Greenhouse Modeling of Nitrogen Use Efficiency in Two Wetland *Cyperus* Species at the University of Mississippi Field Station

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Emergent wetland perennials are an effective component of wastewater treatment wetlands. Members of family Cyperaceae such as *Scirpus*, *Carex*, and *Eleocharis* are commonly used to treat nonpoint source contaminants. However, scientific literature regarding the use of the genus *Cyperus* as potential wastewater treatment species focuses on the C_4 photosynthetic types, which comprise ~80% of this genus. The C_4 pathway in *Cyperus* is evidently an adaptation to temperate wetlands and sandy, infertile environments (Li, et al., 1999). *Cyperus* species using the C_4 pathway have a high photosynthetic nitrogen use efficiency (NUE), which appears to confer a high degree of success in wetland environments with low nitrogen concentrations. This translates to a possible competitive advantage over their C_3 *Cyperus* counterparts where the latter conditions exist.

Our six–month greenhouse experiment, which began in early December 2005, was designed to quantify and differentiate nitrogen use efficiency in two facultative wetland species: *Cyperus haspan*, a C_3 sedge, and *Cyperus strigosus*, a C_4 sedge. Both species co–occur in shallow wetlands and ditches at the University of Mississippi Field Station in Lafayette CO., MS; this situation presented the opportunity to determine each species' response to long–term nitrogen dosing. Each species was subjected to nitrogen dosing regimens of both 2.5 ppm and 4.0 ppm, representing typical lower and higher nitrogen concentrations in agricultural runoff in Lafayette Co. Our expectations are that (1) *Cyperus strigosus* may have higher above– and belowground biomass in the low (2.5 ppm) nitrogen treatments than *C. haspan* at the same dose; (2) however, *C. haspan* may display higher above– and belowground biomass in the high (4.0 ppm) nitrogen treatments than *C. strigosus* at that dose level, and (3) photosynthetic pathway (C_3 versus C_4) may differentially affect the abilities of these two sedge species to sequester nitrogen in their tissues. The combination of both C_3 and C_4 sedge species planted in wastewater treatment wetlands and agricultural drainage ditches may be a more effective method of partially treating fluctuating levels of nonpoint source pollution than using either of the two types singly, since C_3 sedges may function to remove nitrogen at higher concentrations while C_4 sedges may be able to remove nitrogen more efficiently at lower concentrations.

Keywords: Nitrate contamination, nonpoint source pollution, wastewater, wetlands

Introduction

Nitrogen is frequently a component in nonpoint source pollution from agricultural activity (Cooper and Moore, 2003). Ditches and downstream wetlands intercept nonpoint source pollution, where emergent perennials serve to slow water flow and promote transformation of nitrogen via nitrification, denitrification, and volatilization (Cronk and Fennessey, 2001). The denitrification process converts organic nitrogen to NO_2 or NO_{3-}; NO_{3-} and NH_4+ are inorganic forms of nitrogen readily available for plant uptake by both aboveground and belowground structures (Larcher, 1995). Common emergent perennials found in Southeastern wetlands include members of Families Cyperaceae, Poaceae, and Juncaceae. Scientific literature regarding the use of the genus *Cyperus* as potential wastewater treatment species focuses on the C_4 photosynthetic types, which comprise ~80% of this genus. The C_4 pathway in *Cyperus* is evidently an adaptation to temperate wetlands and sandy, infertile environments (Li, Wedin, and Tieszen, 1999). *Cyperus* species using the C_4 pathway have a high photosynthetic nitrogen use efficiency (NUE), which appears to confer a high degree of success in wetland environments with low nitrogen concentrations. This translates to a possible competitive advantage over their C_3 *Cyperus* counterparts where the latter conditions exist. Our six-month greenhouse experiment was designed to quantify and differentiate nitrogen use efficiency in two facultative wetland species: *Cyperus haspan*, a C_3 sedge, and *Cyperus erythrorhizos*, a C_4 sedge. Both species co-occur in shallow wetlands and ditches at the University of Mississippi Field Station (UMFS) in Lafayette CO., MS; this situation presented the opportunity to determine each species' response to long-term nitrogen dosing. Each species was subjected to nitrogen dosing regimens of both 2.5 ppm and 4.0 ppm, representing typical lower and higher nitrogen concentrations in agricultural runoff in Lafayette Co. Our expectations are that (1) *C. erythrorhizos* may have higher above- and belowground biomass in the low (2.5 ppm) nitrogen treatments than *C. haspan* at the same dose; (2) however, *C. haspan* may display higher above- and belowground biomass in the high (4.0 ppm) nitrogen treatments than *C. erythrorhizos* at that dose level, and (3) photosynthetic pathway (C_3 versus C_4) may differentially affect the abilities of these two sedge species to sequester nitrogen in their tissues. The combination of both C_3 and C_4 sedge species planted in wastewater treatment wetlands and agricultural drainage ditches may be a more effective method of partially treating fluctuating levels of nonpoint source pollution than using either of the two types singly, since C_3 sedges may function to remove nitrogen at higher concentrations while C_4 sedges may be able to remove nitrogen more efficiently at lower concentrations.

Materials and Methods

Forty-five 55-gallon split barrels were filled with approximately 12 gallons of clay/sand sediment obtained from UMFS property. Drums were filled to 4 inches above sediment surface with groundwater from UMFS and allowed to stabilize and become anoxic for approximately two weeks. An outlet for overflow was also installed on each barrel at 4 inches above the sediment surface to keep water level constant. Interstitial (pore) water sampling wells were installed to 8 cm below the sediment surface in order to collect pore water samples. *Cyperus haspan* and *Cyperus erythrorhizos* specimens were collected from wetlands at UMFS and ten individuals of each species were transplanted to designated containers and allowed to acclimate for a month. Pretreatment data (plant height, surface water, soil, interstitial pore water, pH, temperature, humidity, and daylight hours) were collected, measured and analyzed at the beginning of January 2006 to establish a baseline with which to compare the subsequent months when nitrogen dosing is taking place. Five-gallon Aquadosers™ were set up to deliver concentrations of either 0, 2.5, or 4.0 ppm ammonium nitrate (NH_4NO_3) at a rate of 3.024 L/day. Dosing began 10 January 2006. Data are being collected every 30 days for 180 days.

Results and Discussion

Figures 1A & 1B show mean NH_{3}N and NO_{3-} values for surface water, by treatment, from January to April 2006. As expected, NH_{3}N levels remain relatively low (>1 mg/L) in the surface water where nitrifying bacteria are absent. The increase in NO_{3-} concentration is reflective of nitrogen dosing over time as the systems receive more ammonium nitrate than they can process at this point in time. Figures 2A & 2B show the same analysis on soil extracts. Both inorganic NH_{4+} and NO_{3-} concentrations in soil are generally low compared with organic soil N. Since N cycles tend to stabilize and move towards a steady state, concentrations of NH_{4+} and NO_{3-} can be used to indicate nitrogen availability for plants (Bohn, McNeal, O'Connor, 1979). Both NH_{3-}N and NO_{3-} shows no significant difference between treatments over time. NO_{3-} is expected to be low in soil where nitrifying bacteria quickly convert it into ammonium form. The NH_{3}N in soil is relatively low as well (>1.5 mg/L) and will likely increase slightly over time as systems become loaded with NH_4NO_3. Figure 3 shows NH_{3-}N in interstitial water samples. NO_{3-} has remained at virtually undetectable levels throughout the experiment; the absence of NO_{3-} combined with NH_{3-}N concentrations that are as much as two orders of magnitude higher than either NH_{3-}N in soil or surface water indicates that the N cycle is proceeding effectively and that ammonium is the dominant form of inorganic nitrogen available for plant uptake. Fig. 4A and 4B illustrates mean plant height for aboveground parts in *C. haspan*. C_4 species begin emerging in late spring and early summer, so *C. erythrorhizos* has only just begun emerging in the past two months. Plant height has significantly increased over three months in the *C. haspan* group, although heights are similar between treatments at this point. Temperature and daylight hour increase likely play a role in this response rather than N concentra-

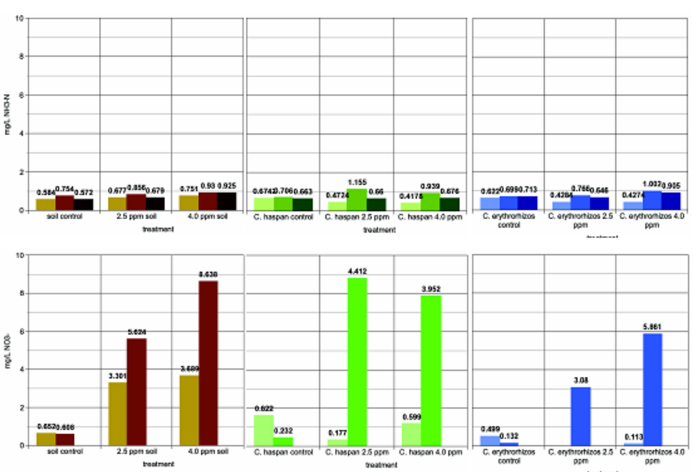


Figure 1A & 1B: Surface water nitrates and Kjeldahl nitrogen from January to March 2006.

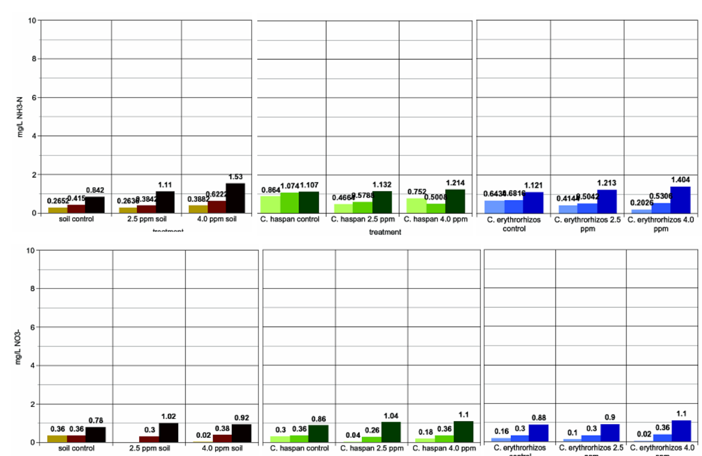


Figure 2A & 2B: Soil extracted nitrates and Kjeldahl nitrogen from January to March 2006.

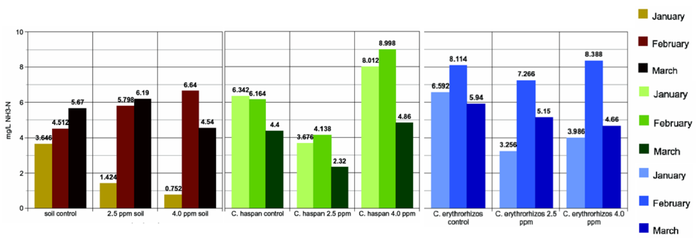
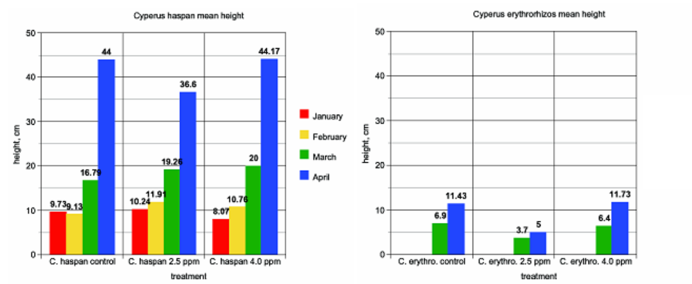


Figure 3: interstitial pore water Kjeldahl nitrogen from January to March 2006.



Figures 4A & 4B: Cyperus haspan and C. erythrorhizos mean heights, from January to March 2006.

tion; however, TN analysis on both species will be performed at a later date to determine N contribution to plant biomass.

CONCLUSIONS

Our preliminary data suggest that all groups (soil only, *C. haspan*, and *C. erythrorhizos*) are functioning as reducing wetland systems. We have recently qualitatively observed several differences in both *C. haspan* and *C. erythrorhizos'* general appearance among treatments. *C. haspan* at the 2.5-ppm dose appears to have weaker culms, smaller culm diameter and density, and appear less healthy than either the control or 4.0-ppm dosed *C. haspan* groups. The same differences have been noted among the *C. erythrorhizos* group as well, with plantlets being taller, healthier in appearance, and more abundant in control and 4.0-ppm treatments but less so in the 2.5 ppm treatment. Further analyses and observations may elucidate the reasons for these observed differences.

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References

Bohn, H.L., B.J. McNeal, and G.A. O'Connor. 1979. Soil Chemistry. John Wiley & Sons, New York, USA

Cooper, C.M. and M.T. Moore. 2003. Wetlands and agriculture. Pgs. 221-235. In Achieving Sustainable Freshwater Systems: A Web of Connections. M.M. Holland, E.R. Blood, and L.R. Shaffer, Eds. Island Press, Washington, D.C., USA.

Cronk, J.S. and M.S. Fennessey. 2001. Wetland Plants: Biology and Ecology. Lewis Publishers, Boca Raton, FL, USA.

Larcher, W. 1995. Physiological Plant Ecology, 3rd Ed. Springer-Verlag Publishing, New York, USA.

Li, M.R, D.A. Wedin, and L.L. Tieszen. 1999. C3 and C4 photosynthesis in Cyperus (Cyperaceae) in temperate eastern North America. Canadian Journal of Botany *77*: 209-218.