Propagation of Native Plants for Restoration Projects in the Southwestern U.S. - Preliminary Investigations[1]

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Abstract-Seed treatments to enhance germination capacity of a variety of native tree, shrub, forb, and grass species are reported. Scarification methods including hot water immersion (HW), mechanical scarification (MS), tumble scarification (TS), proximal end cuts (PEC), and sodium hypochlorite (SH) have been tested: *Psorothamnus fremontii*(HW, TS), *Ceanothus integerrimus* (HW), *Ceanothus sanguineus* (HW), *Rhus glabra* (HW), *Ptelea trifoliata* (PEC of seed separated by size and color), *Rubus strigosus* (SH), *Oryzopsis hymenoides* (TS), *Coleogyne ramosissima* (TS), and a variety of native woody and herbaceous perennial legume species (HW, TS, MS). Gibberellic acid treatments were examined to overcome endo-dormancy of *Alnus tenuifolia, A. oblongifolia, Rubus strigosus*, and *Oryzopsis hymenoides*. Vegetative propagation methods investigated include mound layering of *Platanus wrightii*, root propagation of *Populus tremuloides*, and pole plantings of riparian understory species (*Amorpha fruticosa, Baccharis glutinosa, Forestiera neomexicana*, and *Chilopsis linearis*).

INTRODUCTION

Restoration of disturbed lands in the southwestern U.S. has become a primary mission of many federal and state land management agencies and a regulatory requirement for extractive industries. Frequently, containerized or bare-root plant materials are used for reclamation activities following severe disturbance or for introduction of woody plant species formerly present on poorly managed lands. These plant demands have increased interest in propagation techniques and production methods for obscure native woody species. The lack of propagation information for many native species used in ecosystem restoration prompts nurseries to rely on experimentation to resolve propagation problems or forgo producing certain species. This problem is compounded by the scarcity of propagules (seed or vegetative material) of some species or ecotypes.

Seed propagation of native species often requires growers to rely on information from closely related horticultural species for seed treatment requirements. While this information is useful, many species are produced by the horticulture industry because of their ease of propagation as well as other horticulturally important traits. Secondly, seed used in the horticulture industry is often produced under optimum management conditions with seed lots having high percentages of viable seed. In contrast, seed lots of limited quantity and with unknown levels of viability are most often encountered by conservation nurseries. Therefore, two significant factors must be addressed to develop seed propagation protocols for many native plants: first, seed refinement, or eliminating non-viable seed from the seed lot, and second, overcoming obstacles to germination of recalcitrant species. These obstacles frequently fall into two categories: impermeable seed coats and dormant seed. Typically, scarification and stratification techniques are used to overcome these obstacles, respectively.

Seed refinement procedures for many tree and shrub species are well known (Young and Young 1992, Schopmeyer 1974a). Seed refinement involves increasing the percentage of viable seeds in a seed lot and is often accomplished by seed sizing and liquid or air separation techniques. However, seed refinement techniques for many reclamation species have not been published or conventional techniques are not suitable due to seed properties. For example, seeds with integuments or wings often preclude the use of conventional gravity separation techniques.

Often, seed production of many species in native stands is sporadic with up to ten years intervening between adequate seed crops. Vegetative propagation offers an acceptable alternative propagation system to meet production requirements. The horticulture industry is a good source for vegetative propagation information of species not historically produced in conservation nurseries. However, the differences between horticultural varieties and reclamation ecotypes are very pronounced, largely due to adventitious rooting being strongly controlled by genetics. Cultivar releases in the horticulture industry have often been attributed to the ability to produce adventitious roots.

This paper will address some of our experience in the seed propagation of native tree, shrub, forb, and grass species. These simple experiments are aimed at resolving problems with total germination percentage, rate of germination (germination speed; days to total germination of a seed lot), and germination uniformity. Benefits associated with improving germination percent are straightforward. Improvements in germination speed and uniformity can dramatically influence seedling quality and production costs. In addition, several promising vegetative propagation techniques are discussed. The paper is organized by the type of treatment or propagation method being examined. Within each section a summary report is provided on the species or group of species evaluated.

SEED PROPAGATION

Scarification Studies

Psorothamnus fremontii

This woody leguminous shrub found in the Mojavean and Navajoan Deserts of the Colorado Plateau has various pseudonyms including *Dalea fremontii* (Benson and Darrow 1981). Common names applied to this species include Fremont dalea, indigo bush, and Johnson dalea (Benson and Darrow 1981). The source of seed for this experiment was the Glen Canyon National Recreation Area in northeastern Arizona and southeastern Utah. A means of improving total germination and germination rate was essential because of limited seed supplies. Previous trials with 2-year-old seed had shown that traditional mechanical scarification (Forsburg J seed scarifier) resulted in excessive seed breakage and was therefore not an acceptable scarification technique.

Seed was fractionated into large [11/64 to 13/64 inch (4.3 to 5.2 mm)], medium [9/64 to 11 /64 inch (3.6 to 4.3 mm)], and small seed [7/64 to 9/64 inch (2.8 to 3.6 mm)] using round hole screens. Two scarification treatments were evaluated, hot water soak and tumbling mechanical scarification. The hot water treatment involved immersing 5 to 10 g of seed in 100 ml of 90^{o}C water and letting stand for 1 hour. After immersion, the seed was separated into floating seed, swollen sinking seed, and non-swollen sinking seed. The mechanical

scarification used a rock tumbler (one-liter capacity) with 100 g of pea-sized (10 - 15 mm) gravel, 75 g of coarse carborundum grit, and a rotation rate of 60 rpm. Two batches of medium-sized seed were subjected to 1 day and 3 days of tumbling. Seed receiving no scarification treatment served as a control. Treated and control seed were planted in [288-cell square deep-plug] trays filled with Sunshine #1 Mix®. Seeds were immediately planted and placed in the greenhouse (23°C day, 15°C night). Germination was monitored weekly for the next 10 weeks. The study was replicated six times.

Seed size influenced germination with larger seed having faster and greater germination (Figure 1). The tumbling mechanical scarification of medium-sized seed resulted in better germination than the control and hot water treated seed and tumbling also significantly improved germination speed. As the duration of tumbling increased from one to three days germination speed was significantly increased; however only a minor 4% increase in total germination compared with the control was observed. Hot water scarification treatments improved germination speed, while having only slight effects on total germination at the end of 70 days (Figure 1).

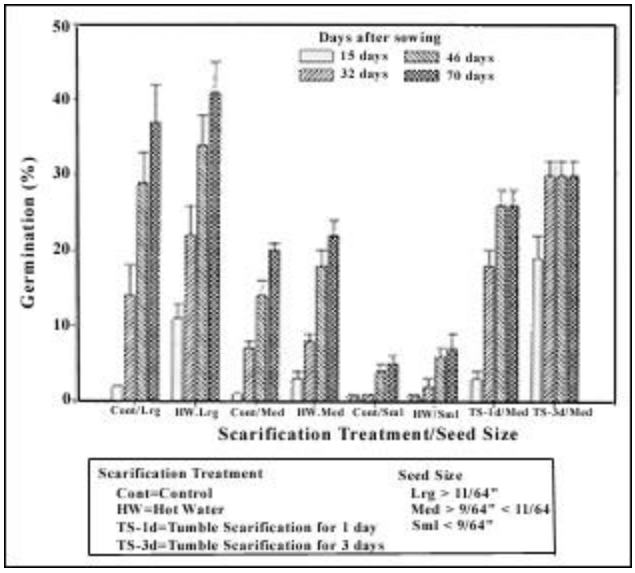

Figure 1. Effect of seed size, hot water and tumble scarification treatments on the germination (± standard error) of *Psorothamnus fremontii*.

The effect of seed size was evident across the three seed conditions (swollen, non-swollen, floating) following hot water incubation (Figure 2). Non-swollen seed had the greatest total germination at the end of the study (70 days) in all three seed sizes. Germination rate was fastest in the swollen seed in the two largest seed sizes, however, total germination was significantly less (at least 50%) relative to non-swollen seed. Only in the largest seed size did floating seed have greater germination rates than controls (Figure 2).

Using seed sizing can be a viable means of seed refinement in this species. If hot water scarification is used, partitioning seed into swollen, non-swollen and floating fractions could be used to further improve germination performance.

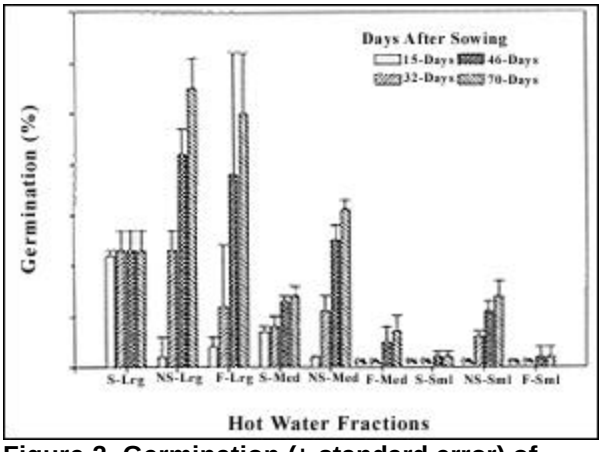

Figure 2. Germination (± standard error) of swollen (S), not swollen (NS) and floating (F) *Psorothamnus fremontii* seed after hot water treatment.

Leguminous Species

The water-impermeable seed coat of legume species generally requires scarification treatment to allow water imbibition and subsequent germination. Treatments often used to overcome obstacles associated with a hard, impermeable seed coat include hot water soaks, concentrated sulfuric acid, and mechanical scarification. Variation between and within species to these treatments makes prediction of treatment efficacy difficult. Also, scarification treatment methodology and severity may influence results.

Sulfuric acid treatments can be effective if the precise treatment time is known; excessive treatment duration can destroy most or all of the seed. Insufficient duration fails to adequately break down the hard seed coat. Difficulties in working with concentrated acid also dissuade some propagators from using this technique. Hot water soaks can be effective but research has shown that the germination response can be a function of both initial water temperature as well as the duration of the soak (Gosling et al. 1995). If this interaction is not known for a particular species, excessive temperature and/or duration can kill the seed. Some laboratory mechanical seed scarifiers can rapidly abrade seed coats through high-energy impact of seed against an abrasive medium such as sandpaper. Again, excessive treatment time can destroy a batch of seed. Seed of certain species are very easily damaged by these high energy impacts, such as some *Lupinus* species, whose cotyledons are split apart by even the briefest conventional scarifier treatment. In some species even when breakage is not observed, these impacts can kill the embryo or damage other seed tissues. The need for more reliable legume scarification information for use by propagators is substantial. Scarification information would also benefit land restoration specialists who drill or hydroseed legumes and often desire rapid germination.

Many nurseries prefer to use hot water or mechanical scarification to treat legume seed because the equipment for these treatments is available and because of the potential hazard of using sulfuric acid. A series of experiments were conducted on several legumes examining hot water treatments and two types of mechanical scarification. The scarification treatments evaluated were:

1) control - no scarification treatment other than that received during standard seed cleaning procedures;

2) hot water - pouring hot water (90^{o}C) over seed batches and allowing to steep for 4 hours;

3) mechanical scarification - using a commercial small sample scarifier (ForsbergR) that employs a rapidly spinning paddle to throw seed against an abrasive lined drum (100 grit sand paper) for 3 to 75 seconds;

4) tumble scarification - using a rock tumbler with pea gravel and coarse carborundum grit for 2 to 3 hours (see Psorothamnus section);

Treated and control seed were planted in [288-cell square deep-plug] trays filled with Sunshine #1 Mix. Seeds were planted immediately after treatment and placed in the

greenhouse (23^{o}C day, 15^{o}C night). The entire study was replicated three times.

Treatment responses were species and seed source specific with no one treatment generating a consistent effect (Table 1). Mechanical scarification resulted in the greatest gain in germination in woody legume seed lots evaluated. Five of eight seed lots had improved germination; however, the remaining three seed lots were negatively impacted by mechanical scarification. Tumble scarification improved germination only in the two ecotypes of *Amorpha fruticosa* and did not detrimentally effect the germination of any other seed lots evaluated. After these initial trials of tumble scarification, the need for longer treatment times became apparent. Hot water scarification improved germination in half of the woody legume seed lots. Only in Amorpha fruticosa was the gain in germination comparable to the gain from the mechanical scarification. All scarification treatments were detrimental to germination in *Caragana arborescens*.

Table 1. Germination percentage of legume seed subjected to scarification treatments.

Species	Form	Origin	Seeds per Replication	% Germination (Mean ± S.E.) Control	Hot Water	Mechanical Scarification	Tumble Scarification 2-3 Hrs
Amorpha canescens	Woody	Native	25	57 ± 7	48 ± 2	3*± 1	58 ± 5
Amorpha fruticosa (C)[1]	Woody	Native	100	25 ± 2	76*± 3	58*± 6	37*± 6
Amorpha fruticosa (LL)	Woody	Native	100	21 ± 2	62*± 3	59*± 2	42*± 4
Caragana arborescens	Woody	Exotic	100	34 ± 2	0*± 0	4*± 1	27 ± 3
Prosopis pubescens (B)	Woody	Native	30	5 ± 2	12*± 1	92*± 3	3 ± 2
Prosopis pubescens (BdA)	Woody	Native	30	5 ± 3	23 ± 8	62*± 7	4 ± 1
Robinia fertilis	Woody	Native	30	31 ± 3	51 ± 7	17 ± 5	40 ± 6
Robinia neomexicana	Woody	Native	30	15 ± 4	39*± 4	78*± 2	17 ± 2
Astragalus lonchocarpus	Herbaceous	Native	20	8 ± 3	2 ± 2	52*± 2	2 ± 2
Astragalus missouriensis	Herbaceous	Native	25	13 ± 2	13 ± 5	75*± 2	88*± 2
Dalea aurea	Herbaceous	Native	30	33 ± 3	65*± 5	10*± 0	70*± 3
Hedysarum boreale	Herbaceous	Native	30	37 ± 4	52 ± 5	32 ± 5	39 ± 4
Lathyrus eucosmus	Herbaceous	Native	30	2 ± 2	0 ± 0	38*± 5	2 ± 2
Lotus oroboides	Herbaceous	Native	35	3 ± 0	30*± 1	77*± 11	7 ± 4
Lupinus alpestris	Herbaceous	Native	30	27 ± 6	40 ± 8	41 ± 13	42 ± 2
Lupinus	Herbaceous	Native	30	72 ± 6	57 ± 3	52*± 2	89 ± 4

perennis							
Oxytropis lambedii	Herbaceous	Native	30	22 ± 9	16 ± 1	59*± 3	39 ± 4
Oxytropis sericeus	Herbaceous	Native	30	3 ± 0	6 ± 2	73±2	9 ± 2
Petalosternum candidium	Herbaceous	Native	30	53 ± 4	46 ± 9	48±1	55±3
Petalostemum purpureurn	Herbaceous	Native	30	67 ± 3	64 ± 9	63 ± 4	63 ± 5
Thermopsis montanus	Herbaceous	Native	302	2 ± 1	48*± 10	37*± 7	3 ± 2
Thermopsis rhombifolia	Herbaceous	Native	30	1 ± 1	14*± 4	42*± 8	2 ± 2
Astragalus cicer	Herbaceous	Exotic	30	27 ± 2	51*± 2	62*± 5	36*± 1
Coronilla varia	Herbaceous	Exotic	30	29 ± 3	42*± 2	63*± 7	ND
Lathyrus sylvestris	Herbaceous	Exotic	30	53 ± 5	58 ± 5	27*± 4	52 ± 3
Lotus comiculatus	Herbaceous	Exotic	30	78 ± 4	3*± 2	22*± 3	ND
Medicago sativa	Herbaceous	Exotic	30	73 ± 2	75 ± 7	90*± 4	84*± 2

[1]C, LL, B, BdA refer to seed source locations.

*Percentages are significantly different from control ($P<0.05$).

ND - No data available.

Hot water and mechanical scarification treatments increased the germination of three herbaceous species, *Lotus oroboides, Thermopsis montanus*, and *Thermopsis rhombifolia* by factors greater than ten. Mechanical scarification was also highly effective on *Lathyrus eucosmus* and *Oxytropis sericeus*. *Astragalus cicer* and *Coronilla varia* benefitted from hot water and mechanical scarification treatments. Only in four of the 19 herbaceous species was short duration tumble scarification effective in promoting germination. In *Dalea aurea*, tumble scarification promoted total germination whereas mechanical scarification reduced total germination compared to controls. In three herbaceous perennial species, *Lupinus alpestris*, *Petalostenium purpureum*, and *Petalostemum candidium*, none of the treatments were significantly different from the controls. Mechanical scarification significantly reduced

the germination of *Dalea aurea*, *Lathyrus sylvestris*, *Lotus corniculatus*, and *Lupinus perennis*. Hot water treatment was detrimental to *Lotus corniculatus*.

The results above indicate the diversity of scarification behavior exhibited by leguminous species. Refinement of scarification procedures for legumes will require intensive investigation of different techniques on a variety of seed lots for each species.

Stratification Studies

Alnus tenuifolia and *Alnus oblongifolia* Thinleaf alder, (*Alnus tenuifolia*), is a dominant shrub or small tree in riparian areas of the Rocky Mountains and Pacific Northwest. Arizona or New Mexican alder, (*A. oblongifolia*), is a riparian tree or shrub of the mid-elevation drainages in the mountains of southwestern New Mexico and southeastern Arizona (Vines 1960). Unlike *A. glutinosa* and *A. rubra*, little work has been done on the propagation of these species. Fresh seed of some *Alnus* species has been found to germinate without cold stratification; however, dried and dormant seed of the same seed lot had improved germination capacity following cold stratification (Schopmeyer 1974b). The need for cold stratification or prechilling can be variable among seed lots within species of alder (e.g. *A. rubra*; Young and Young 1992).

Three experiments were conducted to examine the effect of gibberellic acid (GA_3) concentration and incubation length on the germination of dried alder seed. Seed used in the first experiment was from the Rio Costilla watershed in north-central New Mexico. Thinleaf alder was the only species tested in the first experiment. Seed of both thinleaf alder and Arizona alder from the Gila National Forest in southern New Mexico was used in the second and third experiments. The first experiment examined the effect of GA_3 concentration. Seven levels of GA_3 were evaluated: 0, 31, 62, 125, 250, 500, and 1000 ppm. Seed batches of 100 seeds were placed into flasks containing 25 ml of the GA_3 solution and allowed to incubate for 44 hours. Flasks were placed on a shaker table to provide constant agitation. Following GA_3 treatment, seed was rinsed with distilled water and sown into [288-cell square deep-plug] trays filled with Sunshine #1 Mix and placed in the greenhouse (21°C days and 13°C nights). The entire study was replicated three times.

The second experiment differed in the seed sources evaluated and the incubation technique. Specimen tubes (75 ml) were filled with 25 ml aliquots of the respective GA_3 solutions and aerated using a porous aquarium stone connected with tubing to an aquarium pump. Following a 36 hour GA_3 incubation, seed was handled as described above. The entire study was replicated three times.

Incubation duration at lower concentrations of GA_3 was examined in the third experiment. Seed batches were incubated at 0, 125, 250, or 500 ppm GA_3 for 12, 24, or 36 hours. The incubation apparatus and seeding method was as described in the second experiment. The entire study was replicated three times.

Thinleaf alder seed from the Rio Costilla source required some level of GA_3 incubation for germination. Both germination speed and total germination was enhanced by GA_3 incubation (Figure 3). Germination speed increased with increasing GA_3 concentration, however total

germination after 28 days was not improved by increasing concentration above 62 ppm GA_3. Both alder species from the Gila National Forest were able to germinate with no GA_3 treatment and only in thinleaf alder did GA_3 incubation improve germination after 28 days (Figure 4). Improvement in germination was slight going from 15% for control seed to 21% for the three highest GA_3 concentrations. The effect of GA_3 incubation duration and concentration was different for the two species. In Arizona alder, response to GA_3 was variable across concentration and duration, especially in the two intermediate concentrations of GA_3 125 and 250 ppm (Figure 5). In thinleaf alder all treatments improved germination relative to controls. At the longest duration, 36 hours, 125 ppm GA_3 was sufficient to achieve maximum germination while at the shortest duration, 12 hours, germination continued to improve as concentration increased (Figure 6).

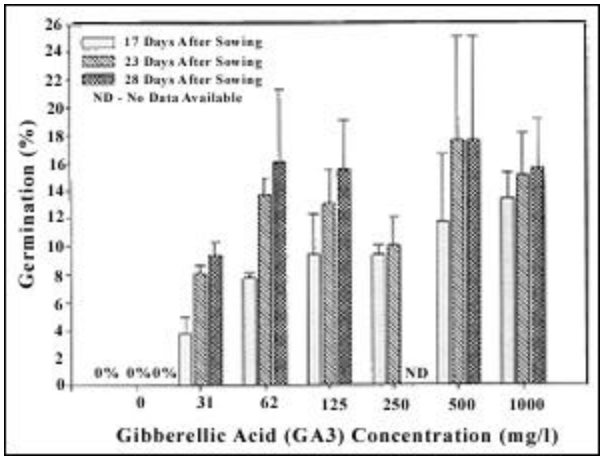

Figure 3. Germination percentages (± standard error) for *Alnus tenuifolia* seed soaked in gibberellic acid (GA_3) solutions of 0, 31, 62, 125, 250, 500 and 1000 mg/l

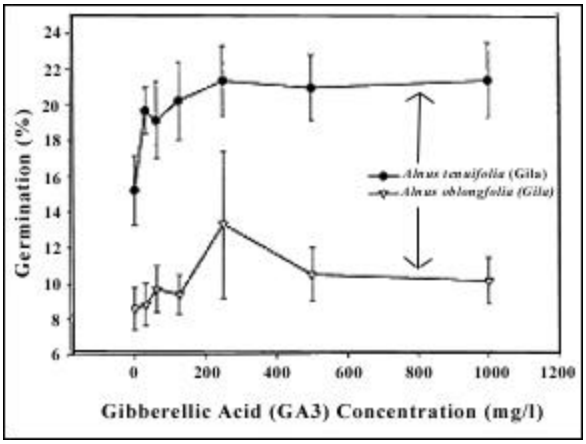

Figure 4. Germination (± standard error) after 28 days for *Alnus tenuifolia* and *A. oblongifolia* following 36 hour gibberellic acid (GA_3) incubation

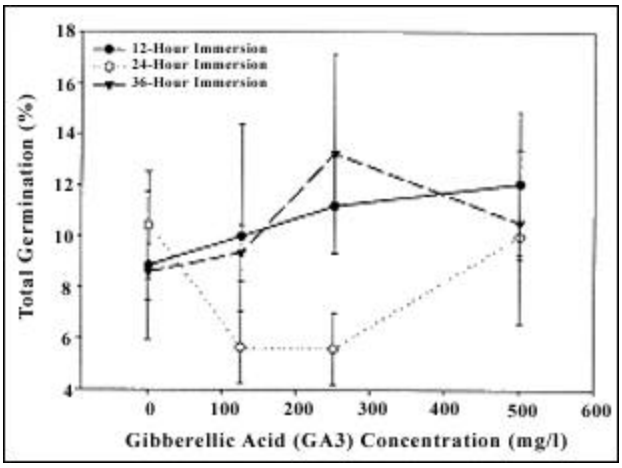

Figure 5. Influence of gibberellic acid (GA_3) soak concentration and duration on the germination (± standard error) of Arizona Alder (*Alnus oblongifolia*)

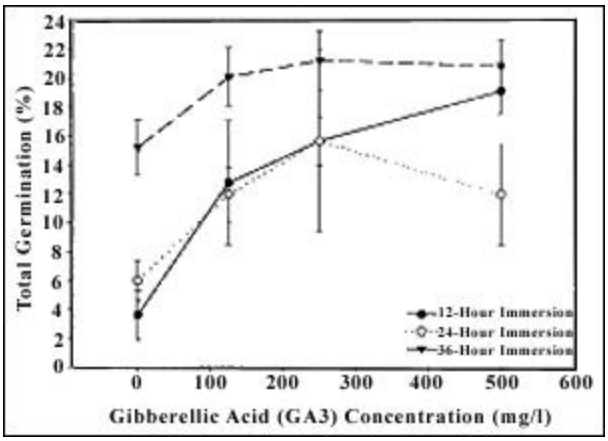

Figure 6. Influence of gibberellic acid (GA_3) soak concentration and duration on the germination (± standard error) of *Alnus Tenuifolia*

While these results are preliminary, it would appear there are strong species and source differences in response to GA_3 pretreatments in southwestern alders. At the highest concentrations evaluated, 500 and 1000 ppm GA_3 some seedlings became etiolated. Poor overall germination capacity of alder seed points to a need for seed refinement procedures. The winged pericarp on alder seed reduces the efficacy of density separations using airflow seed separators. Preliminary work with thinleaf alder seed indicates tumble scarification (see *Psorothamnus* section for details) effectively removes the wing which should allow better seed refinement. We have yet to show whether this seed classification will result in increased germination capacity.

Rubus strigosus

The ability of wild raspberry (*Rubus strigosus*) to colonize disturbed sites and form thickets via root sprouts make it a likely candidate for disturbed land revegetation efforts. Standard vegetative propagation procedures have been developed for production of commercial raspberry cultivars and could be used to produce cloned plant materials. However, to maintain some degree of genetic diversity and possibly reduce cost of production, emphasis should be placed on seed propagation. Treatment with a bleach solution (1 % sodium hypochlorite) has been reported to enhance *Rubus* germination (Brinkmann 1974b, Rose et al. 1996). To examine the suitability of this technique on *Rubus strigosus*, fruits were collected from the Molycorp mine site in north-central New Mexico in early October and immediately depulped by fermentation for 2 weeks. Seed was then air dried and classified by density using an airflow seed separator. Only the heaviest seed, (average seed mass of 1.8 mg), was used in this experiment. Five durations (4, 8, 24, 48, 96 hours), of soaking in 1% bleach solution were evaluated along with a control consisting of a 48 hour soak in distilled water. In addition, four bleach/GA_3 treatments were used. These treatments consisted of. water soak (control), then 250 mg/l GA_3 for 72 hours; 48 hour bleach incubation followed by a 72 hour, 250 ppm GA 3 incubation; 48 hour bleach incubation followed by a 72 hour, 1000 ppm GA_3 incubation; and, 96 hour bleach incubation followed by a 24 hour, 1000 ppm GA_3 incubation. Following all bleach and GA_3 treatments, seed batches were rinsed thoroughly. Treated seed was sown in [288-cell square deep-plug] trays with Sunshine #1 Mix. Trays were then cold stratified (4^{o}C) until first emergence was observed: 20 weeks for the GA_3 treated seed and 23 weeks for the remaining treatments. Trays were then placed in the greenhouse (23^{o}C days and 13^{o}C nights) to monitor germination. Bleach treatments were replicated four times while the GA_3 treatments were replicated six times.

Bleach treatments between 4 and 48 hours duration showed 2 to 3 times greater germination than the control and 96 hour treatments (Figure 7). Translucent seed coats were observed in a few seed in the 24-hour bleach incubation, for many seed in the 48-hour bleach incubation, and for all seed in the 96-hour incubation. The 96 hour bleach incubation resulted in slightly less than 10% of the seed beginning to disintegrate. Addition of a gibberellic acid incubation improved germination of both the 48 and 96 hour bleach treatments. On the basis of this limited study with one seed source, a 48 hour, I% sodium bleach treatment followed by a 72 hour, 250 ppm GA^3 incubation yielded the greatest improvement in germination percentage (73% versus the control at 17%).

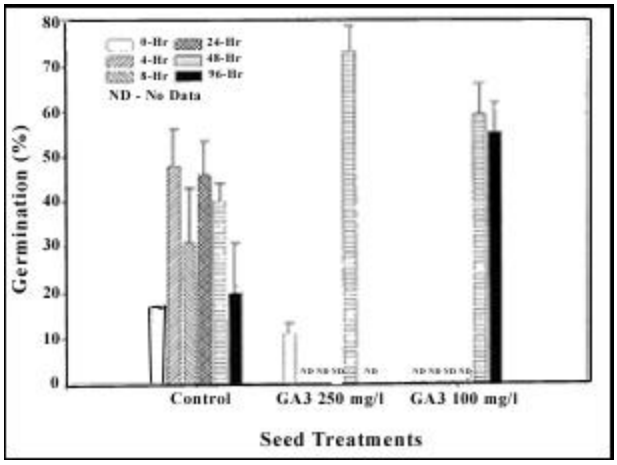

Figure 7. Effect of sodium hypochlorite (1%) treatment duration and subsequent gibberellic acid (GA_3) immersion on the germination (± standard error) of *Rubus Strigosus*

Coleogyne ramosissima

Blackbrush (*Coleogyne ramosissima*) is a dominant shrub in many plant communities occurring in the transition between Mojavean and Sagebrush Deserts (Benson and Darrow 198 1). Published literature indicates a prechilling (i.e., cold stratification) treatment is required for *Coleogyne* (Young and Young 1992). In initial trials, seed harvested from Glen Canyon National Recreation Area had 56% germination with no seed treatment but 83% with 7 weeks of cold stratification. A second study was conducted to examine other seed treatments in combination with cold stratification. Seed used in this study was 5-year-old seed from Canyonlands National Park. Four seed treatments were examined. These treatments included a 24-hour soak in 250 ppm GA^3 a 24-hour soak in de-ionized water, a 24-hour tumble scarification (see *Psorothamnus* section for details), and a untreated control. All treated seed was rinsed thoroughly with distilled water. All treatments were then subdivided into groups receiving seven weeks of cold stratification and groups receiving no cold stratification. Seed was sown in [288-cell deep-plug] trays containing Sunshine #1 Mix. Trays with seed receiving cold stratification were placed in plastic bags with aeration holes and placed in walk-in coolers (4^oC); after seven weeks, they were removed from the cooler, taken out of the bags and placed in the greenhouse (21^oC days and 13^oC nights). Trays with non-stratified seed were immediately placed in the greenhouse (21^oC day, 13^oC night). The study was replicated three times.

Unlike the seed from the Glen Canyon National Recreation Area where seven weeks of stratification improved germination, blackbrush seed from the Canyonlands National Park did not respond to cold stratification. Cold stratification did not improve germination in any treatments with the exception of the tumble scarification treatment where germination was improved from 25% to 40% with cold stratification (Figure 8). However, untreated and unstratified control seed had a germination rate of 46%. Significant source and age differences are apparent in regard to germination improvement or requirement resulting from stratification of blackbrush.

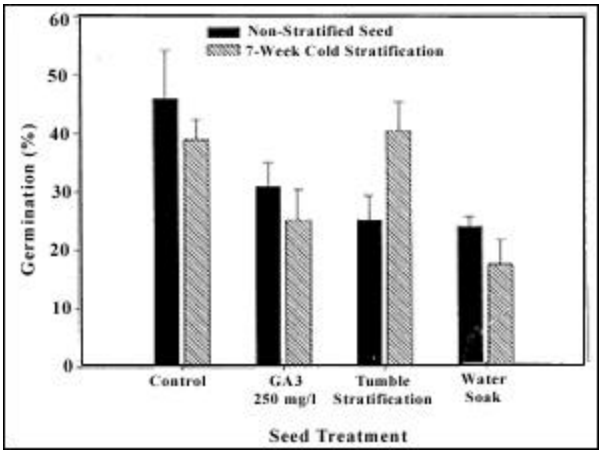

Figure 8. Effect of seed treatments on the germination (± standard error) of *Coleogyne ramosissima*

Combination of Scarification/Stratification

Oryzopsis hymenoides

Indian ricegrass (*Oryzopsis hymenoides*) is an important reclamation grass on disturbed lands with sandy or rocky soils in the west and is being used increasingly as a xeriscape ornamental. Previous work has shown this species has recalcitrant seed. Studies by Khan (1997) indicate both seed coat and embryo dormancy exist in this species. Based on positive responses to tumble scarification and GA_3 treatments with other species, these methods were applied to attempt to enhance the germination of *0. hymenoides* >Nezpar[1].

Seed used in this experiment was from a commercial source. A factorial combination of tumble scarification of 0, 2, 5, and 7days and GA_3 incubations (0 or 1000 ppm for 24 hours) were examined.

Following treatment, seed batches were rinsed thoroughly and sown into [288-cell square deep-plug] trays containing Sunshine #1 Mix. Trays were then placed into the greenhouse (23°C day and 13°C night) and monitored for 28 days. The study was replicated 5 times.

Total germination improved with increasing duration of tumble scarification (Figure 9). This response was more pronounced in the GA_3 treated seed. These results indicate increasing the duration of tumble scarification causes a reduction in seed coat dormancy. Gibberellic acid treatment appears to overcome embryo dormancy (endo-dormancy).

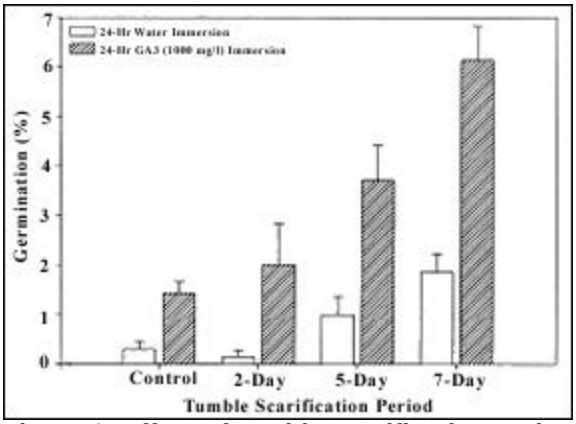

Figure 9. Effect of tumble scarification and subsequent immersion in gibberellic acid (GA_3) on the germination (± standard error) of *Oryzopsis hymenoides*

Rhus spp. and *Ceanothus* spp.
Seed lots (2 to 3 g), from commercial sources, of *Ceanothus integerrimus*, *C. sanguineus*, and *Rhus glabra* were immersed in 90°C water or 25°C water for 22 hours. Treated seed were sown in [288-cell square deep-plug] trays with Sunshine #1 Mix and cold stratified for 12 weeks. Following cold stratification treatment the trays were placed into a greenhouse (23°C day, 15°C night). Germination was monitored for 24 days. Seed treated with the hot water had elevated germination relative to the seed soaked in room temperature water. Germination of hot water incubated seed versus the seed incubated at room temperature was: *C integerrimus*, (73% vs. 3%) *C. sanguineus*, (66% vs. 7%) and *Rhus glabra* (29% vs. 1%). This enhanced germination by hot water treatments prior to cold stratification has been reported in these genera previously (Brinkman 1974a, Reed 1974).

Ptelea trifoliata
Common hop-tree (*Ptelea trifoliata*) is widely distributed with many varieties or subspecies found throughout the U.S. (Vines 1960). Seed used in this experiment was collected in 1992 and 1994 from the Cibola National Forest in canyon bottoms within the ponderosa pine zone. After rubbing to remove the winged pericarp, the seed was separated into 3 morphological classes: small (<13 mm length), large (>13 mm length), and triangular cross section. The seed was also classified as to color: light green throughout (Green), some light green sections along with tan or brown (Mix), and tan or brown throughout (Brown). This classification generated six seed categories as there were no seed in the large brown, small green or triangular mixed categories. To improve germination, the proximal end (i.e., attachment end) was cut using a scalpel until the void in the seed cavity was exposed. This proximal end cut was performed on half of the seeds in each seed lot. Treated and untreated (control) seed was sown into 288-cell flats containing Sunshine #1 mix and cold stratified for 18 weeks at 4°C. This experiment was only conducted once.

Cutting the proximal end resulted in increased germination for all but the triangular brown seed class. Untreated seed in the triangular brown class had the highest germination rate (16%) of all the control seed classifications and was comparable to the germination rate of all but the large green and triangular green treated seed classes (Figure 10). The greatest germination observed was for the treated large green seed which had 50% germination.

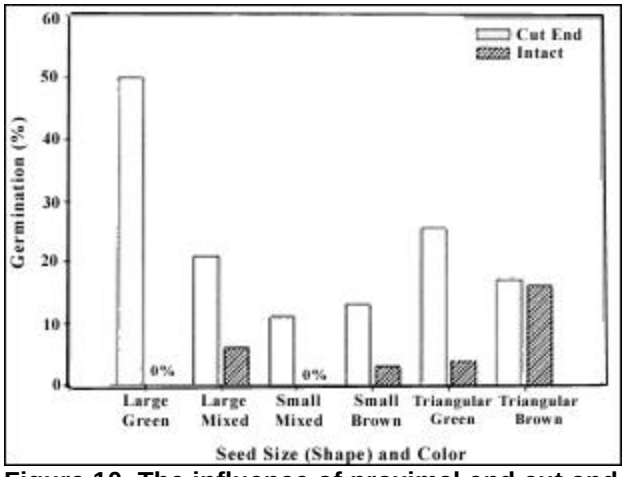

Figure 10. The influence of proximal end cut and seed size, shape, and color on the germination of *Ptelea trifoliata*

The results indicate the potential for screening seed based on color, size and shape. The recommended procedure based on these results would be using large green seed and cutting the proximal end prior to an 18 week cold stratification treatment.

Vegetative Propagation

Mound Layering of *Platanus wrightii*

Arizona sycamore (*Platanus wrightii*) is an important component of riparian ecosystems at mid-elevations in southwestern New Mexico and southeastern Arizona. As riparian restoration projects in these areas become more common, the demand for large containerized materials will likely expand. Although Arizona sycamore can be grown from seed, a more rapid production method for larger plant material is desirable. In addition, vegetative propagation could be used to preserve clones with desirable traits and when viable seed is not available.

Mound layering techniques are sometimes used to produce rooted cuttings of species not easily amenable to more traditional cutting propagation methods. Through trial and error, a methodology has been developed to produce large rooted whips of Arizona sycamore that could be used for production of large containerized stock or possibly as bare root planting material.

To develop stock plants, seedlings of a Gila River ecotype in 1-gallon tree pots were planted in 1993 into sandy loam soil. Stock plants were heavily fertilized in May of each year. Surface soil was amended with sulfur on an annual basis to prevent chlorosis; alkalinity of irrigation water was approximately 150 mg/L as $CaCO_3$ with a pH of 8.0. During establishment, the stock plants were flood irrigated on a weekly basis during the growing season.

Dormant stems layered during the previous year were harvested just above the soil surface (2 to 5 cm) in early spring (March). Any residual media from the previous years mound was removed to allow new stems to easily emerge from the crown of the stock plants. By late May, new stems were approximately 0.5 meter high and the mounding process was initiated. One of three soilless media were used: a pumice, peat, and bark mix; a commercial peat and perlite mix; or, pumice alone. To reduce cost, a technique to minimize the amount of media required for mounding was employed. Inverted bottomless nursery containers were used to contain the mound. For smaller stock plants (fewer than 5 stems), a bottomless 5-gallon egg can was used; whereas, for large stock plants (from 5 to 15 stems) a container equivalent to a bottomless squat 20-gallon nursery can was used. The bottomless container was placed over the stems and filled with medium. No attempt was made to remove any leaves from the stems before filling the container. Mounds were fertilized during June with 50 (small mounds) to 100 grams (large mounds) of 17-6-12 controlled release fertilizer (SierraR 3-4 month plus minors).

A Roberts Mini-flow Spot-SpitterR was inserted into the top of the mounded medium to wet most of the mound surface (large stock plants required several Spot-Spitters). Mounds were irrigated daily during the growing season. Mounds were irrigated every 2 weeks in the winter if no precipitation had occurred. During winter months, all side shoots were pruned to ease harvest and reduce the potential leaf area of the propagule. Stems were in the mound layering system for a total of 9 to 10 months. In early spring (March), mounds were disassembled by removing the bottomless container and as much medium as possible by hand. Stems were

severed 2 to 5 cm above the soil surface with loppers or pruning saw. Large stems were planted into 5-gallon containers coated with copper hydroxide paint (SpinOutR) and small stems (< 1.5 cm) into one-gallon tree pots.

Average number of large stems (caliper >1.5 cm) produced by 3 year old stock plants was 4 per plant in 1997. Several stock plants produced more than 10 large stems while others produced only one. Out of 73 large stems produced, 34% exhibited good to excellent rooting, 27% had poor to fair root development, and 39% were etiolated with few or no fine roots.

Large stem transplants with some root development had 100% survival when evaluated three months after transplanting. Etiolated large stems had 73% survival. Vigor of the large transplants (both rooted and etiolated) 3 months after transplanting was as follows: 74% with good to excellent vigor, 18% with poor to fair vigor, and 8% dead.

Transplanted stems exhibited slow growth until the root system was well developed. Spring application of sulfur and controlled release fertilizer were used. Each 5-gallon container was placed in a pot-in-pot system with copper-coated fabric (Tex-R7InsertR) between the two pots to limit roots from growing through the bottom pot into the soil. A Spot-Spitter inserted into each pot provided daily micro-irrigation of the newly transplanted stems; after the root system was well developed, the large leaf area necessitated daily watering. The 5-gallon transplants were ready for field planting approximately 10 months after potting.

Some preliminary work has been done with mound layering of other riparian woody species. Positive results have been obtained with Arizona alder, desert willow (*Chilopsis linearis*), false indigo bush, and three leaf sumac (*Rhus trilobata*). Stock plants of Arizona alder, thin leaf alder, and water birch (*Betula occidentalis*) are presently being grown to test mound layering of these species.

Novel Species for Understory Pole Plantings

Successful establishment of cottonwoods (*Populus* spp.) and willows (*Salix* spp.) using pole plantings is becoming an accepted restoration technique for disturbed riparian areas. This success has engendered interest in determining whether other woody riparian species could be planted as dormant pole cuttings. Use of long dormant cuttings (i.e., whips and poles) allows planting in deep holes reaching into the capillary fringe above the water table. Numerous successful pole plantings have resulted in many land managers adopting this technique for riparian restoration where the lack of persistent near surface soil moisture would limit survival of containerized stock or seeded materials.

Studies were required to determine whether other woody riparian shrub and tree species were amenable to pole planting technology. These investigations were started in 1994 by evaluating the survival of dominant hardwood cuttings planted into a flood irrigated agricultural field situation. A cutting's ability to survive and grow should be a good indicator of successful establishment by pole planting in riparian areas. Appreciable survival and growth was obtained with cuttings of New Mexico olive (*Forestiera neomexicana*), seepwillow (*Baccharis glutinosa*), one ecotype of desert willow, and one ecotype of false indigo bush. Little success was achieved with cuttings of three leaf sumac, Arizona sycamore,

and one ecotype of desert willow and false indigo bush.

Limited plantings with these species have been performed in riparian areas to date. Preliminary results are promising for New Mexico olive, seepwillow, and false indigo bush. More extensive field-testing is required to validate these results and examine variability among ecotypes within species.

Propagation of *Populus tremuloides* from Root Cuttings

Vegetative propagation of quaking aspen (*Populus tremuloides*) using root cuttings is a traditional horticultural practice. More recent developments have used root cuttings to produce suckers, which are rooted as conventional softwood stem cuttings (Schier 1978). Our objective was to determine the efficacy of direct sticking root cuttings into 164 ml containers (Super Cell Cone-tainer). Cutting length and diameter were recorded before planting in order to relate root cutting dimensions and volume with survival and vigor of the resulting plant. Aspen stock plants were grown in 5-gallon containers using a pot-in-pot system. The stock plants were derived from 6 clones growing on the Molycorp mine site (Questa, NM). Root cuttings were taken from the periphery of the root ball in March. Average number of cuttings produced per stock plant was 9 large (> 6 mm diameter), 8 medium (4 to 6 mm), and 8 small (2 to 4 mm). Cutting diameter ranged from 2 to 13 mm and length ranged from 3 to 14 cm. Cuttings were immersed in a Captan suspension and stored at 4^{o}C in damp peat moss until May when the cuttings were planted in a Sunshine #1 - perlite mix (2: 1). Cuttings were inserted vertically with proper polarity into dibbled holes until the top of the cutting was just below the media surface.

Rooting success after eight weeks ranged from 42% to 91 % (Table 2). In most instances, clones with higher rooting percentages had higher proportions of more vigorous plants. Data relating cutting size attributes to rooting and subsequent vigor have not been analyzed yet. These relationships will indicate the size of the smallest cutting which can be used and still obtain acceptable survival percentages and vigor.

Table 2. Survival and vigor class percentages of Populus tremuloides propagated by root cuttings.

Clone	Percentage in Vigor Class				
	Excellent	Good	Fair	Poor	Percentage Alive
1	23	14	10	9	56
3	19	21	21	17	78
4	51	19	9	12	91
5	11	15	5	11	42
6	42	25	6	5	78
7	26	20	7	19	72

IMPLICATIONS

As forestation projects continue to change from traditional reforestation to remediation of disturbed lands, nurseries will need to develop strategies for producing these difficult to propagate species. These studies and others indicate the need for more work to be done on the propagation of many of these plants. Emphasis will need to be placed on ecotypical variation, seed refinement, and the exploration of new seed and vegetative propagation techniques. The nature and size of these new planting (forestation) efforts will likely preclude the intensive efforts and expenditures which have optimized production of traditional timber species such as ponderosa pine, loblolly pine or douglas-fir. Rather the species required for restoration will be site specific and used in relatively small areas.

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