkbush sumac.

Figure 14: New Mexico olive tall pot transplants in foreground 8 months after planting in August 2005.

Survival of the New Mexico olive tallpots (89 %) was significantly greater (.0001) than survival of the treepots (14 %) in the paired plot trial (see Figure 15). The tree pot transplants broke dormancy in May and dropped their leaves in June and then died while the soil was still inundated. These plants have smaller root system (10–12 inches in length) compared to the root system of plants grown in tallpots (25–27 inches in length). The larger root systems of plants grown in tall pots may have allowed the plants to tolerate inundation for a longer period of time. The buried stem of the tree pot plants would be less tolerant of inundation.

Figure 15: Survival test of New Mexico olive tall pots (white tubes) compared to New Mexico olive tree pots (red tubes) planted next to each other in paired plots in July 2005.

In addition, dense stands of salt cedar seedlings and salt cedar root sprouts are becoming established on the planting areas along the high-flow berm. These stands of salt cedar need to be controlled while they are small and can be killed easily by herbicide applications. If the salt cedar stands are not controlled, they will be more competitive and reduce the density of the desired vegetation.

Table 2: Los Lunas Habitat Restoration Plantings and Survival Rates

Species/Container Type	November 2004 Planting	April 2004 Planting	Planting Survival Rate	March 2005 Planting	Planting Survival Rate
New Mexico olive tree pot	100		14%		
Skunkbush sumac tall pot	100		8%		
Wolfberry tall pot	300		51%		
Cottonwood pole cuttings		580	84%	410	27%
Western black willow pole cuttings		20	76%	845	53%
Coyote pole cuttings				1,425	
New Mexico olive tall pot		700	93%		