Probable Causes for Willow Post Mortality

F. Douglas Shields, Jr., S. Reza Pezeshki, and Peter H. Anderson[1]

Abstract

Described is a field pilot study wherein environmental data and biological response were measured for 13 posts along Harland Creek, Mississippi in July-October, 1996. Highest levels of mean net photosynthesis were associated with posts planted at moderate elevations in silty sands. Photosynthetic activity was lower for posts in sands and gravels at higher elevations and for those in sandy gravel at very low elevations. Biomass for posts planted at moderate elevations was sensitive to soil texture: aboveground and root biomass from posts in silty sand were about six times greater than from posts in slightly more cohesive soils.

Introduction

Planting of dormant willow posts has been recommended for revegetating riparian zones and controlling accelerated streambank erosion. This approach potentially offers a low cost bank stabilization technique that fosters restoration of riparian attributes and eventual recovery of instream habitat quality. Excellent results have been reported for willow post installations in Illinois (Frazee and Roseboom 1997) and Wisconsin (Pingry et al. 1997), but survival rates for willow post projects along incised channels in northwestern Mississippi have been disappointing (0 to 40%) (Cooper et al., 1997). In addition, Wolfe (1992) reported two-year survival of < 6% for small willow cuttings planted on unstable, eroding streambanks. Reasons for post mortality are unknown, but many factors have been suggested including soil conditions, stresses imposed by high velocity flows, and parasites (Grissinger and Bowie 1984, Watson et al. 1997). This study was designed to focus on physiological responses of willow posts to soil conditions.

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[1] Rsrch Hydr Engr, USDA-ARS National Sedimentation Laboratory, P.O. Box 1157, Oxford, MS 38655; Assoc. Prof. and Graduate Assist., Dept. of Biology, University of Memphis, Memphis, TN 38152, respectively.

Soil redox potential (Eh) is responsive to moisture content (flooding) and is expressive of a suite of conditions that significantly affect plant growth and survival. Low soil Eh conditions (say < +350 mV), which typically occur as soils become anerobic after prolonged flooding, can impose substantial stress even on flood-tolerant plants (Pezeshki 1991 and 1994). Although the general response of plants to depressed Eh is well understood, the tolerance limits of willow species have not been established. Preliminary field observations suggested that anerobic soil conditions may be the primary cause of failure of willow posts. Therefore, this study focused on monitoring soil Eh and the physiological functions and growth of willow posts planted along an incised stream in central Mississippi.

Study Site

Field work was conducted on black willow (*Salix nigra*) posts planted along Harland Creek, an incised, sinuous sand and gravel bed stream in central Mississippi. The study site has been described by Watson et al. (1997). About 9,400 dormant willow posts were planted along 4 km of Harland Creek in February and March, 1994. Posts were at least 8 cm in diameter and at least 3 m long. Dormant posts were planted on 1 m centers in holes 2.4 m deep that were created using a hydraulic auger (Derrick 1997). Posts were arranged in four rows parallel to the channel, with the first row 0.6 m from the water's edge at the time of planting. Watson et al. (1997) estimated post survival by examining posts located along 12 selected transects, each about 6 m wide and running perpendicular to the channel. Overall survival eighteen months after planting was estimated to be 41%.

Materials and Methods

Thirteen surviving posts were selected for detailed study during the third growing season after planting (summer, 1996). All posts were located on the outside of a bend along a 200-m reach of Harland Creek. These posts were located at various distances and elevations from the creek. Bank soils adjacent to the study posts were sampled and characterized to a depth of 1 m, and these data were complemented by additional data collected by Wilkerson (1997). During the period from July through October 1996, water table elevation, groundwater dissolved oxygen concentration, soil pH and soil Eh were measured monthly adjacent to the study posts. In addition, net photosynthesis and stomatal conductance were measured during each monthly field visit. Methods are described by Pezeshki (1997).

At the conclusion of the growing season, biomass was collected from seven of the study posts. Soil around each post was removed using a fire hose fed by a portable pump that drew water directly from the creek. Soil was removed to the level of the water table around each post. This depth varied with elevation in respect to the creek. Root material was collected within a one-meter radius of each post and separated into three classes by depth from the soil surface (0-15, 15-30, and 30-60 cm). Root material was not collected below 60 cm because in a majority of the posts (five posts) no roots were present below 60 cm depth. For the remaining two posts the soil conditions and water table would not allow for deeper excavation. Root material was divided into live and dead components at each depth. Above-ground biomass was divided into leaf and stem components. All biomass samples were dried at 70° C until a constant weight was reached.

Results

Although each post represented a unique combination of environmental variables, posts were clustered into four groups, as shown in Table 1. Groups were based on the elevation at which the post was planted relative to low water, soil types, and depth to groundwater.

Table 1. Environmental data for willow posts, 1996, Harland Creek, Mississippi. Means followed by different subscripts are significantly different (ANOVA, $p < 0.05$)

Group (no. of posts in group[1])	Mean height of base of post above low water, cm	Mean depth to water table, cm	Mean groundwater dissolved oxygen concentration, ppm	Mean soil Eh, mV	Mean net photosynthesis, μmol CO_2 m^{-2} s^{-1}	Mean stomatal conductance, mmol H_2O m^{-2} s^{-1}
I--Upper bank, sand and gravel (2)	118_a	113_a	0.4_a	384_a	7_a	146_a
II--Middle bank, sand and silt (3)	48_b	54_b	0.1_b	172_b	11_b	170_a
III--Middle bank sand, silt, and clay (5)	37_b	58_b	$0.2_{a,b}$	107_b	10_b	168_a
IV--Lower bank, sand and gravel (3)	17_c	33_c	0.1_b	202_b	8_a	156_a

Group I: Posts planted in sandy soils at relatively high elevations (115 to 120 cm above low water) had the most favorable levels of soil Eh, but lowest levels of photosynthesis. Evidently these posts experienced stress due to water deficit. Mean depth to water table was more than twice as great for this group than for any of the others (Table 1). Unfortunately, biomass was not sampled from this group.

Groups II and III: Posts located at moderate elevations (31 to 50 cm above low water) were assigned to two groups based on visual assessment of soils and on the relative ease with which soils were washed away using the fire hose. Soil assessments were further supported by Wilkerson (1997), who reported a streamwise gradient of increasing silt and clay content (from 13% to 37%) along the bankline where these posts were located. Differences between the two mid-bank groups were not statistically significant except for biomass. Aboveground and root biomass were about six times greater for posts planted in the less cohesive, less reduced soils (Table 2). In addition, root biomass for group II was evenly distributed throughout the top 60 cm of soil, while 97% of root biomass for group III was confined to the top 15 cm.

Group IV: Posts at extremely low elevations (7 to 24 cm above low water) were planted in sandy gravel. Although water table elevations were higher than for midbank groups, soil Eh was also slightly higher (Table 1). This group exhibited relatively low levels of photosynthesis and biomass and (Table 2). Only one post from this group was sampled for biomass. All root biomass was found within 15 cm of the soil surface.

Table 2. Mean aboveground and root biomass (dry weight)

Group	Number of posts in group that were sampled for biomass	Mean aboveground biomass, g	Mean root biomass, g
I--Upper bank, sand and gravel	0	not measured	not measured
II--Middle bank, sand and silt	2	$1,029_a$	192_a
III--Middle bank sand, silt, and clay	4	173_b	29_b
IV--Lower bank, sand and gravel	1	24	100

Discussion

Although our results must be regarded as preliminary due to the small sample size and short study duration, the importance of site conditions on willow post survival and growth was clearly indicated. In general, posts on middle banks were in better condition than those at higher or lower elevations. These findings are in harmony with published census data for the entire Harland project presented by Abt et al.

(1996). Watson et al. (1997) reported depressed survival rates for posts planted on lower banks, but 50-60% survival for middle and upper banks. The survival data presented by others were not accompanied by soils data. Our environmental, photosynthesis, and stomatal conductance data reflect conditions that prevailed during the latter part of the third growing season, while biomass and survival data reflect overall response to conditions since planting.

Differences in post vigor and survival based on elevation reflect soil moisture, redox potential, and possibly other critical conditions. Live root biomass was positively correlated with soil Eh, which was related to soil type and groundwater elevation. In all groups, very little live root biomass was found in soils with Eh < 50 Mv. Root biomass and aboveground biomass were highly correlated (r = 0.94).

For a given elevation relative to the water table, soil Eh values were lower for silty soils than for sands and gravels. Only two points below the water table had soil Eh > 200 mV, while all points more than 70 cm above the water table had soil Eh > 293 mV. We did not study posts planted in silty clay; presumably, conditions for survival would have been even harsher there. In fact, willow posts planted in steep, cohesive banks on the outside of tight bends along Harland Creek have experienced almost 0% survival. Additional controlled experiments are needed to refine our knowledge of the tolerance of willow posts to environmental variables. These preliminary results suggest that groundwater levels and soil redox data from prospective planting sites would be quite useful in assessing the suitability of willow posts. In some cases it may be advantageous to place permeable soils as fill material on top of posts after they are planted or to induce sediment deposition to assure the availability of a suitable medium for survival and growth.

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