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Controlling *Phalaris arundinacea* (reed canarygrass) with live willow stakes: A density-dependent response

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ABSTRACT

We tested the use of live willow stakes to manage reed canarygrass (*Phalaris arundinacea* L.) invasions on a wetland site. We planted willow at densities of 0.60 m (2 ft) centers, 0.91 m (3 ft) centers, 1.21 m (4 ft) centers, and control (no plantings) on a sloping wetland edge at Lake Washington, Seattle, U.S.A., where reed canarygrass dominated prior to the experiment. Soil moisture content was measured along the slope gradient, resulting in three soil moisture classes per replicate. Willow leaf area index and reed canarygrass aboveground biomass were measured after each of two consecutive growing seasons and analyzed using ANCOVA. Relative to the controls, the willows reduced total biomass of reed canarygrass by 44.9% with 0.60 m spacing in the first year and by 68.0% with 0.60 m spacing and 56.1% with 0.91 m spacing in the second year. Differences in soil moisture did not affect reed canarygrass aboveground biomass or effects of willow on reed canarygrass, but did affect willow growth, perhaps through reed canarygrass competition under lower soil moisture conditions. We recommend the 0.60 and 0.91 m spacings for wetland restoration projects attempting to manage reed canarygrass through live willow staking.

1. Introduction

Phalaris arundinacea (reed canarygrass) is a sod-forming, perennial grass species found in temperate regions worldwide. Reed canarygrass is native to Europe, Asia, and North America (Cronquist et al., 1977). It is reported as an invasive weed in Afghanistan, Hungary, Japan, Indonesia, Korea, Mauritius, New Zealand, Poland, Italy, Portugal, and U.S.A. (Holm et al., 1979). In Europe, dominance by reed canarygrass has reduced the conservation value of unmanaged wet grasslands (Joyce and Wade, 1998). Reed canarygrass has gradually come to dominate neglected floodplain grasslands in central Europe, is reported to expand rapidly into abandoned alluvial meadows in France, and has invaded river banks in England after disturbance such as berm excavation (Raven, 1986; Conchou and Patou, 1987; Prach, 1992; Straškrabová and Prach, 1998). In North America, reed canarygrass is invasive in the Pacific Northwest and the Midwest, where it infests many wetland restoration projects. Although reed canarygrass is native to North America, it is thought that introgression of germplasm from a Eurasian cultivar into native genotypes may account for the invasiveness of this species (Merigliano and Lesica, 1998). Reed canarygrass is found along streams, lake margins, springs, meadows, and even montane wetlands

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(Merigliano and Lesica, 1998). Furthermore, reed canarygrass grows densely in artificially modified wetlands (Fennessy et al., 1994). While its typical habitat is poorly drained and wet areas, it is as drought tolerant as many other cool-season grasses found in humid and sub-humid regions (Marten, 1985). Reed canarygrass has been introduced across the U.S.A. as a soil binder and as forage because of its rapid above- and belowground growth and tolerance of wet soils and has been planted for use in erosion and sedimentation management (Antieau, 2004). This strongly rhizomatous species suppresses other wetland plants, thereby diminishing biological diversity. For example, Lesica (1997) demonstrated that reed canarygrass displaced populations of the endangered aquatic plant *Howellia aquatilis*. Reed canarygrass has also been shown to reduce plant species richness in wetlands altered by beaver (Perkins and Wilson, 2005).

Management strategies for reed canarygrass infestations include mowing, herbicide application, grazing, cultivation, burning, shading, flooding, and mechanical barriers. Lindig-Cisneros and Zedler (2001) found that reed canarygrass did not germinate in the dark and observed that reed canarygrass easily established seedlings after canopy disturbance. Rapid development of a dense canopy in a managed wetland reduces the number of microsites available for reed canarygrass seed germination (Lindig-Cisneros and Zedler, 2002). Heavy shade decreases reed canarygrass aboveground biomass by up to 97% in greenhouse experiments (Maurer and Zedler, 2002; Perry and Galatowitsch, 2003), and barnyardgrass (*Echinochloa crus-galli*) reduced reed canarygrass biomass by 65% in an experimental wetland (Perry and Galatowitsch, 2003). Mature reed canarygrass is also reported to be intolerant of deep shade (Cooke, 1997), However, controlled experiments demonstrating responses to shade from trees are lacking.

Many chemical agents are available to land managers for invasive species control. However, biological agents are preferable due to minimal or acceptable side effects. In addition, ecological engineering principles (Bergen et al., 2001) suggest that an appropriate approach to the solution of problems caused by the invasion of reed canarygrass would include (1) design, (2) sustainable systems, and (3) would be consistent with ecological principles. Identifying effective biological means for managing reed canarygrass infestation is a top priority for restoration managers. We view willow staking as an appropriate technique. The design of the method can be tailored to the density of reed canarygrass and may be modified depending on site conditions (sun, water). The system is sustainable because of the hardy and vigorous nature of willows, yet in-planting may occur or areas of willow cleared after site conditions have been satisfactorily modified. The use of willows is consistent with ecological principles; competition from a taller growth form is used to attack a shorter growth form that is dependent on the sun. Here we report field results from a controlled, replicated experiment that tested the effectiveness of three live willow stake planting densities in reducing biomass of the reed canarygrass where it dominated a wetland area. Our goals are to investigate whether willow live-staking is effective for reducing reed canarygrass biomass, to identify the threshold of soil moisture content above which either the willow or reed canarygrass lose their competitive ability, and to determine whether planting density significantly affects the ability of willow to control reed canarygrass through shading.

2. Materials and methods

2.1. Site description

The study site was the East Basin of the Union Bay Natural Area (lat. 47°N 39.5′, long. 122°W 17.2′; Seattle, Washington, U.S.A.), a sloping wetland along the western edge of Lake Washington (Fig. 1). The basin has a generally south-southeast aspect and is on glacial till. The lower portion of the site is modified fill, which is saturated year round at the shoreline. Monotypic stands of reed canarygrass dominate the East Basin landscape, with estimated cover >95%.

The periphery of study site is characterized as abandoned, highly disturbed ground with non-native *Rubus armeniacus* (Himalayan blackberry) covering ~50–60% of the site in dense thickets. *Phalaris arundinacea* (reed canarygrass) appears in large patches in the wetland and buffer area, with *Lythrum salicaria* (purple loosestrife), *Ranunculus repens* (creeping buttercup), and *Iris pseudacorus* (yellow-flag iris) also abundant in places. *Hedera helix* (English ivy) is found sporadically across the site, sometimes reaching 5–6 m up the stems of the taller trees. Native trees include several mature specimens of *Populus trichocarpa* (black cottonwood) in the eastern portion of the site, as well as *Alnus rubra* (red alder) in the eastern and southern portions. Less common native species include *Spiraea douglasii* ssp. *douglasii* (hardhack), *Rosa pisocarpa* (clustered wild rose), *Polystichum munitum* (western sword fern), *Fraxinus latifolia* (Oregon ash) and *Crataegus suksdorfii* (black hawthorn). *Salix lucida* ssp. *lasiandra* (Pacific willow) is found in the primarily wetland areas of the eastern and southern portions of the site, covering ~15% of the basin. *Salix scouleriana* (Scouler willow), *Salix lasiandra* (Pacific willow), *Juncus effusus* (common rush), *Typha latifolia* (cattail) and *Carex* spp. also occur. Significant areas of bare soil occur along the seasonally fluctuating shoreline.

2.2. Plot establishment

All aboveground vegetation on the study site was removed by mowing in spring and summer of 2003 to prepare for planting live willow stakes. Three foliar applications of Roundup® were made to control vegetation regrowth in summer of 2003, and spot foliar applications of Crossbow® were made to suppress Himalayan blackberry in summer of 2003. The subsequent regrowth was mowed down and wood chip mulch was spread evenly across the area at a depth of 10–15 cm from the spring to the fall of 2003 to slow reed canarygrass regeneration.

The study site was 0.09 ha in size, and ran 72 m along the edge of Lake Washington. The site was divided into seven replicate blocks in spring 2004. Within each block, four treatments (three willow densities and an unplanted control) were applied in strips that ran from the upper edge of the site toward the lake margin. Each treatment strip was 2.57 m in width. The vertical length of each block varied from 10 to 15 m, according to the varying dimensions of the site (Table 1). The mean vertical length of all seven blocks was 12.6 m (Table 1).