Riparian/Wetland Project Information Series
No. 24
January, 2008

Effects of pre-plant soaking treatments on hardwood cuttings of peachleaf willow

Derek Tilley, Range Conservationist, and **J. Chris Hoag**, Wetland Plant Ecologist, USDA - Natural Resources Conservation Service, Plant Materials Center, Aberdeen, ID 83210

INTRODUCTION

Dormant hardwood cuttings of willow (*Salix*) and cottonwood (*Populus*) species are commonly used for riparian restoration and bioengineering efforts (Hoag 2007; Schaff et al. 2002). The greatest factors for successful restoration plantings are cutting placement in the soil profile and matching species to soil texture and moisture availability (Bentrup and Hoag 1998; Pezeshki and Shields 2006). Other factors, such as herbivory and competition for light, water and nutrients by other plants, are also important to the long-term survival of cuttings. Studies have indicated that one practice that can help increase initial survival rates is the soaking of dormant cuttings in water prior to planting. Several studies performed on black willow (*Salix nigra* Marsh.) showed that pre-soaked posts had increased root, shoot and leaf biomass as well as improved overall survival when compared with non-soaked posts (Schaff et al. 2002; Pezeshki et al. 2005; Pezeshki and Shields 2006). Other studies show similar results for nursery grown cottonwood and poplar clones (Krinard and Randall 1979; Phipps et al. 1983; Desrochers and Thomas 2003). Additionally, Edwards and Kissock (1975) found increased root and shoot development resulting from soaking 9 ft willow and poplar poles at water depths of 2 in, 31 in, or fully submerged versus unsoaked. They also noted different total water weight gain as well as different rates of water uptake for the different treatments.

It has been suggested that the increased survival and root and shoot production gained from pre-soaking is a result of improved stem water content coupled with early root and shoot initiation during soaking (Phipps et al. 1983; Schaff et al. 2002). In many cases cuttings used in riparian restoration efforts encounter water stress before developing a sufficient root system (Edwards and Kissock 1975). The increased water content provided from pre-soaking is believed to allow cuttings to more readily cope with the often stressful conditions associated with planting by delaying desiccation and loss of cell turgor (Schaff et al. 2002). Quicker initiation of roots and shoots also aid the cuttings in droughty environments and can help cuttings compete with other vegetation found at the site. Phipps et al. (1983) summarized that pre-soaking in water is beneficial under hot, dry conditions that induce high moisture stress, but may also be beneficial under ideal conditions.

There is a great deal of variation on how to pre-soak dormant cuttings. One way is to soak the cuttings in the stream where the restoration is taking place. Other ways include soaking cuttings in buckets, troughs or garbage cans. Water conditions differ with each of these methods.

Shallow, still waters generally have higher temperatures than deeper, flowing streams. Some cuttings may be fully submerged under the water's surface, while some have portions exposed to the air. Recommendations for soaking durations also vary, ranging from 24 hrs (Hoag 1991), to as long as 14 days (Briggs and Munda 1992). Cutting diameter is also believed to be an important factor in increasing cutting survival. In streambank restoration and bioengineering practices, cuttings less than 0.38 inches are generally not recommended for use in actual streambank plantings because of limited energy reserves in the stem (Hoag 2007). Nursery protocols where the cuttings are grown in controlled conditions on benches differ with some using 0.19 inch diameter cuttings for bareroot stock propagation (Zeidler and Justin 2003), and others using 0.55 to 0.98 inch diameter cuttings (Mathers 2003).

In this study we addressed the following questions to determine the most effective strategy for successful cutting establishment.:

1) Is pre-soaking beneficial?
2) What temperatures are optimum for soaking?
3) At what depths should cuttings be soaked, fully or partially submerged?
4) How long should cuttings be soaked?
5) What is the best diameter cutting to plant?

We also examined cutting water weight gain in response to the different soaking treatments, and evaluated cutting survival as a factor of cutting size regardless of pre-treatment to determine the ideal size cutting for planting. For this study, we chose to use peachleaf willow, a tree-type willow, native to riparian zones in low to mid-elevation plant communities in the United States. The species is commonly utilized in riparian restoration and streambank bioengineering projects throughout its native range and is known to have good to excellent rooting capabilities.

MATERIALS AND METHODS

The trial was designed as a randomized complete block with 4 replications. Each replicate consisted of five cuttings. Cuttings were harvested from multiple accessions on March 5 and 6, 2007 at the Aberdeen Plant Materials Center (PMC) from trees established in 1994. The base of the cuttings ranged in diameter from 0.3 to 0.9 in and 18 inches long. All secondary branches were trimmed off in the field.

Cuttings were subjected to increasing durations of four soaking treatments (partially submerged in warm and cold water, and fully submerged in warm and cold water) plus a non-treated control. The partial soak treatments were placed vertically in five gallon buckets with a maintained water depth of 11.5 to 14 in. Full soak treatments were placed horizontally in styrofoam coolers and weighted down with metal frames so that the water was between 2 to 4 in over the top of the cuttings. Cold soaking treatments occurred in dark conditions in the PMC storage cooler, while the warm treatments occurred under natural light schedules in the PMC greenhouse. Temperatures for the cold treatments were maintained around 35º F and warm soaking treatments ranged from 60 to 68º F. Soaking initiation was staggered so all cuttings would be ready for planting on the same date. Cuttings not soaking were kept in cold dry storage at 35 º F to maintain dormancy. Cuttings were allowed to soak for 1, 2, 6, 14 or 21 days and were then planted into 40 cubic inch "contetainers" filled with a mixture of 80% vermiculite and 20% perlite and placed on a greenhouse mist table. All roots and shoots that had formed prior to planting were removed by hand to approximate root and shoot damage occurring at field plantings. All cuttings received approximately 0.8 inches of water every 7 days from overhead misters. This low water rate, compared to 0.98 to 1.82 inches of water every 7 to 10 days used by nurseries (Mathers 2003), caused water stress and allowed only the most vigorous cuttings to survive. Greenhouse temperatures were maintained between 68 and 86 ºF. Twenty-eight days after planting, cutting survival, and air dried root and shoot biomass production were evaluated. Because the survival data did not meet assumption of normality, data were analyzed using the Friedman non-parametric two-way analysis of variance.

Cutting survival was also evaluated against cutting diameter without regard to pre-soaking treatment. This was done by analyzing survival of all cuttings as a completely randomized design and plotting a linear regression for the data. To be sure there was a totally random assignment of cuttings of different diameters to each of the 21 treatments, an analysis of variance was conducted on cutting diameter per treatment. No significant differences were detected ($P=0.1738$).

A second set of cuttings was used to evaluate water weight gain caused by different soaking treatments, and to determine at what duration maximum weight gain from soaking occurred. Six cuttings were pre-weighed prior to soaking in cold or warm water. Weights were then taken at 1, 7, 14, 21, 28 and 35 days after initiation. Development of any epidermal lesions (ruptures in the bark where roots will emerge), roots or shoots was documented. Roots and shoots were trimmed before weighing to measure only water weight gain within the cutting. In those cases where root and shoot growth had occurred, growth was evaluated by measuring the length of the longest root or shoot. The same cuttings were evaluated repeatedly for the cold treatments where there was no root or shoot growth. However, different batches of cuttings were used for each soaking duration in the warm treatments where root and shoot removal may have affected later measurements.

To test if long-term soaking treatments had an effect on the overall health of cuttings, the cuttings used in the weight gain test were planted into five gallon buckets filled with water following the 35 day evaluation. The cuttings thus had ample water and ideal conditions in which to grow. Cuttings survival and root and shoot growth were evaluated after 28 days and these data compared to data obtained from the survival study to ascertain if long-term soaking treatments had any detrimental effects. These results were strictly observational and were not analyzed statistically.

RESULTS

Survival and growth

When portions of the cuttings were exposed to air (partial soak treatments), root lesions and buds began to form after about 7 days of soaking in warm water. Root and shoot elongation was first visible between 7 and 14 days. Cuttings fully submerged in warm

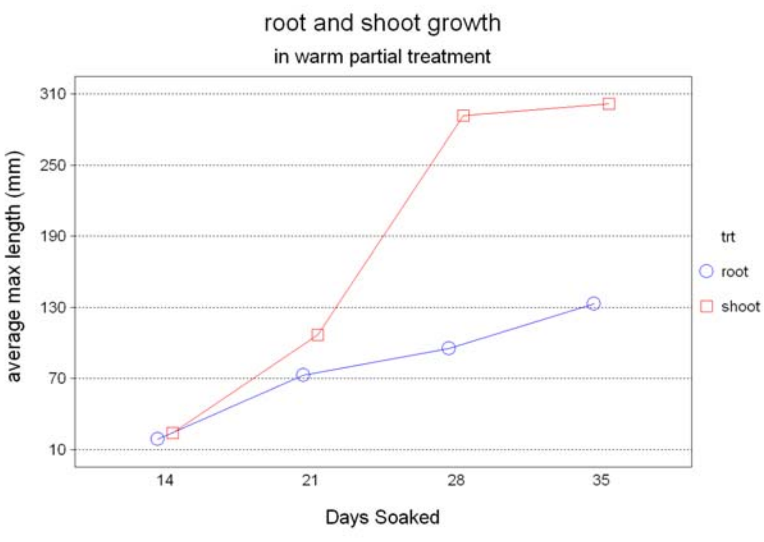

Figure 1. Root and shoot growth in average maximum length while soaking partially submerged in warm water.

water showed epidermal lesions after 14 days, and by 35 days all cuttings in the warm full treatment had epidermal lesions present. However no fully soaked cuttings ever showed signs of root or shoot growth, even after 35 days. Additionally, no cuttings in either of the cold treatments ever showed any indications of breaking dormancy.

Significant differences were detected in survival response to pre-plant soaking treatments ($P<0.0001$). Survival generally increased with longer durations of soaking (figure 2). One hundred percent survival was achieved by pre-soaking partially submerged cuttings in cold water for 14 days. Other pre-soaking treatments had varying levels of success. Nearly all pre-soaking treatments had better survival rates than the non-soaked control treatment. Only the 1 day cold water partial soak had zero percent survival. Survival of the cold partial treatments increased until reaching 100% at 14 days and then dropped to 80% after 21 days. The highest survival for the fully submerged cold treatment came at 21 days (80%); however the trend for the cold full treatment was still increasing. Longer soaking periods under fully submerged cold conditions may produce even better survival rates.

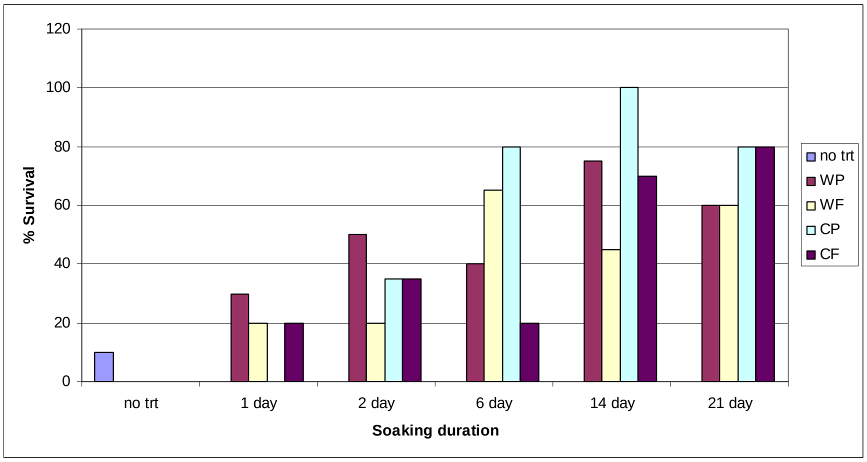

Figure 2. Survival of dormant hardwood peachleaf willows following different presoaking treatments.

- ***WP****=warm partially submerged,*
- ***WF****=warm fully submerged,*
- ***CP****=cold partial,*
- ***CF****=cold full.*

Cutting survival increased as soaking duration lengthened. P<0.0001.

Plants that did survive produced varying amounts of roots and shoots which were not readily separable statistically ($P=0.38$ and $P=0.21$ respectively). Shoot growth averaged from 0.75g per cutting to 0.008 g per cutting. Root growth ranged from 0.31 g to 0.003 g per cutting. The 14 day and 21 day warm partial treatments both had root and shoot growth prior to planting. Removal of the roots and shoots appeared to set back new root and shoot initiation and, in the case of the 21 day warm partial treatment, killed the above ground portion of the cutting (figure 3). Sites where roots and shoots had been removed never recovered and resprouted; all growth came from new growing points.

Figure 3. Cuttings 28 days after planting that had been pre-soaked for 21 days, partially submerged in warm water.

Cutting size

We discovered a very clear positive relationship between cutting diameter and survival (figure 4). Cuttings having diameters of 0.75 inches or greater all had 100% survival regardless of what pre-plant soaking treatment they were in. According to the regression trend, the recommended diameter for bareroot nursery stock (0.19 inches) would have had essentially zero percent survival (y= -4.4) under high water stress conditions.

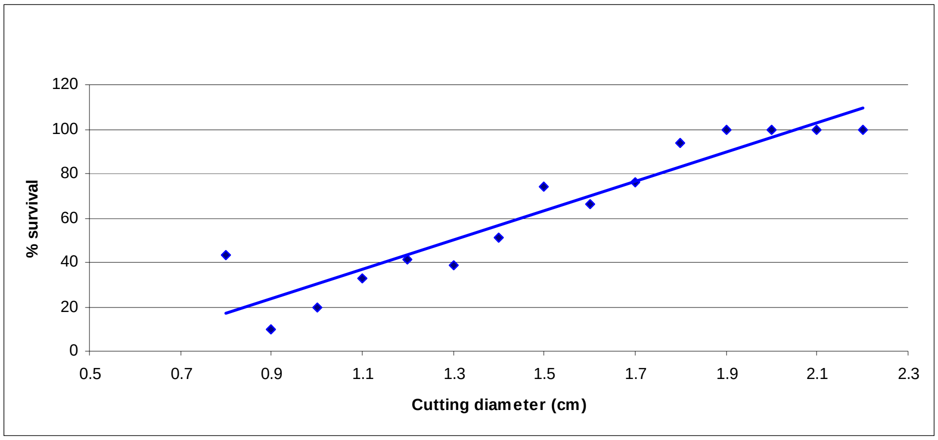

Figure 4. Linear regression graph of cutting diameter versus percent survival. y=66.25x-36.242. R^2=0.8843.

Weight gain

Soaking completely submerged cuttings in warm and cold water resulted in steady weight gain. Both treatments had reached approximately 45 percent weight gain at 35 days and the trend was still increasing, so no optimum duration for peak weight gain was discovered (figure 5). Soaking cuttings partially submerged in cold water also had steady gains, but leveled at just under? 20%. Cuttings soaked partially submerged in warm water produced small weight gains after seven days, but lost weight after root and shoot initiation as water stored in the cutting was translocated to new shoots and roots. After about 28 days the cuttings resumed gaining weight, presumably as cells began actively growing and dividing in the vascular cambium. When compared to the survival data, it becomes apparent that higher levels of water in the stem cannot wholly account for improved survival. The highest survival rate was achieved by the 14 day cold partially submerged treatment which would have had approximately 16 percent weight gain. All of the fully submerged soaking treatments from cold and warm water had higher weight gains, yet lower rates of survival.

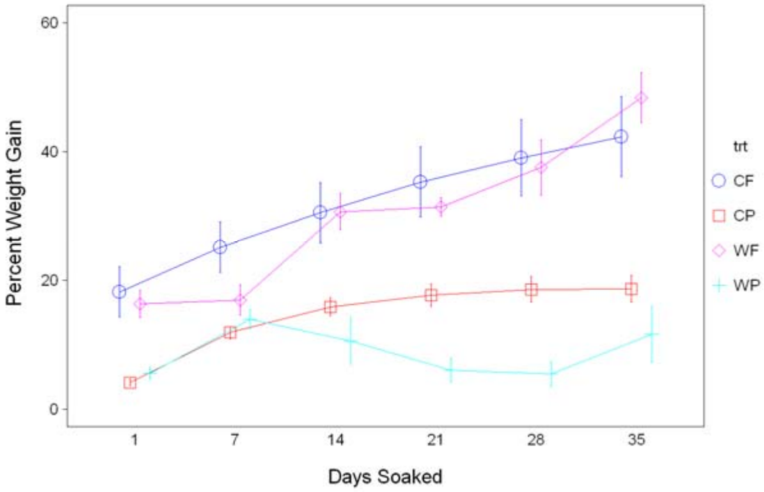

Figure 5. Cutting weight gain as a result of soaking. Fully submerged treatments had far greater weight gain than those of partially submerged treatments.

Cutting health after long-term soaking

No apparent damage occurred to cuttings in the cold soaking treatments after 35 days. Water in the warm full soaking treatment turned cloudy after several days, while the water used for other treatments remained clear. After soaking for 35 days, all cuttings were planted into five gallon buckets filled with water. Survival was, 100% for the cold full soak, 100% for the cold partial soak, and 33% for warm full soak treatment. All cuttings from the cold soaking treatments had excellent vigor and root and shoot growth. Cuttings from the warm full soak treatment were covered in a slimy film and were slow to produce roots and shoots. Only two of six cuttings from the warm full soak treatment produced roots or shoots, and these were much smaller and less vigorous than those from the other treatments. Root and shoot growth after 28 days averaged 3.18g (shoot) and 0.36g (root) for the cold partial treatment and 2.06 g (shoot) and 0.25 g (root) for the cold full treatment. Growth from cuttings in the warm full treatment averaged much lower, 0.39 g (shoot) and 0.06 g (root). It is unclear what affected the cuttings in the warm full soak treatment. Possibilities include, but are not limited to, fungal or bacterial infection, or the cuttings simply drowned without oxygen being supplied to the cells once dormancy was broken due to warm temperatures.

SUMMARY

Pre-plant soaking of dormant peachleaf willow cuttings can increase cutting survival under stressful conditions. All soaking treatments tested had better survival than the non-soaked control treatment, with the exception of a single day soaking partially submerged in cold water. Cuttings soaked for 14 days partially submerged in cold water had 100 percent survival. The survival of cuttings in the fully submerged cold soaked treatments was greatest (80%) with a 21 day soak, the longest duration tested. It is unknown whether or not longer soaking periods of this treatment would have resulted in even better survival. Soaking for extended durations in warm water with portions of the cuttings exposed to oxygen can initiate root and shoot growth which can be easily damaged and affect the vigor of the cutting.

Water weight gain does not appear to be the only factor determining increased survival from pre-soaking. Fully submerged cuttings in cold and warm water had much greater weight gain than those from partially submerged cuttings of the same duration, but there appeared to be no corresponding increases in survival.

Increasing cutting diameters resulted in higher rates of survival. Cuttings 0.75 inches in diameter and larger had 100 percent survival. Using cuttings of this diameter may not be feasible for nursery stock propagation, and the increased vigor may not be necessary under the ideal moisture conditions provided in typical greenhouse situations; however, these data suggest that for streambank restoration and other “natural” site applications, use of larger diameter cuttings would be beneficial.

From the data gathered in this study, we recommend soaking peachleaf willows for seven to fourteen days in cold water. This can be accomplished by using streams, ponds or backwaters at or near the planting site, especially in early spring when streams are full with snowmelt water. Temperatures should be watched carefully. As daily air temperatures increase, the cuttings should be monitored for any signs of growth, especially if the cuttings are not kept fully submerged. Best results will come from planting cuttings before buds form and epidermal lesions appear on the cutting. By doing this, water content should be high, and the roots and shoots are ready to emerge.

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