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Effects of burial depth and water depth on seedling emergence and early growth of *Scirpus planiculmis* Fr. Schmidt

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ABSTRACT

Seed burial and water regime are both crucial factors influencing seedling emergence and plant growth in wetlands and thus exert important effects on revegetation in degraded wetlands. We conducted a pot experiment to determine the effects of burial depth and water depth on the seedling emergence and growth of *Scirpus planiculmis* Fr. Schmidt. Seeds of *S. planiculmis* were buried at 0, 0.5, 1 and 2 cm depths in plastic pots with non-sterilized sediment under exposed (−5 cm), waterlogged (0 cm) and submerged (5 and 10 cm water depths relative to sediment surface) water regimes. The results showed that the percentage of seedling emergence at a burial depth of 0 cm was enhanced under 10 cm and 5 cm water depths (78.89% and 81.37%, respectively) in comparison to the results under −5 cm and 0 cm water depths (0 and 2.22%, respectively). Seedlings did not grow through the water to the surface and no tuber formed when covered by 10 cm of water. The total biomass per seedling was generally higher at 0.5 cm or 1 cm burial depths than that at other burial depths. The tuber number per seedling was highest at a 0.5 cm burial depth, while the value was lowest at a 0 cm burial depth. Our results provide valuable guidance for the establishment of *S. planiculmis* from seeds in wetland revegetation programs.

1. Introduction

Scirpus planiculmis is one of the important plants in the wetlands of the Momoge National Nature Reserve (MNNR) in northeastern China (Zhang et al., 2014). Tubers of *S. planiculmis* are the major food source for migratory Siberian white cranes (Hui et al., 2009). In 2010, the Chinese government started to divert water to the wetlands to improve the habitats of Siberian white cranes. Unfortunately, *S. planiculmis* abundance was very low in most of the rewetted sites and populations of this species did not establish (Liu et al., unpublished data). Limited information is available on the ecological requirements of *S. planiculmis*, and this impacts the successful establishment of the species in wetland revegetation sites.

Seed burial depth and the water regime are both critical factors influencing seedling emergence, survival and early growth (Kim et al., 2013; Sun et al., 2014). As such, they have an important role in restoring *S. planiculmis* from seeds. In general, there is an optimal range of burial depth or water depth to maximize the emergence of seeds and subsequent growth (Li et al., 2006). To date, information on the optimum environment for seedling establishment of *S. planiculmis* is very scarce. To develop a technique for restoring the plant populations, we conducted a greenhouse experiment to determine the effects of burial depth and water depth on seedling emergence and growth.

2. Materials and methods

2.1. Plant material

S. planiculmis seeds were collected at maturity in July 2013 from Etou wetland that located centrally within MNNR (45°55′N, 123°39′E). In recent years, the wetland has been used to receive flow from paddy fields (Jiang et al., 2015). Water level in Etou wetland has an obviously seasonal variation with the higher water level occurring from August to April in the next year (Jiang et al., 2015). A detailed description of the study area was reported by Wang et al. (2010). Seeds were collected from 80 individual plants across

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Table 1
Two-way ANOVA results (*F*-values) of the effects of burial depth and water depth on seedling emergence, plant height, total dry weight per seedling, and tuber number per seedling of Scirpus planiculmis Fr. Schmidt.

Dependent variable	Burial depth (*B*)	Water depth (*W*)	$B \times W$
Percent emergence (%)	4.72*	39.96***	37.56***
Plant height (cm)	1.56 ns	1.48 ns	3.00*
Total biomass (mg)	2.18 ns	5.30**	0.56 ns
Tuber numbers	2.93*	11.02***	1.51 ns
d.f.	3	3	9

ns $p > 0.05$.
*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

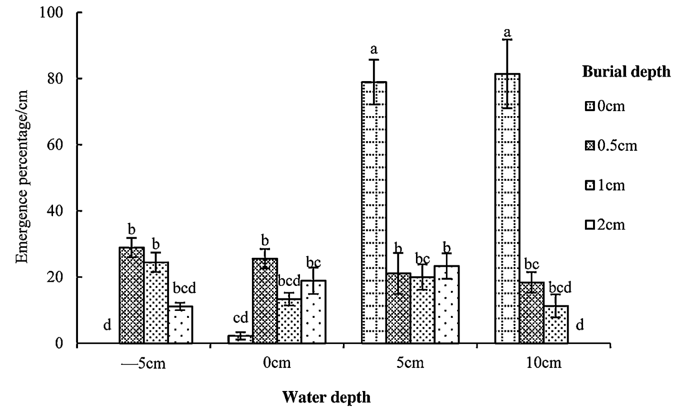

Fig. 1. Percent seedling emergence (%) of *Scirpus planiculmis* Fr. Schmidt at four burial depths and four water depths. The values are the means ± SE ($n = 5$). Different letters represent significant differences among all the treatment combinations.

the wetland. One-thousand seeds had a mass of approximately 3198 mg and a mean length:width:height ratio of 28.7:22.5:1. The seeds were cleaned, dried at room temperature for 4 weeks and then stored at 4 °C under wet, dark conditions for 3 months to break dormancy.

2.2. Experimental design

Seeds were buried at 0, 0.5, 1 and 2 cm depths in transparent plastic pots (26 cm in diameter, 20 cm in height) with non-sterilized wetland sediment under exposed (−5 cm), waterlogged (0 cm) and submerged (5 and 10 cm water depths relative to sediment surface) water regimes. The burial depth and water depth were chosen based on previous studies (Li and Zhang, 2013; Ning et al., 2014). There were five pots per treatment, and each pot contained 20 seeds. Sediment was collected from three different sample plots in Etou wetland in July 2013 from the upper 20 cm profile and was air dried, blended and crushed to pass through a 2 mm sieve. The sediment had a total nitrogen, phosphorus and soil organic carbon of 713, 224, and 1.25 mg g^{-1}, respectively (Liu, unpublished data). Sediment was poured into each pot up to the lower mark, then the seeds were assigned on the sediment surface and the pots were filled up to the upper mark (near the top) with additional sediment. All the pot had the same quantity of sediment. Pots had drainage holes at the bottom (for the exposed and waterlogged treatments), and these were covered with strips of nylon mesh to prevent sediment loss while allowing the drainage of excess water. All the pots were placed in tanks and were regularly watered with tap water to maintain the water depth. The experiments were conducted in a greenhouse of Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences.

Emerged seedlings were recorded daily. Seedling emergence was defined as the first appearance of a seedling at the surface of the sediment. After 30 days, the seedlings were thinned to three per pot, and the height of each seedling above the sediment surface was measured. Five weeks later, we measured the plant height, number of belowground tubers and biomass of all of the surviving individuals. For the statistical analysis, we used two-way ANOVA and Tukey's post hoc test (SPSS 16.0) at the 5% significance level.

3. Results

3.1. Seedling emergence

Seedling emergence of *S. planiculmis* was significantly affected by both water depth and burial depth, with significant interactions (Table 1). Only very few or no seedling emerged at the 0 cm burial depth under waterlogged (0 cm) and exposed (−5 cm) water regimes (Fig. 1). There were no seedlings emerging from 2 cm burial depth under the submerged condition (10 cm water depth). However, the optimal conditions for seedling emergence were the 0 cm burial depth under submerged conditions (Fig. 1).

3.2. Seedling morphology

Seedling height was not significantly affected by water depth and burial depth, but there was a significant interactive effect on seedling height (Table 1). The total biomass per seedling was significantly affected by water depth rather than burial depth, and there was no significant interactive effect on the total biomass (Table 1). The total biomass per seedling decreased linearly as the water depth increased (Fig. 2B). Under the water depth of 5 cm, both the seedling height and total biomass per seedling increased with increasing burial depth, but there were no significant changes among burial depths for other water treatments (Fig. 2A and B).

Tuber formation was greatly affected by the burial depth and water depth, but there was no significant interactive effect on tuber formation (Table 1). Under the 10 cm water depth, no tuber formed in any sediment depth treatment. There was no tuber formation at the 0 cm burial depth under the waterlogged and submerged (5 cm water depth) water regimes. The optimal conditions for tuber formation were at the 0.5 cm burial depth under the exposed, waterlogged and submerged (5 cm water depth) water regimes (Fig. 2C).

4 Discussion

3.3. Effects of burial depth and water depth on seedling emergence

Both burial depth and water depth influenced the emergence of *S. planiculmis* seedlings; the effect of burial depth was greatly dependent on water depth. The results showed that under the exposed and waterlogged treatments, very few seedlings emerged from the 0 cm burial depth; a similar phenomenon also occurred in other species, such as *Sagittaria latifolia*, *Scirpus* spp., *Vicia faba*. (Harper and Benton, 1966; Jurik et al., 1994). The fact that few seedlings emerged on the sediment surface could be accounted for by a higher seed weight and flat shape in *S. planiculmis*, resulting in a large surface area of the seed, for which the rate of water uptake is likely to be small relative to the rate of water loss so that the seeds are unable to absorb sufficient water to germinate. Furthermore, the percent emergence was highest for seedlings with a 0 cm burial depth when there was shallow water (5 cm to 10 cm) relative to the soil surface. Thus, an adequate water environment is necessary for the emergence of *S. planiculmis*.