Evaluation of Willow Propagation Methods
FHWA Canyonville 5 Project

David Steinfeld
November 2007

Summary: Willows that were planted as rooted cuttings became established at a much greater rate than those from live stakes (90% vs. 12%). Live stakes cut in the dormant period (November or January) had greater viability than those cut in early October (68% vs 12%). Future bioengineering projects should consider the viability, establishment potential, and production costs of the plant materials when developing a strategy for establishing willows on a construction site.

Background: During the Winter of 2003, a recently constructed fillslope on the Canyonville 5 Highway (road section 30+400 to 30+800; commonly referred to as the Schaeffer Fill) developed shallow slope failures due to high moisture conditions. To increase slope stability, the FHWA implemented a bioengineering project that included pinning the slope at approximately 1-meter centers with live willow stakes and installing willow brush layers where shallow slumps had occurred (see Roadside Revegetation Manual Chapter 10.2.2 Collecting Wild Cuttings and 10.3.3 Installing Cuttings for background on this type of plant material).

Construction crews were scheduled to install willow waddles and live stakes between November 1 and November 30, 2004. To meet this timeline, willow plant material was harvested during October 2004. Given that the willows were still physiologically active during this period, there were reservations that the cuttings would not successfully root. In addition, the fillslopes are hot and dry (south facing aspect) from May through September, further limiting plant establishment. Knowing these limitations we proceeded under several assumptions: first, storing willow material in water after cutting would increase willow rooting and plant establishment; second, live willow stakes would add slope stability whether or not they rooted.

From October 5 through October 28, 2004, 3,450 willow stakes and 190 willow bundles were collected on the Tiller Ranger District by a local contractor, district employees and Stone Nursery employees. Cuttings were placed in a shallow part of the South Umpqua River for soaking. During the third week of October a storm raised the water level of the South Umpqua River three feet, floating the willow stakes and bundles downriver. A few days later, the bundles were retrieved from the river and placed in large stacks above the flood zone. They were not put back in water because of the obvious concern that they would float downriver again. There were no logistical alternatives for storing in water. The weather had also changed and had become overcast during this period, reducing the potential that the willows would dry out. Had the sun come out during this period, the only part of the large pile that would have potentially dried out was the top layer of willows. There was discussion whether these cuttings would root because they were not in water but the project engineer decided to stick the cuttings under the premise that even if they didn't root, they would still increase slope stability.

Since the FHWA uses willows in other bioengineering projects for slope stability, this project created an opportunity to test the effectiveness of several methods of installing willow plant material in a controlled study. A simple study was established on this site with the objectives of determining if there were any differences in willow establishment

and growth between five different willow treatments – 1) willows cut in early October and installed in late November, 2) willows cut in early November, placed in water and installed in late November; 3) willows cut in early November, stacked under moist, shaded conditions, installed in late November; 4) willows cut in February and immediately installed and 5) *rooted cuttings* grown in a nursery and planted in February. The species used in this trial was Scouler's willow (*Salix scouleriana*).

Methods

Treatments

Oct cut, soak, late Nov stick. 100 four-foot long live stakes were cut on October 6, 2004 and placed immediately in the South Umpqua River. On October 25, the stakes were pulled from the river and placed in a large pile of stakes and stored there until they were installed on November 30, 2004. The collection site was Scott's Mill (1200 foot elevation). The willow stands where the stakes were collected still had most of their leaves attached indicating the plant material was not dormant.

Nov cut, *no soak*, late Nov stick. 100 four-foot long live stakes were collected on November 3, 2004 from the Pickett Butte Road (3000 foot elevation). The willows had lost most of their leaves indicating that they were dormant. The stakes were stacked in a pile under a shaded canopy near Tiller RS. On November 30, 2004, the live stakes were installed in the fillslope.

Nov cut, *soak*, late Nov stick. 100 four-foot long live stakes were collected on November 3, 2004. The willows were from the same collection as the no-soak treatment material. 100 stakes were placed in a small pond near Tiller RS. On November 30, 2004, the live stakes were installed in the fillslope.

Jan cut, no soak, Feb stick. Willow stakes were harvested from the Pickett Butte Road (same source as Nov collections) on January 24, 2005 and stored in a pile under a shaded canopy near Tiller RS. Willows were installed on February 14, 2005. The willows collected at this time had lost their leaves.

Feb rooted cutting plant. 80 rooted cuttings were started at J. Herbert Stone Nursery from willow cuttings taken from a site near the project. They were grown in long tubes - 3 inch diameter PVC pipe by 18 inches long with vexar tubing to hold the media together. Rooted cuttings averaged 5 mm caliper and 24 inch top. Rooted cuttings were planted so that 4 to 6 inches of the stem were buried below the surface of the soil. Vexar tubing was slit longitudinally with an exacto-knife because of the concern that the mesh it was too fine and would not break down in the soil.

Study Design

The trial consisted of 8 replications (or blocks) located randomly across the Schaeffer Fill. The five treatments were randomly assigned row position within each block (Figure 3). Each treatment within a block consisted of 10 willows. A total of 80 willows were installed for each treatment (8 blocks x 10 cutting or rooted cuttings per block). Willows were installed 2 feet apart within row and 3 feet between treatment rows.

Installation

For the November treatments, live stakes were installed using a homemade "stinger". This equipment consisted of rebar welded to the bucket of an excavator to create a 2 - 2.5 foot deep by 2" diameter hole. Willows were inserted in the hole and the back of the bucket was used to push the stake to the bottom of the hole. For the February installed treatments, holes were augured (stinger was not available or practical at this time).

All willows were installed perpendicular to the slope gradient. Soil around each willow was lightly tamped with a tile shovel to obtain good soil contact. After installation, the tops of the stakes stuck approximately 1.5 to 2 feet above the ground line. These were trimmed with a chain saw (which left a clean cut) so that the final height of all stakes was approximately 6 inches above the soil surface. The weather during installation on all dates was overcast and cool in the morning and clear and cool in the afternoon.

Plot Care

All blocks were weeded several times during the spring and summer to reduce the effects of weed competition on willow survival.

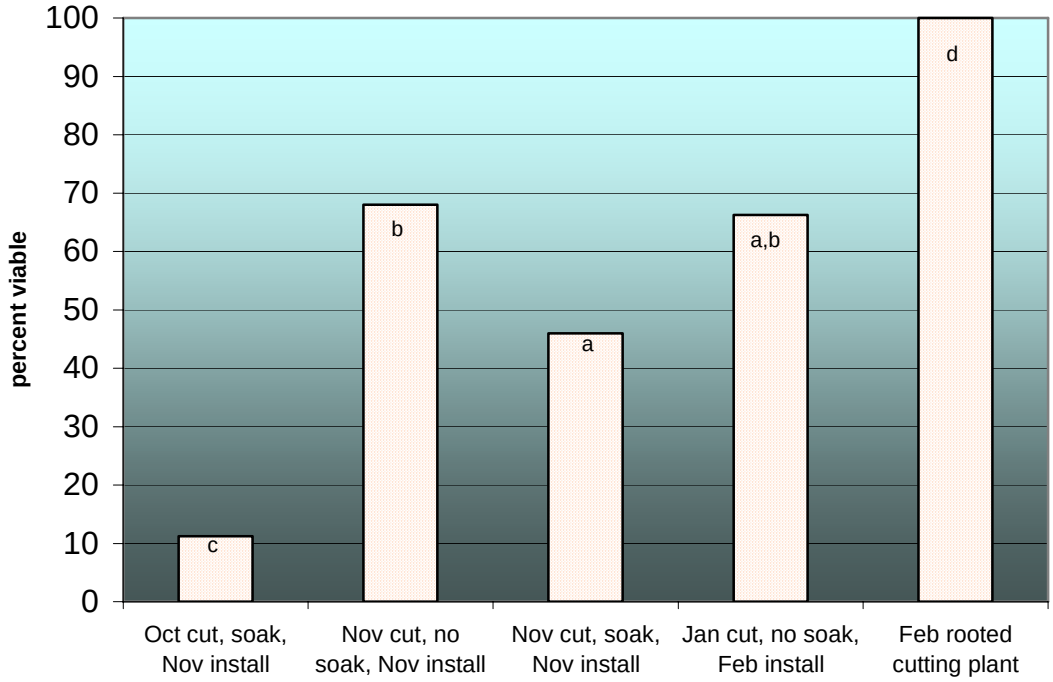
Data Collection

Data was collected May 23, 2005 and September 9, 2005. On May 23, any stake or seedling with the presence of new leaves was considered to be *viable* and had initiated roots. Any stake or rooted cutting with the presence of live leaves on September 9, 2005 was considered *established*.

Results and Discussion

Viability. The quality of the live stake material to produce roots under a low stress (or ideal growing environment) I refer in this report as "live stake viability". Much like the concept of "live seed", live stake viability is independent of the site and reflects the *potential* of the plant material to grow when placed in an *ideal growing environment*. Since the weather at the Canyonville site during spring 2005 was almost perfect for establishing roots on cuttings and new roots on rooted cuttings (there were few days without rain and temperatures were mild), data taken at the end of this period reflect the viability of the plant materials.

Figure 1: Plant material viability – data collected May 23, 2005



Treatments not sharing the same alpha character are significantly different at p<0.05

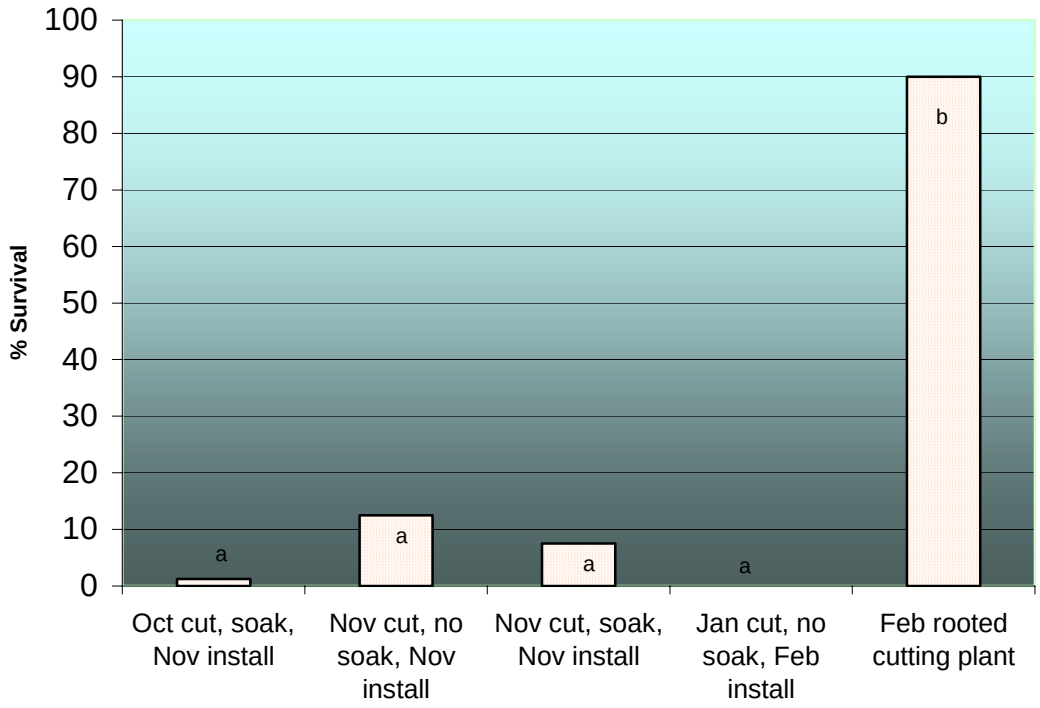
The viability of willows as determined by the May 23 evaluation (Figure 1) was excellent for the rooted cutting treatment, while fair for cuttings taken in November and February and poor for collections made in October. Comparing the viability of cutting treatments, it appears that willows cut in October were less viable than material cut during the dormant period. Cuttings made in January had the best viability of all cutting treatments.

The premise that soaked willow stakes perform better than non-soaked stakes when collected in the fall was not supported in this trial. The timing of the soaking could have played a role in this. If these same treatments had been done earlier in the fall or in the late winter or early spring, a positive result might have been observed. Chris Hoag (NRCS) has research results showing that soaking willow cuttings in the spring increases establishment[1]. He says that there is good evidence that soaking swells the root primordial, decreasing the time after willows are installed for roots to emerge from the bark.

Establishment. The fact that willows were viable when they were installed, doesn't necessarily mean they will survive and become established on all sites. After a mild, moist spring on the Canyonville site, the weather turned hot and dry for three months. While many live stakes appeared to have developed roots (as indicated by leaf growth in late May), the live stakes had not established well enough to withstand the hot dry conditions of this site (Figures 2 and 3). Only planted rooted cuttings became established at a 90 percent survival rate. Surprisingly, there were no significant differences between the survival rates any of the live stake treatments, which indicates the predominance of site climate over timing of cutting.

[1] email from Hoag October 2004

Figure 2: Plant Establishment – Data collected September 5, 2005

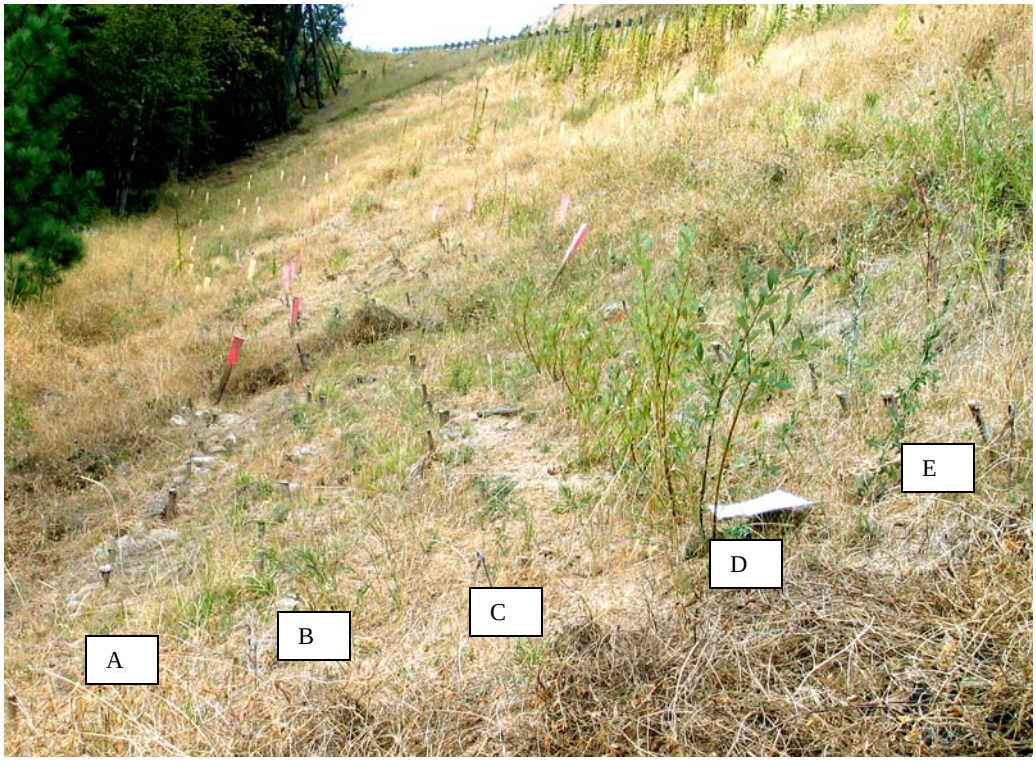


Treatments not sharing the same alpha character are significantly different at $p<0.05$

Considering the harshness of the site, it is not surprising that the establishment of willows from cuttings was low. Many of the healthy, Douglas-fir, madrone, and some ponderosa pine seedlings, grown in one-gallon containers and planted on the same site in late winter perished in the first year after planting. What is unexpected is that rooted cuttings pf willow survived at higher rates than many of the other species planted on this site.

The results of this study support the premise that on harsh sites, rooted cuttings have an advantage over live willow stakes because their root systems are already established and ready to grow. Immediately after planting, roots elongate from the bottom of the root plug and access moisture in the lower soil horizons. Live willow stakes, on the other hand, must first initiate roots from the stem. The abundance of root initiation and growth depends on the viability of the plant material.

Figure 3. Photo of Block 5 taken on September 9, 2005. Planted willow rooted cuttings (D) had 100% establishment; both November cutting treatments (A and B) had 10% establishment and October and January cutting treatments (C and E) had no establishment. Rooted cuttings (D) had heights ranging from 2 to 4 feet.



Management Considerations.

These findings show that planted rooted cuttings had a greater chance for establishment than live stakes on a harsh site in southwestern Oregon. Bioengineering projects don't often call for rooted cuttings in lieu of cuttings because obtaining cuttings is often considered an easier or cheaper avenue than propagating and planting rooted cuttings. In addition, the results of live cutting projects are often "acceptable", even when establishment rates are low. Consider this: if 10 percent of the live stakes in this project established into willow plants, as the results from this trial indicate, there should be around 350 established plants (a walk through the Schaeffer Fill shows that these estimates are pretty close). While this establishment rate is low, the number of plants for the site might still be acceptable for meeting project objectives. On a less stressful year, the establishment rate at this site might have approached 50 to 60%, which would have translated into 1700 to 2000 established plants on this site. This would have been a very well-stocked area.

Future bioengineering projects should address: 1) the desired spacing between established willow plants (density) one year after sticking or planting, 2) the predicted rooting viability of the collected material, 3) the sites potential for willow establishment and 4) the cost of obtaining the plant material. Based on these factors a simple equation would predict the amount of cuttings or rooted cuttings to plant on any given site:

 # cuttings or rooted cuttings to plant = desired plant density x (100/predicted % viability)
x (100/predicted % survival)

desired plant density = number of established plants per area one year after installing per area (acre, hectare etc)

predicted % viability = percent of cuttings or rooted cuttings that will initiate roots when planted in a low-stress environment. Much like germination testing, which is done in a growth chamber, cuttings can be placed in a low stress environment (e.g. greenhouse, growth chambers) to determine the percent of material that will root at weekly intervals. The viability of rooting material is affected by the date when the material is cut, age of stem material, willow species, appearance or disease, soaking, handling, storage etc.

predicted % survival = percent of viable plant material that will survive on a construction site. This is affected by site factors such as evapo-transpiration rates (aspect, slope, rainfall, precipitation, wind), plant competition, soil water holding capacity (texture,% rock fragments, bulk density, % organic matter).

On the Canyonville site, for example, the project objectives might have called for a desired plant density of 400 established plants per acre after one year from live stakes cut and installed in November. From Figure 1, 68 percent of the cuttings were viable in the spring and 12% of this amount survived the summer (from Nov cut, no soak, Nov stick in Figure 2). This equals to an overall survival rate for the site of 18% (12 x 100/68). Using the above equation to meet the objective of 400 live plants per acre -

 # cuttings to stick = 400 x (100/68) x (100/18)
= 3460 cuttings

And for establishing rooted cuttings at 100 percent viability and 90 percent survival rate -

 # rooted cuttings to plant = 400 x (100/100) x (100/90)
= 444 rooted cuttings

The costs of obtaining and planting 444 rooted cuttings can then be compared to collecting and sticking 3460 cuttings. For this project the estimated cost (2004 rates) for a planted seedling is roughly $6 ($3.50 for growing[2], $.50 for transportation, $2.00 for planting) and the estimated cost for an installed stake is $2.50 ($1.50 for collection[3] and $1.00 for planting). At these rates, obtaining 400 established plants per acre from cuttings would cost $8,650 and from rooted cuttings $2664.

Plant establishment from cuttings on a site with more moisture and less stress could be less expensive than planted rooted cuttings, especially if cuttings have high viability and are easily obtained. Future work to develop high viable cuttings at reasonable costs might come from established cutting or stooling beds.

2007 Site Review.

A review of the study site was made in early November 2007. Several of the blocks had undergone surface sliding in Spring 2006 however, all of the rooted cuttings that were planted were still alive. Growth rates depended on the block – some blocks had rooted cuttings exceeding 6 feet in height (see Figure 4).

[2] Costs for rooted cutting production could be lowered significantly if a smaller container was used.

[3] This project had higher collection costs because of the lack of accessible willows. Costs for rooted cutting production could be lowered significantly if a smaller container was used.

Figure 4. Appearance of rooted cutting treatment. November 2007. Stripes on staff are one foot lengths.