Water level affects growth of endangered northeastern bulrush, *Scirpus ancistrochaetus*
Schuyler

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Abstract

The effect of four static water levels (−5, 0, +5, and +10 cm in relation to the soil surface) and five sites (origin of parent plant) on growth of the federally endangered northeastern bulrush, *Scirpus ancistrochaetus*, was examined in a greenhouse experiment. Maximum live leaf height was not affected initially by water level. By mid-experiment, leaf height was greater at higher water levels but did not differ among treatment water levels by the close of the experiment. Final biomass did not differ among any treatment. The ratio of final root to shoot mass (R:S) decreased with an increase in water levels from 0 to 10 cm. The ratio of final live shoot mass to dead shoot mass (LS:DS) was affected by both water level and site. LS:DS was lower in the two higher water levels, suggesting a shorter leaf life span at these depths. Final LS:DS of plants from each site had a significant negative linear relationship with initial site plant mass, perhaps due to different developmental stages or ages of offshoots of plants collected from each site. Small differences in water depth were found to affect height, leaf life span, and R:S in this species while site-of-origin had little effect on growth under greenhouse conditions. Even moderate changes in water level therefore may be an important factor in growth of *S. ancistrochaetus* in the field and management decisions related to conservation of this species should take possible disturbances to the hydrologic regime under consideration. © 1998 Elsevier Science B.V.

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1. Introduction

An important controlling influence in aquatic and emergent plant communities is the stress of inundation. For example, water level can affect the distribution of aquatic plant species (van der Valk et al., 1994; Coops et al., 1996), possibly through altering the outcome of competitive interactions (Grace and Wetzel, 1981; Berton, 1991). For many species, an increase in water level decreases root to shoot ratio (Gorbisch and McIninch, 1994; Coops et al., 1996; McIninch and Gorbisch, 1996), increases plant height and decreases overall biomass (Lieffers and Shay, 1981; Stevenson and Lee, 1987; Coops et al., 1996). Sexual reproduction has been shown to increase with increasing water level (Lieffers and Shay, 1981; Gorbisch and McIninch, 1994; Coops et al., 1996; McIninch and Gorbisch, 1996), although some plants respond in the opposite manner (Stevenson and Lee, 1987; Karagatzides and Hutchinson, 1991).

Northeastern bulrush, Scirpus ancistrochaetus (Schuyler, 1962), is an emergent sedge typically found in small depressional palustrine wetlands that exhibit annual and/or seasonal water fluctuations. S. ancistrochaetus is limited to approximately 60 extant populations in the northeastern United States and is listed as endangered by the U.S. Fish and Wildlife Service (1991). The range of water level experienced by S. ancistrochaetus within a given season can be striking; surface water levels for one pond containing S. ancistrochaetus ranged from 0 cm (late summer) to 51 cm (early spring) (Lentz and Dunson, unpublished data). In this study, the effect of different static water levels on the growth of S. ancistrochaetus was investigated to determine how hydrologic changes to a wetland may affect this species. The effect of plant site-of-origin was also examined to determine if variation existed among sites in plant response to varying water levels.

2. Materials and methods

In October 1995, greenhouse stock populations of S. ancistrochaetus were established from a field collection of culm nodal shoots. Approximately 100 shoots were collected from each of five hydrologically dissimilar native pond sites. The pond sites ranged from 7.5 to 49 km apart from each other and S. ancistrochaetus at these isolated ponds are probably not interbreeding. Rhizomatous offshoots used in the experiment were then collected from 10 to 15 greenhouse stock plants from each site. Offshoots were placed individually in 11.0 (depth) × 16 cm (diameter) pots in Peter's Plant-and-Feed potting soil and peat in a 2:1 ratio. Five potted plants, one from each of the native pond sites, were placed in a large rectangular polyethylene container (55 × 40 × 22 cm depth). Four replicate containers of each of four water depths were used. In addition, an extra set of four large containers of the same size as above was used to root plants for destructive sampling at the onset of the experiment. Containers were arranged in a completely randomized block design on greenhouse benches. All plants were allowed to root for 1 month in −5 cm of tap water.

On January 28, 1996, the water was drained from each container and filled with 'Artificial Soft Water' (ASW) to one of four treatment levels (either −5, 0, +5, or
+ 10 cm in relation to the soil surface). ASW simulated natural water concentrations of sodium, potassium, calcium and magnesium in ponds containing S. ancistrochaetum, and was created by using chloride salts of each element. At this time, plants from the extra set of replicate containers were harvested, measured, separated into roots and shoots, dried at 100°C for 48 h and weighed to determine an initial subsample of mass, height, and root:shoot ratio (R:S). In order to simulate natural photoperiods during the growing season, photoperiod was increased incrementally from 10 h to 16 h in 1 h intervals over a period of 12 weeks starting in late February. Natural daylengths were supplemented with sodium vapor lamps as necessary. Light intensity of photosynthetically active radiation (PAR) measured with a quantum radiometer/photometer (Li-Cor Model LI-185B) ranged from approximately 400–1000 μE/m²·s PAR, which is similar to the amount these plants encounter in the field. Greenhouse temperatures averaged 25°C.

Water levels were monitored every 2–3 days and refilled to each treatment level with distilled water to compensate for evaporation. The length from the soil surface to the tip of the longest live leaf (height) in each pot was measured in 1–4 week intervals. From September 26 to October 3, blocks were disassembled, one per day. Final height of the tallest live leaf on each plant was measured. The plants were separated into roots, live shoots and dead shoots, dried and weighed as above. Vegetative growth and rhizomatous vegetative reproduction were therefore not differentiated in the biomass measurements in this study.

Two-way Analyses of Variance (ANOVA)s were used, with fixed site and block effects, for R:S, height and total biomass of the initial subsample (SAS Institute, 1989). Height and final data were analyzed using a split-plot design in four fixed blocks, with water level as the fixed main plot factor, and native pond site as the fixed sub-plot factor. Six separate dates, spaced approximately 6 weeks apart, were analyzed for effect of water level and site on the maximum live leaf height of each plant. A Multivariate Analysis of Variance (MANOVA) was conducted using each date as a separate variable.

Fig. 1. The maximum live leaf height of plants in each water depth (mean ± SE) over time, averaged over all five sites. Asterisks indicate that the univariate ANOVA was significant for that date. Within each date, treatments with the same letter are not significantly different from each other.
in the model (von Ende, 1993). The ratio of final live shoot mass to final dead shoot mass (LS:DS), R:S and total biomass were used in a separate MANOVA. The one plant that died during the experiment was removed from all statistical analyses. Transformations were made as needed for all statistical analyses to meet the model assumptions of normality and homoscedasticity. If significance was found in a MANOVA (using an $F$ statistic calculated from Wilk’s $\lambda$), separate univariate ANOVAs were conducted, followed by a Tukey test to determine significant differences between means. The alpha level used for all tests was 0.05.

3. Results

Initial R:S and height did not differ between sites ($F_{4,12} = 1.56$, $p = 0.25$ and $F_{4,12} = 0.35$, $p = 0.84$, respectively). Biomass, however, initially differed between sites ($F_{4,12} = 4.08$, $p = 0.026$). An overall significant effect of water level ($F_{18,12} = 3.93$, $p = 0.010$) but not site ($F_{24,148} = 1.45$, $p = 0.096$) on the maximum height of each live

![Graph A](image1)

**Fig. 2.** (A) Final live shoot:dead shoot mass and (B) final root:shoot mass in each water level treatment (mean ± SE), averaged over all five sites. Treatments with the same letter are not significantly different from each other.
leaf over six dates was found in the MANOVA. Maximum leaf height did not differ between water level treatments initially (Fig. 1). By March 21, plants in the higher water levels were taller. This trend continued through June 29, but height in all water level treatments converged by August 18.

In the MANOVA, water level ($F_{9,17} = 5.01$, $p = 0.0021$) and site effects ($F_{12,119} = 2.43$, $p = 0.0073$) on final biomass, LS:DS, and R:S (both live and dead shoots) were significant. Final biomass was not significantly different among water levels ($F_{3,12} = 0.43$, $p = 0.74$) or sites ($F_{4,47} = 0.60$, $p = 0.66$). LS:DS differed significantly between water levels ($F_{3,12} = 23.1$, $p = 0.0001$) and sites ($F_{4,47} = 4.27$, $p = 0.0050$). LS:DS for each treatment fell into two distinct Tukey groupings of two means each: the highest water levels had the smallest ratios and the lowest water levels had the highest ratios (Fig. 2A). LS:DS also differed between sites; however, this difference may be due to differences in the initial mass of plants from each site. A regression analysis of final mean LS:DS of plants from each site vs. mean initial biomass of plants from each site showed a significant negative linear relationship ($r^2 = 0.84$, $F_{1,3} = 15.48$, $p = 0.029$).

R:S differed between water levels only ($F_{3,12} = 4.72$, $p = 0.030$). The only significant difference between water level treatments was found between the 0 and 10 cm treatments, but R:S in general decreased from 0 to 10 cm (Fig. 2B).

4. Discussion

*S. ancistrochaetus* responded to increasing water levels with an decrease in both LS:DS and R:S and an increase in height. Increased leaf extension in response to submergence is a common response of many aquatic plants, mediated by the release of ethylene (Jackson, 1985; Ridge, 1987). The height response was not immediately detectable, possibly due to slow growth during the early stages of the experiment. Differences in height became evident in late March, when photoperiods reached 14 h, and all plants exhibited a marked overall increase in growth. The differences in height between water depths disappeared at the close of the experiment, possibly due to plant roots becoming restricted in their pots.

The lower LS:DS in the higher water levels suggest that leaf life span was shorter at these levels. This study is the first to suggest decreased leaf life span in response to increased water level in *Scirpus* spp., although the results are not unexpected based on earlier evidence. Because ethylene concentration can increase with increasing water depth through impedance of ethylene diffusion in water (Jackson, 1985), plants were probably subjected to a higher concentration of ethylene at higher water levels. Since ethylene has been implicated in foliar senescence (Roberts et al., 1985; Smart, 1994), increased ethylene concentration at higher water levels may have caused leaves to senesce faster.

R:S decreased with increasing water depth from 0 to 10 cm, a response found in other studies (Garbisch and McIninch, 1994; Coops et al., 1996; McIninch and Garbisch, 1996). However, in the −5 cm water depth, R:S was unexpectedly low. Total biomass (root + shoot) did not differ between water level treatments, which conflicts with many studies (Lieffers and Shay, 1981; Stevenson and Lee, 1987; Garbisch and McIninch,
1994). However, earlier studies used a larger range of water levels which may have caused more pronounced effects on biomass and survival.

Plant site-of-origin was found to have an effect on only LS:DS in this experiment. This difference was negatively correlated with the initial biomass of plants from each site and therefore is probably related to the developmental stage or age of each offshoot collected. This is not unexpected, since older (and therefore probably larger) plants would be expected to have a higher proportion of senesced leaves than their younger counterparts. Therefore, for the sites examined, there was apparently no ecotypic variation among sites in response to water level.

5. Conclusion

This greenhouse study has important implications for management of *S. alterniflora* in the field. Increase in water levels through such practices as logging could adversely affect existing populations by causing leaves to senesce faster. The loss of potential capture of resources when leaves die early could influence other important processes such as reproduction, both asexual and sexual. The decrease in R:S with increasing water depth, without any overall differences in total biomass, suggests that at lower water levels, more resources are allocated to below-ground structures, creating a larger reserve to be used for asexual reproductive growth or growth of new shoots the following spring (Steinmann and Brandle, 1984). Conversely, a decrease in water level due to an impact such as groundwater pumping could also detrimentally affect this species. Although growth was not adversely affected in this study at low water levels, this is not necessarily representative of what may happen in field populations. This species may be a poor competitor in dry soils and a decrease in water levels may allow species that are not as tolerant to inundation, yet are better competitors, to dominate (Grace and Wetzel, 1981; Bertness, 1991).

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References


