Scirpus atrovirens Root Architecture Responses To Aeration And Dairy Wastewater

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Abstract

Constructed wetlands are becoming a popular alternative to conventional methods of wastewater treatment. Numerous studies have shown that wastewater contaminants are removed by wetlands. The overall goal of this research was to investigate the effects that aeration and chemical oxygen demand (COD) have on plants in constructed wetlands. Greenhouse experiments using *Scirpus atrovirens* Willd. were conducted at the University of Vermont in laboratory-scale constructed wetland cells. Measurements of biomass and root architecture, including length, surface area, diameter and volume, were taken to characterize plant responses to dairy wastewater. Data indicates that supplemental aeration has a significant negative effect on the growth of wetland plant roots, but a positive influence on reduction of COD. Roots in non-aerated cells had a greater increase in length, surface area and volume, under all COD conditions, than those grown in aerated cells. After 30 days, root length increased by 93% in non-aerated cells compared to only 18% in aerated cells. Aeration did not significantly impact plant biomass, however the addition of wastewater significantly reduced plant dry weights, and root:shoot ratios.

Introduction

The presence of vegetation has been hypothesized to play a key role in wastewater remediation. Plant species selection can have impacts on sedimentation, plant nutrient accumulation, and the creation of microenvironments that facilitate microbial degradation of contaminants (Luckeydoo *et al.* 2002). Furthermore, the removal of specific pollutants can be enhanced by the thoughtful selection of appropriate wetland plant species. Allen *et al*. (2002) found differences in organic material removal and root zone oxidation among species were greatest at low temperatures, suggesting a key role for plants in colder regions, especially during plant dormancy. In addition, root surface area will vary with species and plants with greater root surface area will provide increased area for microbial attachment and interaction with wastewater (Wolverton 1987; Stober *et al.* 1996). However, plant considerations are not always taken into account in engineering models due to lack of data. The purpose of this research was to determine the effects of supplemental aeration and dairy wastewater on the root architecture of Green Bulrush (*Scirpus atrovirens* Willd.).

Materials & Methods

S. atrovirens was grown in the green-house for 60 days[1a]. After this time, plants were removed from pots and roots were cleaned and scanned[1b] using a RHIZO-Tron scanner[1c] and WinRHIZO Pro software[2a] (Regent Instruments Inc., Quebec, Canada) to establish initial values for root size. Using the RHIZO-Tron scanner measurements were made for total root length, root surface area, average root diameter and root volume. Plants were then placed in wetland cells that were either aerated or non-aerated and contained a synthetic dairy waste (SDW) mixture with either 0, 500, or 900 mgL^{-1} chemical oxygen demand (COD)[2b]. Each cell contained eight plants and each treatment was replicated, for a total of 2 cells and 16 plants per treatment. Plants were allowed to grow into the wastewater for 15 days[2c]. At this time, wastewater was replaced and plants were allowed to grow for another 15 days. After 30 days, plants were again scanned and biomass data collected. To obtain percent growth data the following formula was used:

[(Harvest scan – Initial Scan) / Initial Scan] * 100

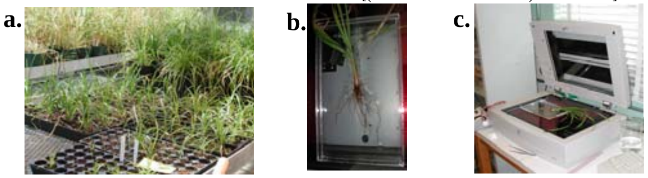

Figure 1 – Research Images (detail in text).

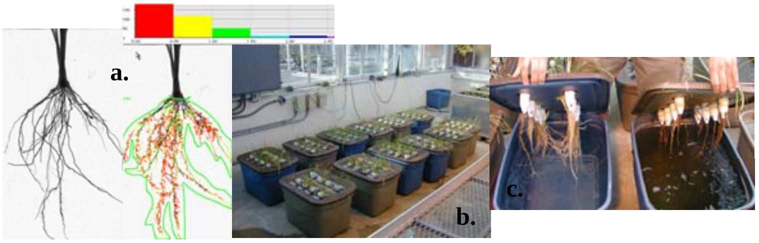

Figure 2 - Research Images (detail in text).

Results

Table 1 - *Scirpus atrovirens* ANOVA dependent variables p-values				
	p-values			
	ANOVA	Aeration	COD	Aeration*COD
Length	<0.0001 **	0.0001 **	<0.0001 **	<0.0001 **
Surface Area	<0.0001 **	0.0006 **	<0.0001 **	<0.0001 **
Average Diameter	0.3826 ns	0.6673 ns	0.1044 ns	0.7588 ns
Volume	<0.0001 **	0.0011 **	<0.0001 **	<0.0001 **
Root Dry Weight	<0.0001 **	0.3256 ns	<0.0001 **	0.3748 ns
Shoot Dry Weight	0.0085 **	0.5126 ns	0.0008 **	0.6996 ns
Root : Shoot	0.0376 *	0.6987 ns	0.0033 **	0.9414 ns
New Shoots	0.002 **	1.0000 ns	0.0002 **	0.4435 ns
** = significant at 0.01 level, * = significant at 0.05 level, ns = not significant, n=96				

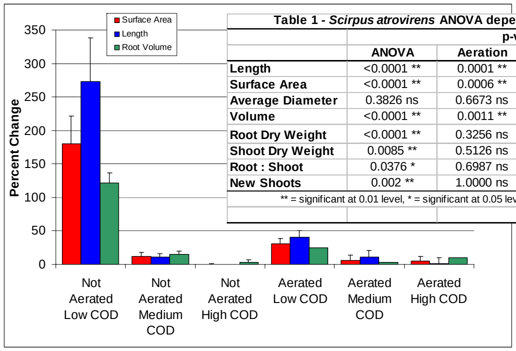

Figure 3 – Percent Change In *Scirpus atrovirens* Root Architecture By Treatment. Means ± SE, n=32.

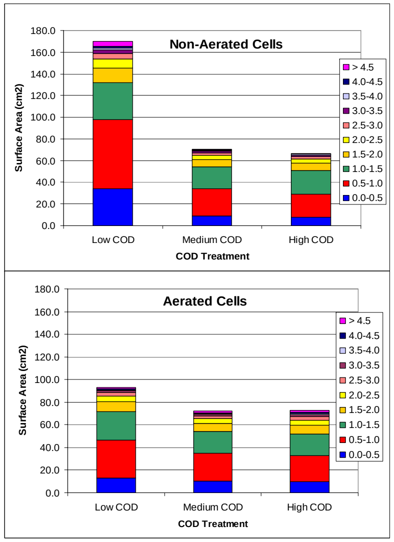

Figure 4 - Surface Area of *Scirpus atrovirens* Roots By Treatment and Root Diameter Class (mm). n=32

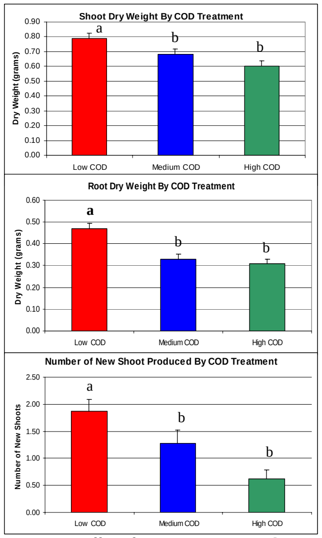

Figure 5 – Effect of COD Treatment on Shoot Dry Weight, Root Dry Weight and New Shoot Production of *Scirpus atrovirens.* Means ± SE, n=64.

Results & Discussion

Scirpus atrovirens grown in cells provided with aeration had less root growth over a 4-week period when compared to plants grown in those cells not provided with aeration over the same duration of time. Significant differences were observed in root length, surface area and volume (Figure 3). Aeration had no effect on average root diameter, root dry weight, shoot dry weight, root:shoot ratio or the number of new shoots that plants produced. The Chemical Oxygen Demand (COD) of Synthetic Dairy Wastewater (SDW) also had an effect on root growth. Plants in cells with low COD SDW showed increased root growth when compared to those plants grown in medium and high COD SDW. Plants grown in low COD SDW had roots that were significantly longer, had more surface area and greater volume than the roots of plants grown in medium and high COD SDW. Plants grown in medium and high COD SDW did not differ significantly from each other, only from the low COD SDW. No differences were observed in average root diameter between treatments. The COD of SDW also had a significant effect on *Scirpus atrovirens* biomass accumulation. Plants grown in cells with medium and high COD SDW had significantly lower root, shoot and total dry weight, as well as a lower root:shoot ratio than plants grown in low COD SDW. COD also had an effect on the number of new shoots that *Scirpus atrovirens* produced (Figure 5). New shoots produced averaged 1.88, 1.28 and 0.63 in low, medium, and high COD SDW, respectively.

Conclusions and Future Direction

Root growth of *S. atrovirens* was heavily influenced by the addition of supplemental aeration to wetland research cells. Significantly less root surface area was available for microbial colonization in aerated cells. However, as COD increased this difference became less pronounced. Additionally, the increased COD of SDW reduced plant size and new shoot emergence. These issues impact wastewater treatment and should be included in wetland design models.

The results of this research indicate that future experiments should be conducted over a range of SDW mixtures with lower COD concentrations, and variable aeration levels, to provide the data necessary for accurate wetland design models. Also, a variety of plant species should be tested to optimize plant selection in wetland design. All experiments should be evaluated under field conditions to ensure greenhouse experiments correctly reflect what happens in a working system.

Literature Cited

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