# Revegetation Methods for Urban Streams: The Use of *Salix laevigata* and *Populus fremontii*

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## Abstract

Riparian zones require a healthy plant base to provide ecosystem functions such as erosion prevention and sequestration of chemical pollutants. In this project, the methods of riparian restoration using two common riparian trees, *Salix laevigata* and *Populus fremontii*, were explored along a small stream in an urbanized setting of northern California. Revegetation success was studied by comparing the survival of one group of rooted cuttings versus another group planted directly into the soil. Establishment and growth were assessed at two elevations along the creek bank. The goal of the project was to determine both the optimal rooting method and location along the bank for maximum cutting survival and growth, and to compare the success of the two plant species. During the first spring season following planting, all methods resulted in pole survival with no appreciable differences resulting from rooting method. The average number of leaves and stem length was 19.1 and 7.4, respectively. Bank location was a significant determinant of growth for *S. laevigata* and not significant for *P. fremontii*. The *S. laevigata* cuttings grew more than the *P. fremontii* perhaps because of different optimal growing seasons, as willows tend to initiate growth earlier in the spring. Despite an initial lead in leaf formation by pre-rooted plants, the directly planted cuttings grew more than the rooted cuttings, perhaps because handling of the cuttings twice resulted in double transplantation shock. The use of both species represents a viable strategy for urban stream restoration, and consideration should be given to both rooting method and bank height.

## Introduction

Riparian zones are important transition areas between aquatic and terrestrial ecosystems. The vegetation is also useful as the basis for in-stream food webs, but has been degraded worldwide as a result of human activities in urban, agricultural and wildland settings. Relatively recent human activities, such as the increase in agricultural runoff, streamflow diversions, and deforestation, have degraded riparian zones (Auble 1994). Increased sedimentation, lowered water tables and other impacts have caused the decline of the cottonwoods (*Populus* spp.) in many parts of North America (Rood et al. 1995). Increased air pollution and industrial waste have caused the continual decline of willows (*Salix* spp.) in northwest Russia (Kozlov et al. 1999). Periodic soil desiccation has contributed to the failure of riparian vegetation in Mississippi (Pezeshki et al. 1998). Decreases in land quality causes decreases in the resiliency of riparian vegetation, and thus in the ecosystem as a whole.

Riparian zones provide many ecosystem functions, including intercepting excess chemicals and nutrients that flow from the land into the streams, armoring stream banks to decrease erosion, and supporting a diversity of invertebrate and vertebrate species (Gregory et al. 1991). Riparian zones are often identified as corridors for the movement of animals and the dispersal of plants (Gregory et al. 1991, Harris 1999). Healthy riparian plants are essential to providing an effective buffer zone (Wade 1995). It is often desirable to manipulate the vegetation in order to establish diverse communities of animals and plants on either side of the buffer zone, which is the area that collects the inflows of the other ecosystems (Wade 1995). While some riparian zones are isolated from one another, migrating birds use riparian corridors, as well as connected riparian vegetation patches, as refueling resources (Skagen et al. 1998). Some isolated riparian zones include urban streams that occur along the migration path. When riparian zones are degraded, the riparian vegetation is harmed, and is unable to support birds as well as invertebrates.

In urban streams and streams near agricultural lands there are increasing efforts to revegetate the degraded stream banks (Harris 1999). These are preliminary steps in restoring the ecosystem functions of the riparian zone, and will provide recreational and economic amenities in the urban environment (Wade 1995). In California, revegetation efforts often include the planting of willows because they are native riparian species which establish rapidly and provide useful services in riparian environments (Friedman 1995). These plants are dominant native riparian plants, and require ample soil moisture for growth (Pezeshki et al. 1998). Cottonwood (esp. *Populus fremontii)* is also native to California's riparian zones, and can be used in revegetation efforts (Friedman 1995). Cottonwoods are especially sensitive to the absence of natural disturbance, particularly flooding. They require conditions of channel movement of bare soil caused by flooding to establish seedlings because the seeds germinate on open gravel beds and other clear substrates. Regulated urban streams inhibit such movement (Auble et al. 1997).

Another problem is that high creek banks result from highly incised urban streams, and may cause loss of contact with the water table. The steepness of the bank and lowered water tables cause the plants to be far from the water table. This distance can affect the water availability and consequently the growth of the plants. Some willows may survive at the water's edge better than at higher heights above the creek bank in wetland environments, and some willow species tolerate dryness better than others (May 1995). Species that are found at higher elevations survive less successfully close to the water's edge, and researchers recommend that considerations should be given to water table elevation when planning a restoration strategy (Pezeshki et al. 1998).

The objective of this study was to test the effectiveness of two factors for promotion of riparian vegetation. The first was a test of differential establishment of plants depending on bank height along a small creek within an urban setting. My project compares the growth of red willow, *Salix laevigata*, and cottonwood, *Populus fremontii,* at two different heights along a creek bank. *S. laevigata* was chosen because studies have shown that it has an effective root system that will tolerate moderate water table lowering (Williams and Matthews 1990). Plants from of the genus *Salix* are often used in restoration projects, but *Populus fremontii* is rarely used because they do not naturally persist in channels that are restricted in movement, which is the case in most urban streams (Auble 1997). Rooting method was the second factor, and I compared the success of direct planting versus establishing roots on the cuttings first. I tested whether poles that have been cultivated from cuttings in the greenhouse and formed root systems will survive better than those cut from trees and planted directly into the creek bank.

Local restoration groups have limited funds with which to pay for greenhouse space, so I anticipate my results will offer an effective method for introducing the vegetation.

Direct planting versus rooting tests the hypothesized trade-off between efficiency (plant cuttings directly, less expensive) and higher success in survival (plant cuttings after rooting, more expensive). I hypothesized that the willows will show more growth than the cottonwoods based upon similar studies by May (1999) and Pezeshki et al. (1998) which indicated that willows grow faster from cuttings than other plants used for restoration. I hypothesized that the plants that have been rooted will have greater survival and grow to a larger size than those planted directly in the soil. This is because the rooted cutting's water uptake will be easier than the non-rooted cutting, because it will have established roots upon transplantation. Finally, I hypothesized that the willows will perform better at levels closer to the stream, while cottonwoods will perform better at the higher elevation. This is because in their natural riparian habitats, cottonwoods are found higher along the creek bank, while willows are found closer to the creek's edge (Pezeshki 1998).

**Study site and organisms** This research was conducted at Marin Creek, a remnant stream channel within the urbanized area of Berkeley and Albany, California. The latitude and longitude are 37:53:27 North and 122:19:28 West and the elevation is 2 meters above sea level. The stream section studied runs through the U.C. Berkeley Gill Tract Agricultural Station. This urban creek runs east to west, and is culverted upstream and downstream of the property. The creek width is about 0.6-0.7 meters and the depth ranges from 0.1 to 0.4 meters. The riparian area width is about 5 meters on either side of the stream. The soil type is serpentine soil, and the bank gradient is varies from 40-50 degrees. The vegetation along the Marin Creek includes many non-indigenous species, including *Hedera helix*, *Conium maculatum*, *Rubus* spp., *Pinus radiata*, *Eucalyptus globulus* and various grasses.

## Methods

Plant cuttings were taken for both pre-rooting and direct planting. The *S. laevigata* cuttings were obtained from trees along Wildcat Creek in the Berkeley hills. One set of *P. fremontii* cuttings were collected at the Sonoma Creek, and another set was collected from along the Codornices Creek in El Cerrito. All cuttings were about one meter long and were stripped of branches and leaves upon collection. The low bank sites were approximately 10 centimeters above the streamflow, and the high bank sites were 2.5 meters above the stream. I removed the existing branches to insure that the water that has been taken up is not lost through evapotranspiration (Pezeshki et al. 1998). The plant cuttings were rooted in coarse sand beds in the greenhouse. Plants were watered every two to three days, for two months.

I dug 48 holes 0.45 meters deep and 0.15 meters in diameter into the soil. The areas surrounding the holes were cleared of debris, leaf litter and vegetation to remove sources of obstruction and plant competition. I transplanted the rooted cuttings, and the fresh cuttings, into the holes in the cleared creek bank area on February 28. The cuttings were planted in blocks of four: a rooted willow, a direct willow, a rooted cottonwood and a direct cottonwood. Each set of four was planted in a line, with a 0.3-meter distance between each plant. There were twelve blocks of plants, six at the creek edge, and six on the bank above the creek bed. Each treatment was replicated six times. They were watered once after transplanting to reduce moisture stress associated with transplantation.

At weeklong intervals, from February 28 to April 14, I counted the number of leaves and measured the mainstem length of each planted cutting. I analyzed the number of leaves and stem length formed during the six-week growth period using a three way analysis of variance (ANOVA). The factors were species, bank height, and rooting method. In addition, I performed a two way ANOVA for each species to compare the growth of rooted versus direct and high and low bank posts.

**Results**

There was no mortality of planted cuttings; all 48 survived. Their growth varied, and the mean number of leaves and stem length was 19.053 and 7.348 cms (Table 1). The *P. fremontii* rooted cuttings that were planted on the lower bank exhibited buds at the last measurement, indicating that they survived and were ready to produce new tissue.

| Factors | Measurement | Mean | F-statistic | P-value |
|---|---|---|---|---|
| Species*Rooting*Height | Leaf Number | 19.053 | 0.252 | 0.618 |
| Species*Rooting*Height | Stem length | 7.348 | 0.049 | 0.825 |

Table 1: ANOVA results for growth responses where factors were species, bank location and rooting method.

In the three-way ANOVA, there was no significant difference in the mean number of leaves or the stem length (Table 1). This procedure tests for differences in the means between the treatments of species, rooting method and bank location. The results indicate that the main effects of species and rooting method are not modified by bank location.

| | *Salix* | *laevigata* | *Populus* | *Fremontii* |
|---|---|---|---|---|
| Factor | F-statistic | P-value | F-statistic | P-value |
| Bank height | 17.915 | 0.000 | 0.047 | 0.831 |
| Rooting method | 15.426 | 0.001 | 15.426 | 0.001 |
| Bank height* Rooting method | 0.000 | 0.992 | 0.000 | 0.990 |

Table 2: The two 2-way ANOVAs with species separate, and number of leaves as the dependent variable and bank height and rooting method as the factors.

| | *Salix* | *laevigata* | *Populus* | *Fremontii* |
|---|---|---|---|---|
| Factor | F-statistic | P-value | F-statistic | P-value |
| Bank height | 14.264 | 0.831 | 0.708 | 0.126 |
| Rooting method | 10.425 | 0.004 | 10.425 | 0.867 |
| Bank height* Rooting method | 0.086 | 0.772 | 0.086 | 0.059 |

Table 3: The two 2-way ANOVAs separated species, with stem length as the dependent variable and bank height and rooting method as the factors.

I separated the measurements by species and performed a 2-way ANOVA in order to determine whether rooting method and bank location differed between species. The results of the two-way ANOVA, in which species were kept separate and rooting method and bank location were the factors, showed a significant difference in the mean number of leaves and stem length for the willows and for the cottonwoods (Tables 2 and 3). Bank height resulted in a significant difference in mean number of leaves for *S. laevigata* but not for *P. fremontii*. Bank height did not result in a significant difference in stem length for *S. laevigata* nor *P. fremontii*. Rooting method resulted in significant difference in mean number of leaves for *S.*

*laevigata* and *P. fremontii*. Rooting method resulted in a difference in stem length for *S. laevigata*. The combined effect of bank location and stem length did not result in statistically significant differences in mean number of leaves not rooting method for either species.

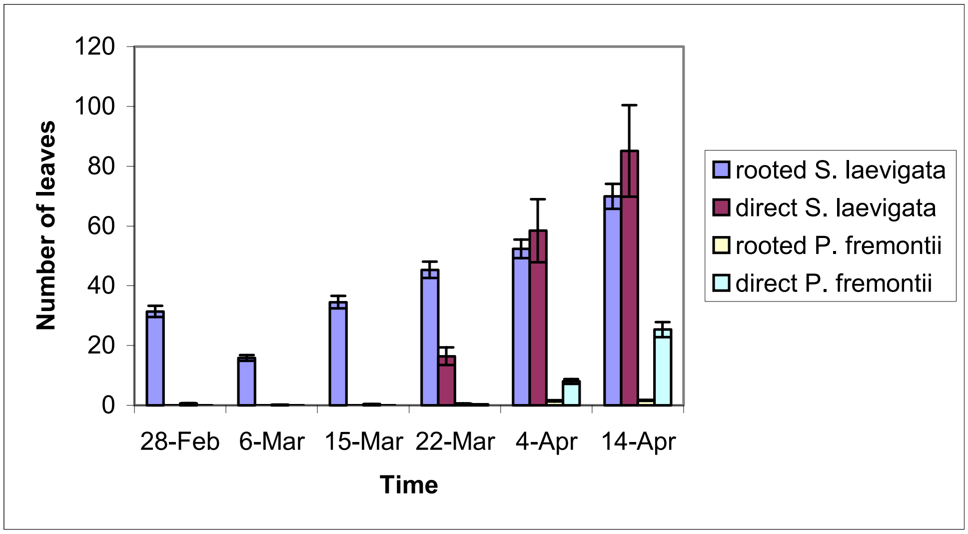


Figure 1: The mean number of leaves of each treatment from the day of transplantation, February 28 until the final measurement on April 14.

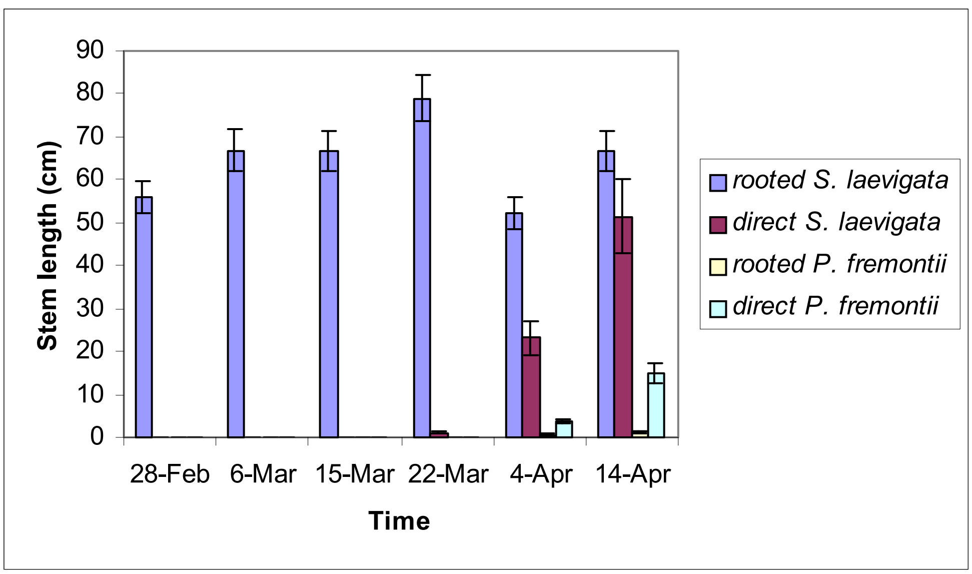


Figure 2: The mean stem length of each treatment from the day of transplantation, February 28 until the final measurement on April 14.

Willows grew rapidly in leaf number and stem length especially after about March 15 (Figures 1 and 2). After April 4, the number of leaves on the direct *S. laevigata* cuttings exceeded the number on the rooted cuttings. At the time of the last measurement, the willows had grown a larger number of leaves than the cottonwoods. The direct *P. fremontii* cuttings were increasing in leaf accumulation at a higher rate than the rooted ones. The stem length of the cuttings increased for all treatments except for the rooted *S. laevigata* during the period of March 23 to April 4.

**Discussion**

**Species differences** The results showed that the number of leaves and stem length of the different species were different. The willows had a significantly larger number of leaves and stem lengths than the cottonwoods. One factor that might explain these findings is that the roots were longer and larger in diameter on the rooted willows than the rooted cottonwoods upon transplantation. This might have enabled the willow cuttings to gain access to sufficient groundwater and nutrients more readily. I also observed that the willow roots were distributed evenly around the lower length of the cuttings, while the cottonwood roots were distributed less evenly. This might have affected the cottonwoods' ability to take up water and nutrients, and thus their capacity for growth.

The cottonwoods might also have a later growing season than the red willow, resulting in less leaf and stem growth. The growing season of *P. fremontii* is usually late spring and summer, and many researchers sample *Populus* at that time of year, such as Auble et al. (1997). Since I conducted this study during late winter and early spring, the cottonwood transplants were probably not yet at their peak of biomass production. Some willow species achieve 60-100% of maximum leaf number in March, and this might explain the high mean leaf number for the willows (Woodhouse 1983). Indeed, willow germination and seedling establishment is usually observed in late May and early June (Freidman et al. 1995). Comparing the means during both of the separate growing seasons might be appropriate for a longer study. Researchers found that restrictions on channel and flow change decrease the rate of cottonwood establishment (Bradley and Smith 1986), and this might have been the case in the urban stream. However, this seems to be more of a consideration when long-term establishment of a cottonwood grove is anticipated.

**Bank height** In general, I found that the bank height difference did not significantly affect the growth of the *P. fremontii* transplants. The height difference of 2.5 meters might not be a large enough difference in distance from the water table to affect biomass accumulation. Also, the March rains might have kept both high and low creek bank sites sufficiently moist for growth, and so the distance from the water table might not have affected the *P. fremontii* growth. It would be useful to continue the experiment into the summer, when the water table height and moisture availability become more important. Some sites were waterlogged at the lower bank height, and others were dry for most of the experimental period; this combination might have inhibited the growth of these plants. Researchers found that *Salix* survives poorly when planted at the water's edge and inundated with heavy rains (May 1995). However, in this study, many of the willows planted at the lower bank heights survived the waterlogged conditions. *Salix* leaf and shoot biomass were also found to be reduced in flooded areas because of decreased stomatal conductance and photosynthetic activity (Pezeshki et al. 1998). This might have occurred for some individual poles planted at the low bank height, but not to a degree that showed up statistically.

**Rooting method** The results showed that the mean number of leaves, and stem length, were greater for the direct cuttings was higher than the means for the rooted cuttings. This was true for both cottonwoods and willows. The significantly different performance could be explained by a double transplantation shock. The rooted cuttings were taken from trees in December and put in a greenhouse sand bed. After two months of rooting, they were transplanted into the ground. The plants were probably stressed first when cut and put in the sand bed, and then a second time when they were transplanted to the field site. The second shock might have been avoided if the plants were allowed to root for a longer period of time. Also, if the cuttings had been transplanted at a time when the ground was moister, biomass accumulation might have been higher. In addition, some of the roots might have been damaged when the cuttings were removed from the sand beds. This might have caused energy expenditure to repair the roots or reduced water uptake by the cuttings. These would have resulted in less leaf development and stem growth.

The general trends over time given in the graphs indicate that the rooted and direct willow cuttings experienced greater growth than the cottonwood cuttings. This may be because the measurements were taken in the optimal growing season for willows and not for cottonwoods. The willow cuttings show an increased growth rate of number of leaves and stem length after four weeks, in both the rooted and direct cuttings. In the number of leaves, the direct willow cuttings performed better than the rooted willows, overtaking the mean number of leaves in about 4 weeks.

**Future studies** Over the two-month period, there were significant differences in sunlight, rainfall and temperature. It would be useful to quantify these data in order to extract more information from the experimental results. The joint effects of some of the experimental factors and these physical factors might be detected. For example, in the period between March 23 and April 4, stem length of the rooted willow posts decreased. This appeared to be because a number of stems dried out. This might be accounted for if physical factors such as weather were used in analysis.

Researchers have found that long-term survivorship does not occur in areas with either flooded conditions or drought (Pezeshki et al. 1998). However, they also found that *Salix* develop morphological and anatomical adaptions to flooded conditions (1998). I observed that some of the sites at the Gill Tract were saturated, while others were well-drained for most of the two months of measurements. The adaptions were not observed for this project, and would require a longer-term study of the plant system.

The long-term establishment of riparian vegetation, especially cottonwoods, requires an unrestricted stream site (Auble et al. 1997). Thus researchers suggest that riparian cottonwood populations can be expected to decline in urban areas (Auble et al. 1997). In my study, there was no mortality in the willows or cottonwoods, but their survival through the seasons and propagation might be hindered at the culverted creek. The artificial creation of flood conditions and the removal of exotic plants could enhance their long-term survival. In addition, establishing cottonwood stands using post rather than seedling planting could increase survivorship (Ohmart 1988).

The prevalence of non-native plants in the field site might inhibit the overall growth of the plants (Wade 1995). Though the sites were cleared of debris and other vegetation, roots and chemicals might persist in the soil, affecting the plant growth. The *Eucalyptus globulus* were found at the higher elevation sites, but their root structure was not discernable from above ground. The *Hedera helix* plants and non-native grasses were found at the lower sites, and are known to interfere with frowth of native plants (Le and Sonu 2000). The *Hedera helix* and *Eucalyptus globulus* might have exerted competition pressures that caused the growth of the cuttings to be reduced. In coming months, when the area surrounding the posts is not cleared of debris or encroaching non-native vegetation, the natural effects of competition can be observed. Particularly, the cuttings at the lower bank heights might have a problem because of the close proximity of the non-native vegetation.

The project highlights the importance of dominant riparian plant species as a starting point for successful restoration. From my results, it appears that direct planting results in better early growth both willow and cottonwood cuttings. This might indicate that creek restoration groups need not root the cuttings before transplantation, if the transplanting is to occur within two months. Willows exhibited a greater amount of growth than cottonwoods, but this might be due to the differences in growing seasons and will require a re-assessment at the end of the growth season. However, the three-way ANOVA using the three factors of species, rooting method and bank location did not affect the number of leaves or stem length of the plants.

The results may have useful applications in nearby East Bay streams such as the Codornices, Temescal, Sausal and Strawberry Creeks. These creeks are located in close proximity to the Marin Creek, and have similar problems resulting from their urbanized environments. The 1997 partial restoration of the Codornices Creek by volunteer and creek groups in Berkeley included the revegetation of native trees and wildflowers, and further plans on this creek include the daylighting of a ten-block stretch of the creek in Berkeley (Bradt 1998). The City of Oakland has undertaken a series of urban creek restoration projects for its fourteen creeks, and one of its goals is to restore aquatic habitats (Schwartz 1998). Riparian restoration at these sites will include the planting of native tree species (Bradt 1998, Schwartz 1998, McDonald 1996). Such a goal requires the development of a strong vegetation base (Wade 1995).

According to the results of the study, either of the rooting methods could be used as well as either *S. laevigata* or *P. fremontii*. However because of growth patterns, it would be effective in terms of time and expense to use the direct planting method. The bank location does not affect *P. fremontii* growth in the first two-month period, and so further studies in urban streams should be undertaken to see if dry season moisture differentials cause later differences in plant growth and establishment. In addition, issues of non-native and native plant competition should be studied to understand how the posts might survive in an area that has not been cleared of non-native plants.

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