VEGETATIVE PROPAGATION OF ASPEN, NARROWLEAF COTTONWOOD, AND RIPARIAN TREES AND SHRUBS[1]

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ABSTRACT—Vegetative propagation of planting stock for revegetation projects may be required if unique genotypes are desired, viable seed is unavailable, or unconventional establishment methods are used. Aspen (*Populus tremuloides*) propagation studies using root cuttings from pot-in-pot stock plants showed appreciable growth and survival differences among clones and among stock plants of the same clone. Long root cuttings (10 cm) had generally superior survival and growth. Small caliper root cuttings (3-4 mm) were not detrimental to survival and growth and for some clones are preferable. The effect of source plant physiology, timing of collection, post cutting treatments, and rooting environment on the rooting and growth of *Populus angustifolia* cuttings was evaluated. Stock plant vigor exhibited the greatest influence on rooting and growth. Timing of collections contributed to rooting success but had only a marginal effect on shoot growth. Incorporation of controlled release fertilizer had significantly improved growth, but had no effect on rooting. Geographical location had a significant effect on the rooting and growth of cuttings. The success of riparian forest regeneration using large dormant cuttings of willows and cottonwoods as planting stock ("pole planting") is dependent on cutting characteristics, cutting handling, planting site characteristics, and post-planting care. Preliminary studies investigating pole planting of woody riparian species outside the Salicaceae family have shown some success with seepwillow (*Baccharis* sp.), false indigo (*Amorpha fruticosa*), and New Mexico olive (*Forestiera neomexicana*).

INTRODUCTION

The restoration of lands disturbed by the extraction of mineral resources or by the poor management of sustainable natural resources often involves the re-establishment of woody species. The use of seed or vegetative propagules from local sources is preferable to maintain genotypes that evolved by natural selection pressures at the site. Vegetative propagation of these plant materials is often required because seed of the local ecotypes is not available. In other instances, vegetative propagation provides stock types with characteristics advantageous to establishment on certain planting sites.

Our revegetation research at a high elevation mine in north-central New Mexico has concentrated on two deciduous tree species, aspen (*Populus tremuloides*) and narrowleaf cottonwood (*Populus angustifolia*), in addition to the dominant conifers at the mine site (e.g., *Pinus ponderosa, Pinus flexilis, Pseudotsuga menziesii,* and *Abies concolor*). Both of these deciduous species have naturally invaded mine overburden piles to a greater extent than any other tree species probably because of the extent of wind dissemination of aspen and cottonwood seed. A number of studies have been conducted to determine the most important factors influencing the propagation of aspen from stock plant root cuttings and the propagation of narrowleaf cottonwood from hardwood cuttings. The ultimate goal is to develop cost effective propagation methods for these mine site ecotypes to enable large-scale revegetation.

In addition to high elevation mined land revegetation, we have been investigating restoration of riparian areas perturbed by the lack of natural flood events or disturbed by excessive browsing pressure by both domestic and wild ungulates. A revegetation technology relying on vegetative propagation has been developed to reestablish woody riparian species using large dormant cuttings ("poles") up to 5 m in length. This technology has been used for many decades but large-scale plantings in the past decade have provided information which enables successful re-establishment of cottonwood and willow species on some sites where they can no longer naturally regenerate. Applications of this technique to woody species outside the Salicaceae family are also described.

PROPAGATION OF ASPEN FROM ROOT CUTTINGS

Preface

Although aspen has invaded many sites on the mine overburden piles, we have been unable to find seed-bearing clones in the vicinity of the mine. Therefore, we had to resort to vegetative propagation from root cuttings, a procedure with a long history in forestry literature (Hall and others 1990, Starr 1971). For this propagation methodology to be employed on a large-scale, a number of considerations would have to be investigated. Stock plants would have to be grown in a nursery because the native stands could not provide sufficient root cuttings and these stands are inaccessible during the winter months. The size of root cutting (caliper and length) with superior performance would dictate the number of propagules that could be obtained from each stock plant. The influence of clonal genotype on the survival and growth rate would determine the cost effectiveness of propagating each clone. Another production complication would be introduced if different stock plants of the same clone yielded root cuttings with different survival or growth rates.

Methods

Root cuttings were collected from aspen clones growing in natural stands adjacent to overburden piles; the elevation of these stands ranged from 2400 to 2900 m. Several stands were adjacent to each other (Clones No. 1 and 4; Clones

[1]Dreesen, D.R.; Harrington, J.T. 1999. *Vegetative propagation of aspen, narrowleaf cottonwood, and riparian trees and shrubs.* In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 129-137.
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No. 3, 5 and 7) and could be the same clone; only root cuttings from Clones No. 3 and No. 7 had similar survival and growth. The individual plants obtained from these cuttings were transplanted from flats to 1.3 liter tree bands (81 cubic inch) and finally to 13.7 liter nursery cans (5 gallon egg cans) over one year. These stock plants were grown for an additional growing season in a pot-in-pot system buried in the ground to moderate media temperature. The first experiment was initiated 2.5 years after initial cutting collection; cuttings were collected from each stock plant between March 20 and 26, 1997. The cuttings were harvested within 2 cm of the periphery of the root ball; from 22 to 36 cuttings were harvested from each pot. Each cutting was harvested so that the distal end had a slant cut and the proximal end had a perpendicular cut. The root cuttings were soaked in a Captan suspension (1:125 volumetric ratio, i.e., 2 tbs/gal) immediately after harvesting. The root cuttings were removed from the suspension after 15 to 30 minutes and placed in polyethylene bags containing moist spaghnum peat moss. The bags were stored at 4°C for six weeks before planting. On May 7, 1997, the cuttings were stuck vertically in 160 ml Super Cell Conetainers containing media (2 parts Sunshine #1 pent mix to 1 part perlite). Before sticking, the length and caliper of each cutting was recorded. The cuttings were inserted into dibbled holes until the proximal end was just below the media surface. Eight weeks after sticking, the length and number of shoots and branches were determined. Second experiment was commenced on March 2, 1998 when cuttings were harvested from the same group of stock plants. In this experiment, the cuttings were harvested from most of the root ball, not just the periphery, as in the first experiment. Cuttings from 3 stock plants of each clone were kept separate to investigate stock plant effects. One set of cuttings was measured and stuck immediately. The remaining cuttings were immersed in a Captan suspension and stored for 12 weeks in moist spaghnum peat moss at 4°C. Significant temperature deviations occurred during storage as a result of refrigeration malfunction. Before sticking, the cuttings from each stock plant were grouped into sets of 4 having similar caliper and length. One cutting of each set was immersed for 15 minutes in one of the following treatments: tap water, Cleary 3336 (thiophanate methyl) at 1:250 vol., Captan at 1:125 vol., and Banrot (thiophanate methyl, ethazol) at 1:250 vol. Cuttings were measured and stuck as in the first experiment.

Table 1—Mean caliper, mean length, mean calculated volume, number of root cuttings, and number of stock plants for 6 *Populus tremuloides* clones.

Clone	Mean	Mean	Mean	Cuttings	Stock plants
	mm	cm	cm³	No.	No.
1	5.4 (2.3)	8.4 (2.0)	8.4 (2.0)	432	21
3	5.2 (1.7)	7.9 (2.1)	7.9 (2.1)	231	9
4	5.4 (1.8)	8.3 (1.7)	8.3 (1.7)	170	6
5	5.1 (1.5)	8.3 (1.7)	8.3 (1.7)	88	3
6	5.1 (1.2)	8.9 (1.4)	8.9 (1.4)	109	3
7	4.5 (1.2)	8.9 (1.5)	8.9 (1.5)	101	3
Mean	5.1 (1.6)	8.5 (1.7)	8.5 (1.7)		

Standard errors presented in parentheses.

Results

The mean caliper, length, calculated cylindrical volume, number of cuttings, and number of stock plants are presented in table 1 for the 6 aspen clones. The mean calipers ranged from 4.5 to 5.4 mm, the mean lengths ranged from 7.9 to 8.9 cm, and the volumes ranged from 1.5 to 2.1 cm^3. The percentages of ramets present in 6 vigor classes are given in table 2 for each clone. Two clones (No. 4 and No. 6) showed high survival and growth with 63 to 73 percent of the ramets having good vigor (>8 cm total shoot and branch length 8 weeks after planting). An intermediate group (No. 7 and No. 3) had 39 to 42 percent with good vigor. A low survival group (Clones No. 1 and No. 5) had 41 to 52 percent mortality (including those which died soon after shoot emergence) versus 6 to 23 percent for the other 4 clones.

Total stem and branch length was correlated with root cutting caliper, length, calculated volume, and length:caliper ratio to determine which root cutting characteristics were related to ramet growth. The correlation coefficients and significance levels are presented in table 3. The limited number of cuttings available for 3 clones (No. 5, No. 6, and No. 7) resulted in no significant correlations. However, trends indicate that growth was negatively correlated with caliper (3 out of 6 clones), positively correlated with length (5 out of 6 clones), and positively correlated with length:caliper ratio (4 out of 6 clones). The poorest performing clone, No. 5, had correlation trends which were the opposite of the majority of the other clones. The overall correlation trends suggested an analysis to investigate the performance of large caliper short cuttings versus small caliper long cuttings. Therefore, the root cutting data was divided into four groups each representing one of the 4 permutations of caliper (large, small) and length (short, long) classes. The mean cutting dimensions of the 4 groups are presented in table 4 along with the group mean stem length (based on live plants only) and group survival. The mean of caliper-length classes for all clones are as follows: small-long 3.8 mm and 10.3 cm; large-long 6.2 mm and 9.3 cm; small-short 3.9 mm and 7.7 cm; and, large-short 6.5 mm and 6.7 cm. The small-long root cuttings provided appreciably greater growth for Clones No. 4 and No. 7. The large-short root cuttings yielded substantially less growth for Clones No. 3, No. 4, and No. 6. The large-long root cuttings provided superior growth in the poorest growing clone, No. 5. The mean growth of all clones shows an overall trend with small-long cuttings having the best growth and thick-short cuttings having the poorest growth. The overall survival trend for all clones indicates that the longer cuttings were superior; this trend was most evident for Clones No. 3 and No. 7. The lowest survival was found in the small-short cuttings of Clone No. 5 and the large-short cuttings of Clone No. 1.

Table 2—Percentages of *Populus tremuloides* ramets in vigor classes based on total shoot and branch length evaluated 8 weeks after sticking

Clone	Total Shoot and Branch Length Class				Shoots emerged then died	No shoot emergence
	>22cm	9 to 22 cm	4 to 8 cm	<4		
1	15	18	12	14	05	36
3	13	26	22	19	04	16
4	54	19	16	05	02	04
5	07	13	14	16	05	47
6	44	19	10	07	03	18
7	15	27	20	16	10	13

The root cuttings stuck immediately after harvest in early March 1998, exhibited universal delayed shoot emergence and substantial mortality soon after emergence. This set of cuttings was not investigated further because of these anomalies. These results suggested that the cuttings might not have received a sufficiently long cold period to overcome dormancy. The high mortality suggested possible pathogen presence; therefore, pre-planting fungicide soaks were investigated in the next phase of the experiment.

The root cuttings in the second phase of the second experiment had severely depressed survival versus the first experiment. These cuttings had received a Captan soak at harvest, were cold stored for 12 weeks, and then treated with fungicide or water at sticking. If the control treatment (water) of the second experiment (see table 5) is compared with the results of the first experiment, the survival percentages are depressed from 40 to 48 percent except for Clone 6 (24 percent depression). These results suggest that the refrigeration problems resulting in cold storage temperatures reaching approximately 10° C for long periods had a substantial deleterious effect on survival. Banrot had a definite negative influence on both survival and growth (see table 5) compared with the control and other fungicide treatments. The growth depression with Banrot is at least partially a result of the large delay in emergence for those few cuttings which were viable; the first shoot emergence from the Banrot treatments was noted 4 weeks after the other treatments. For Clones No. 1 and No. 7, the control and Cleary 3336 treatment had significantly higher survival than the Captan treatment. For the other clones, the control, Cleary 3336, and Captan treatments did not have significantly different survival percentages. Large variances among ramets from different stock plants resulted in no significant growth differences among clones. These large variances were also apparent in the survival results and indicate a substantial stock plant effect. The superior clones in the second experiment (No. 3, No. 4, and No. 6) had smaller mean coefficients of variation for survival and growth data (0.19 to 0.41) than the inferior clones with coefficients of variation of 0.52 to 1.18. Therefore, differences between stock plants are more apparent among poorer performing clones.

Table 3—Correlation coefficients of total stem and branch length of Populus tremuloides ramets with root cutting caliper, length, calculated volume, and length:caliper ratio.

Clone	Caliper	Length	Volume	Length: caliper ratio
1	-.13**	0.20***	-0.07	0.17***
3	-0.04	0.27***	0.09	0.17*
4	-0.24**	0.23**	-0.16*	0.28***
5	0.12	-0.09	0.14	-0.19
6	-0.03	0.14	0.03	0.07
7	-0.15	0.15	-0.12	0.18

Significance at P<0.05, P<0.01, and P<0.001 noted with *, **, or ***, respectively.

Conclusions

Clonal and stock plant differences can have appreciable effect on the survival and growth of aspen root cuttings. A Captan soak after harvest and before cold storage appears to be sufficient pathogen protection. Long cuttings averaging 10 cm in length are preferable. Cutting caliper as small as 3 to 4 mm is not detrimental and in some cases may be beneficial. Pot-in-pot systems for aspen stock plants appear feasible; small stock plants (5 gallon) can provide about 20 to 30 cuttings from the outer portion of the root ball at an early age. Annual root cutting harvest from the periphery of the root ball grown in large pot-in-pot systems (15 gallon) is currently under investigation.

Table 4—Root cutting length, root cutting caliper, ramet growth, and survival of *Populus tremuloides* clones classified into 4 classes (caliper-length). Mean stem length based on the number of live plants

Class	Clone 1	Clone 3	Clone 4	Clone 5	Clone 6	Clone 7	Mean
			Mean root cutting length (cm)				
Small-long	10.7	10.3	10.1	9.7	10.3	10.4	10.3
Large-long	9.2	8.6	8.9	9.3	9.6	9.9	9.3
Small-short	7.8	7.2	7.4	7.5	8.1	8.0	7.7
Large-short	6.1	5.7	6.6	6.6	7.6	7.5	6.7
			Mean root cutting caliper (mm)				
Small-long	3.6	3.8	4.0	3.9	4.2	3.5	3.8
Large-long	6.8	6.6	6.9	5.8	5.7	5.6	6.2
Small-short	3.9	3.9	3.8	4.1	4.1	3.6	3.9
Large-short	7.5	6.6	6.8	6.4	6.3	5.3	6.5
			Mean stem and branch length (cm)				
Small-long	15	14	32	6	25	19	18
Large-long	14	13	25	11	25	8	16
Small-short	13	11	21	7	21	10	14
Large-short	12	6	17	9	15	8	11
			Survival percentage (percent)				
Small-long	69	90	98	68	74	92	82
Large-long	59	95	93	59	89	100	83
Small-short	61	69	90	32	79	76	68
Large-short	46	71	93	55	81	81	71

Table 5—Percentage survival and total stem and branch length for *Populus tremuloides* root cuttings treated with water (control), Cleary 3336, Captan, or Banrot at sticking

Fungicide	Clone 1	Clone 3	Clone 4	Clone 5	Clone 6	Clone 7	Mean
			Survival percentage (percent)				
Control	19	36	52	2	55	29	32
Cleary	26	64	62	5	38	38	39
Captan	10	48	38	5	43	19	27
Banrot	0	10	2	0	12	12	6
			Mean shoot length (cm)				
Control	6.0	10.2	11.3	3.0	13.5	7.0	8.5
Cleary	7.5	10.5	8.5	2.3	8.8	6.5	7.3
Captan	4.1	6.0	12.3	8.5	13.7	5.8	7.6
Banrot	0.0	1.4	1.0	0.0	0.9	1.3	0.8

Table 6—Narrowleaf cottonwood ecotype locations and elevations

Ecotype	Elevation
	m
Capulin	2,990
Raspberry Ridge	3,000
Pinon Knob	2,830
Neutral	2,620
River	2,470

FACTORS INFLUENCING THE ROOTING AND GROWTH OF NARROWLEAF COTTONWOOD PROPAGATED FROM HARDWOOD CUTTINGS

Preface

Narrowleaf cottonwood (*Populus angustifolia*) commonly occurs at elevations of 1,520 m to 2,440 m in riparian areas of the Rocky Mountains (Elmore and Janish 1987). Narrowleaf cottonwood has been found in drastically disturbed upland mine sites and undisturbed upland sites at elevations up to 3,000 m (Harrington and Dreesen, personal observations). The ability to naturally colonize such sites indicates members of this species may be suitable for high elevation revegetation projects.

Many species in the genus *Populus* are considered easy to root from dormant hardwood cuttings. Traditionally, Populus species are propagated in outdoor nursery beds using 15 to 22.5 centimeter cuttings (Morin and Demeritt 1984). Under certain circumstances, primarily riparian plantings, cuttings or whips can be successfully used in lieu of rooted cuttings. However when using cottonwood in drier or upland plantings, superior survival and early growth are obtained when rooted cuttings are utilized (Phipps and others 1977). Little published work exists on the performance of bare-root rooted cuttings versus container grown rooted cuttings of cottonwood.

Published research on container production of narrowleaf cottonwood is sparse regarding the most basic information including media composition, fertility, timing of collections, and utility of exogenous auxin applications. Phipps and others (1977) report that for other species of *Populus*, a 3:1:1 ratio of peat:perlite:vermiculite is typically used. Previous work on other cottonwood species indicate a lighter, more porous media may be better (Harrington, unpublished data). Fertilizing is considered not necessary or effective prior to root initiation (Dirr and Heuser 1987). After root initiation, a well balanced fertilization regime is required to produce vigorous containerized plants. A common approach to fertilizing container plants in the southwest is to incorporate controlled release fertilizer into the growing media and supplementing with liquid based fertilizer applications after shoot growth begins (Harrington 1995). Rooting hormones are not commonly used in *Populus* propagation and in some cases have been inhibitory to root production (Phipps and others 1977).

Stock plant physiology and vigor, strongly impact rooting success and cutting growth (Dirr and Heuser 1987). In Populus, 3-10 year old stock plants produce the most vigorous cuttings and the highest rooting percentages (Phipps and others 1977). Frequently, nurseries establish stooling blocks of desirable clones to maximize stock plant vigor through irrigation, fertilization, and pest management. In some situations, establishment of stooling blocks is not feasible and post harvest treatment of cuttings must be employed to obtain satisfactory rooting and growth.

The objectives of this study were to evaluate the effects of timing of collection, auxin formulation and concentration, media density, incorporation of controlled release fertilizer and stock plant location (vigor) on the rooting response and shoot growth of narrowleaf cottonwood.

Methods

To examine the influence of several factors on rooting success of narrowleaf cottonwood stem (branch) cuttings and the subsequent shoot growth of rooted cuttings four factorial experiments were conducted. Factors examined were source, stock plant vigor, exogenous auxin formulation, exogenous auxin concentration, density of rooting media, fertility and collection date. The first three experiments were initiated in February 1996. The fourth experiment which examined timing of collection was performed during the following dormant period and was conducted from November 1996 through February 1997.

Stem cuttings used in these experiments originated from five distinct stands (sources) of narrowleaf cottonwood growing in the Red River canyon approximately five miles east of Questa, New Mexico. Stands were separated by no less than 1,000 meters with four stands in upland situations and the fifth stand adjacent to the Red River (table 6). Stem cuttings originally taken from these stands in 1992, were used to establish stooling blocks at the Plant Materials Center in Los Lunas, New Mexico in 1993. The stooling blocks were kept under a cultural regime to promote rapid growth. Source identification of the stooling block material was maintained to the stand level.

The stem cuttings used in these experiments were harvested from both the original stands at the mine as well as from the 3-year-old stooling block material. The source plants at the mine site ranged in age from 3 years to 15 years. When possible, branches were harvested from young trees or younger materials from older trees. Branches were transported to the nursery facilities at the Mora Research Center and stored at 2° to 4° C until utilized (less than two weeks). Individual branches were subdivided into stem cuttings immediately prior to use. Stem cutting length ranged from 10 cm to 15 cm and contained a minimum of three vegetative buds.

When used, rooting hormones included in this study were indole-3-butyric acid (IBA) and naphthalenacetic acid (NAA). Stock solutions of 1,000 ppm were prepared for each hormone and through dilutions the various treatment levels were obtained. A distilled, deionized water control was also used. Rooting hormone application was a 5 second dip into the appropriate treatment immediately followed by sticking the cuttings into 105 ml copper coated styroblock cells (Beaver Plastics LTD).

Media components for all facets of this study were mixed using a large paddle mortar mixer. The media formulations utilized for these experiments were either 1:1:1, 1:2:1, 1:1:2, 2:1:1 and 1:3:1 ratios of peat:perlite:vermiculite (v:v:v). Fertilizers, when incorporated into the media, were encapsulated controlled release (Osmocote 14:14:14; 3 month) and triple super phosphate at rates of 4 kg/m^3 and 600 g/m^3, respectively.

After treatment, stem cuttings were placed in a greenhouse on a propagation bench with bottom head which kept root zone temperature at 24°C. Greenhouse temperature were 20° – 22°C days and 16° – 18°C nights. Photoperiod was a 10 hour light 14 hour dark with the dark cycle interrupted twice at 5 and 10 hours with 30 minute light periods. Artificial light used to extend the ambient light period and provide light interruptions was supplied by 1,000 watt high pressure sodium vapor lamps suspended 3 meters above the stem cuttings.

Cuttings were misted 4 times daily until the majority of cuttings had significant bud break. Following bud break, cuttings were irrigated as necessary, increasing from once every 3 days at the beginning to once every day at week 20. Foliar applications of a 25 ppm nitrogen solution of Peter's Foliar Feed (27:15:12) were made following every second irrigation from week 4 through week 12. At week 13, fertilization was increased to applications of 100 ppm nitrogen of Peter's Conifer Grower (20:7:19) every other irrigation.

After 20 weeks, cuttings were destructively sampled to evaluate rooting success and shoot growth. Shoot growth was measured from the origin of the longest shoot to its growing apex. All successful rooted cuttings had well developed root systems so rooting success was simply a measure of presence or absence of roots.

In the first experiment, stock plant source, stock plant vigor and exogenous auxin formulation were evaluated in a factorial experiment. All five sources from both the native stand and the stooling blocks were evaluated. Auxin formulations examined were: 1) 250 ppm IBA; 2) 250 ppm NAA; 3) 125 ppm IBA + 125 ppm NAA; and, 4) 0 ppm control. The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

Table 7—Location and timing of narrowleaf cottonwood source material collections

Site	Collection date
Native Stand	11/13/1996, 12/11/1996, 01/04/1997
Los Lunas PMC	11/20/1996, 12/13/1996; 01/17/1997, 02/19/1997

In the second experiment, stock plant source, stock plant vigor, rooting media density and exogenous auxin concentration (dosage) were evaluated in a factorial experiment. All five sources from both the native stand and the stooling blocks were evaluated. Auxin concentrations evaluated were: 1) 500 ppm IBA; 2) 250 ppm IBA; 3) 125 ppm IBA; and 4) 0 ppm control. Media densities evaluated were: 1) 2:1:1; 2) 1:1:1; 3) 1:2:1; and, 4) 1:3:1 mixtures of peat:perlite:vermiculite (v:v:v). The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

In the third experiment, stock plant source, rooting media, and fertility were evaluated in a factorial experiment. All cuttings originated from stooling blocks growing at the Los Lunas Plant Materials Center. The three sources evaluated were Capulin, Raspberry Ridge, and Pinon Knob. Media densities evaluated were: 1) 2:1:1; 2) 1:1:1; and, 3) 1:1:2 mixtures of peat:perlite:vermiculite (v:v:v). The four fertility treatments were: 1) Osmocote and triple super phosphate; 2) Osmocote only; 3) triple super phosphate; and 4) no fertilizer incorporated into the media. No exogenous hormones were applied. The experimental design was a completely randomized design with each treatment combination replicated by 14 cuttings.

In the fourth experiment, collection date, stock plant source, and stock plant vigor were evaluated. The locations and dates for the timing of collection are provided in table 7. The rooting media was a 2:1:1 ratio of peat:perlite:vermiculite (v:v:v). Cuttings were monitored daily and tagged when bud break occurred. No exogenous auxin applications were used. Each treatment combination was replicated by 14 cuttings. Chi-square tests of homogeneity were used to detect differences in rooting response. Heavy snowfall in the native stand precluded collections for the final sample period (February 1997).

Results

All sources evaluated appear to be suitable for cutting propagation. Source and stock plant vigor significantly impacted rooting percentage. Overall, cuttings from the 3 year-old stooling blocks had an average rooting success in excess of 90 percent while cuttings from the native stands ranged from 62 percent to 85 percent (fig. 1). Collection date also impacted rooting success with rooting peaking in the latter three collection dates (fig. 2). However, sources differed at the two earliest collection dates in the rooting response. All sources had at least three collection dates with greater than 90 percent rooting success.

The influence of auxin formulation and concentration was dependent on source and plant stock vigor. In both cases, the addition of exogenous auxins only slightly (less than 5 percent) improved the rooting response. Media density and fertility treatments did not influence rooting success.

Final shoot size was satisfactory in all treatment combinations examined. Cuttings from the more vigorous stooling blocks were faster growing; however, this trend was dependent on the original source (stand) (see fig. 3). There was some sensitivity to media density with the cuttings

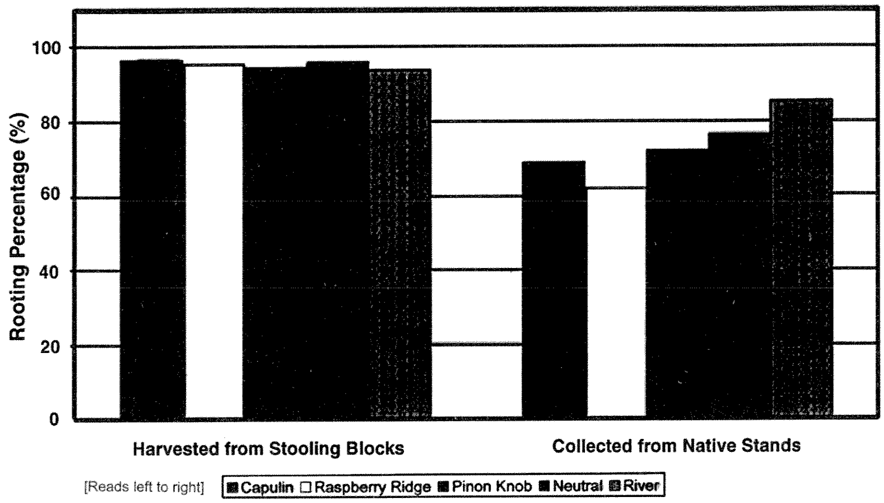

Figure 1—Effect of stock plant vigor and source on rooting of *Populus angustifolia* cuttings.

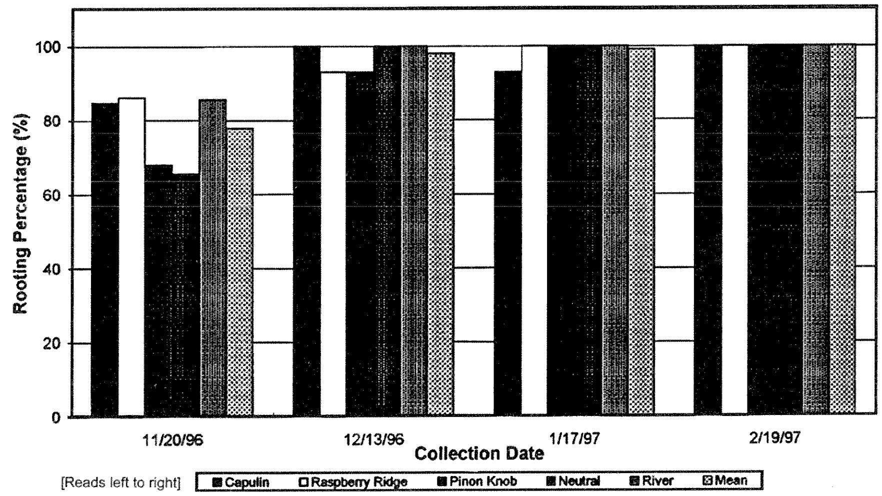

Figure 2—Effect of collection date on the rooting of *Populus angustifolia* cuttings from stooling blocks.

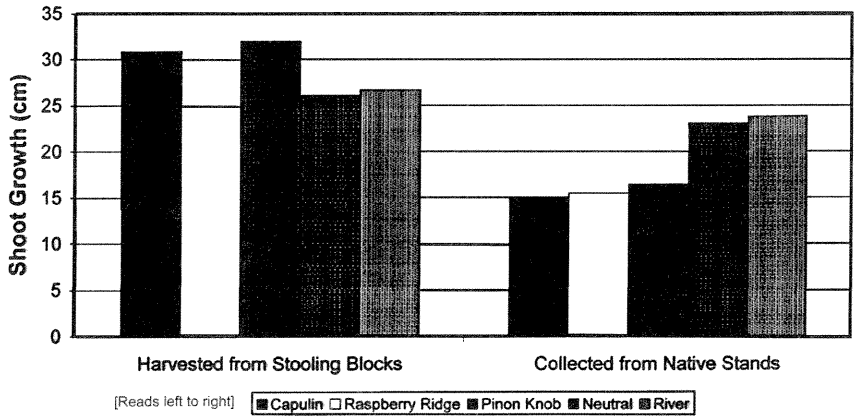

Figure 3—Influence of ecotype on shoot growth of rooted *Populus angustifolia* cuttings.

growing better in the slightly heavier (2:1:1 and 1:1:1 peat:perlite:vermiculite) media. However, the magnitude of the media affect was also dependent on the source (stand) of the cutting material. The triple super phosphate treatment had minor impact on the subsequent growth of shoots. The presence of Osmocote in the rooting media also significantly promoted shoot growth. Again, the magnitude of this response was dependent on the source (stand) of the cutting material.

Conclusions

While all treatments generated relatively high percentages of viable cuttings after 20 weeks, some treatments were more effective. Source of the stock plant impacted the effectiveness of other cultural treatments in promoting rooting and subsequent shoot growth. Cuttings from the stooling blocks consistently had better success than cuttings from the original stands. Use of exogenous auxin applications does not greatly improve the rooting response. To sustain the rapid growth of cuttings, the incorporation of controlled release fertilizers appears to be a cost effective technique. While all media mixtures generated suitable cuttings after 20 weeks, the heavier media treatments required less frequent irrigation.

POLE PLANTING OF RIPARIAN TREES AND SHRUB

Preface

The cottonwood gallery riparian forests of the southwest U.S. are one of the most endangered forest types in North America. The conversion of forest to agricultural and urban land uses, the lack of natural regeneration of the dominant native tree species with the cessation of natural flooding, and the invasion of invasive exotic woody species (saltcedar and Russian olive) have resulted in a drastic reduction in the extent and health of these riparian forests. Several regeneration techniques are being investigated to reestablish the native tree and shrub species: 1) artificial flooding of former flood plain areas to simulate spring flood events and allow natural regeneration (Crawford and others 1996); 2) micro-irrigation of former flood plain sites to allow regeneration from naturally disseminated cottonwood seed (Dreesen and others 1998); and, 3) the planting of large dormant cuttings or poles (Carlson and others 1992). The principal concept of pole planting is to plant a dormant cutting of sufficient length to reach the water table which allows establishment with no supplemental watering. Over a decade of pole planting experience allows the development of some generalizations and recommendations which will maximize pole planting success

Pole Characteristics

Pole cuttings are grown in large production blocks containing either superior selections or particular ecotypes. The production block rows are 90 m long with plants on one meter centers and rows 3 m apart. Large dormant cuttings (>50 cm long, >1 cm caliper) are inserted into collapsed trenches created with a large single ripper and are flood irrigated immediately after sticking. During the first growing season, frequent flood irrigation (weekly) is required until roots are well established; at maturity the production blocks are flood irrigated on a monthly basis unless substantial rains have occurred. Mechanical and manual cultivation is required to control weeds primarily during the first growing season. Some cuttings will produce multiple shoots, others will form a dominant leader which when harvested will generally result in the emergence of multiple shoots. Under ideal conditions, large poles (3m) can be harvested after 3 growing seasons. Only the large stems on each plant are removed during the winter harvest (January through March) releasing the smaller stems to grow for future harvest. After the large poles are removed with a chain saw, all the lateral branches are pruned off. The butt end of the pole is submerged in water until transport to assure the pole is well hydrated before planting. As long as the weather is cold and bud break is far off, the poles can be stored for several weeks or more in water. Transporting and planting must take place before bud break for best results. The hydrated poles are often transported on flat bed trailers with tarp coverings to limit desiccation.

Site Characteristics

A site characteristic which needs early definition is the depth to the water table and the variation in water table depth over an annual hydrologic cycle. Monitoring wells should be drilled at least a year before planting to determine water table depth fluctuations. This knowledge will determine the length of pole necessary so that the butt end of the pole is always in contact with moisture in the capillary fringe above the water table. The drilling of monitoring wells can also provide knowledge on the type of alluvium present at the site. Clay rich soils are generally detrimental to pole planting success possibly as a result of poor soil aeration. At the opposite extreme, augering holes in cobbly soils is very difficult. Two alternatives to augering have been successful on occasion: 1) a sharpened steel rod mounted on a backhoe bucket which can poke and wiggle a hole between cobbles, "a stinger", or 2) a high pressure water jet to wash out sediments between cobbles allowing the insertion of a pole. Drilling techniques include one-person gasoline powered augers, manual bucket augers with long shafts, and tractor-mounted augers. For small pole or whip sized material such as coyote willow (*Salix exigua*), shallow holes can be dug with electric hammer drills powered by portable generators; this technique can be helpful for winter plantings where the surface soil is frozen. Accessibility of the site to heavy equipment is an important consideration especially when deep holes must be augered.

Shallow water tables are one site characteristic often encountered in montane riparian areas and produce wetland conditions not appropriate for planting cottonwoods and often even willows. Thus, extreme water tables either too shallow or too deep are often limiting site characteristics. The salinity and sodicity of the alluvium are other critical factors in determining pole planting success. Many pole planting failures have occurred from planting in high salinity sites. Sites supporting a halophyte like saltcedar (*Tamarix* sp.) can be too saline or sodic for cottonwoods and willows.

Care after Planting Poles

Large herbivore control is often a required step before pole planting and usually involves fencing. Among small herbivores, beaver are the major problem and can easily gnaw down poles and even steal poles stored on the shore of a river or pond. Planted poles can be protected with tree guard tubes constructed from 1.5 m tall poultry wire. These guards will protect poles from all but the smallest herbivores, e.g., mice. One of the most costly endeavors is to protect the poles during first several years of establishment from defoliation by insects; the cottonwood leaf beetle (*Chrysomela scripta*) is a significant problem at lower elevation sites in the Southwest. Several readily available insecticides are currently effective in controlling this pest, but several applications per growing season are required for the first few years.

Non-Traditional Species for Pole Plantings

Pole plantings have focused on cottonwoods and willows known to be easily rooted from hardwood cuttings. Several shrub and small tree species are important components of cottonwood gallery forests. Some preliminary studies have shown some promising results with pole planting species outside the Salicaceae family. False indigo or indigobush (*Amorpha fruticosa*), New Mexico olive (*Forestiera neomexicana*), seepwillow (*Baccharis spp.*), and desert willow (*Chilopsis linearis*) are species which have shown some reasonable survival percentages in trial pole plantings. Further work is required to better define pole cutting characteristics which will maximize success for these species. Although some of these species are not as fast growing as willows and cottonwoods, it appears that conventional pole production blocks are feasible. It is probable that high success rates with these species may require selection of genotypes with favorable rooting characteristics.

Conclusion

Pole plantings are particularly advantageous in riparian situations with deep water tables because no watering is required; containerized stock would require substantial watering until the roots could reach the capillary fringe. In addition, pole plantings are not effected by herbaceous weed competition because of their large initial size and deep roots. Potential disadvantages of pole planting would result from the planting of selected clones with limited genetic diversity. If pole production blocks were planted with diverse stock from many seedling trees, these concerns of the lack of genetic diversity could be reduced. Pole planting is an expensive planting method because of the cost of the pole planting stock, the equipment needed to plant the pole, and the aftercare required. However, there may be situations where this planting technology is the only feasible method of reestablishing these riparian forests.

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