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Establishment of Submerged Aquatic Vegetation in Everglades Stormwater Treatment Areas: Value of Early Control of Torpedograss (*Panicum repens*)

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ABSTRACT

Management and manipulation of vegetation community characteristics of constructed stormwater treatment areas (STAs) is an important component of efforts to improve water quality in Florida's Everglades. Results of this study indicate that herbicide treatments of torpedograss (*Panicum repens*) during STA startup will help promote subsequent establishment of desired submerged aquatic vegetation (SAV) species. Extensive beds of southern naiad (*Najas guadalupensis*) rapidly colonized areas where herbicide treatments prior to initial flooding of the STA reduced torpedograss cover to <1%, while SAV colonization was largely precluded in untreated locations that developed dense mats of torpedograss after the STA was flooded. Treatments with the herbicides imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid) and an imazapyr/glyphosate (N-phosphonomethyl-glycine) mix were equally effective in reducing cover of torpedograss. Results also provide some evidence indicating that controlled burns may be a useful supplemental management measure for controlling torpedograss in shallow organic soils like remnant Everglades muck within the STAs.

Key words: stormwater treatment areas, torpedograss, glyphosate, imazapyr, fire, submerged aquatic vegetation, southern naiad.

INTRODUCTION

Constructed stormwater treatment areas (STAs) are crucial elements of ongoing efforts to restore Florida's Everglades (Guardo et al. 1995). The STAs are designed to utilize wetland systems to remove phosphorus from agricultural runoff. While initial conceptualization of the STAs was based on use of emergent vegetation to promote phosphorus uptake and removal, improved plans (Burns and McDonnell 2003) involve additional compartmentalization with cells that are comprised of submerged aquatic vegetation (SAV). Submerged aquatic vegetation communities provide characteristics that have the potential to lead to improved performance in nutrient removal (Dierberg et al. 2002, Knight et al. 2003).

While management efforts to eliminate or control undesirable vegetation such as water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) have been a continual facet of STA operations, proposed enhancements necessitate more challenging manipulation of vegetation characteristics. Establishment of SAV cells, for example, requires elimination of emergent wetland plant species that are well adapted to the shallow hydrologic regimes that are provided by the design and operation of the STAs.

Torpedograss (*Panicum repens*) is an exotic, emergent grass species and highly invasive weed in south Florida, and has growth characteristics that could preclude establishment of submerged aquatic vegetation in STAs. Its invasiveness is largely due to an extensive and rapidly growing belowground rhizome system with numerous axillary buds that provide for prolific tiller (shoot) production (Wilcut et al. 1988, Chandrasena and Peiris 1989, Chandrasena 1990a, Hossain et al. 1996, 1999). Torpedograss can form dense cover in a wide range of edaphic conditions (Chandrasena and Dhammika 1988), including the drained and continuously inundated muck soils that are typical of the pre- and post-construction characteristics and operation of STAs.

The objective of this study was to determine if management measures for eliminating or reducing torpedograss cover can facilitate colonization of SAV in STAs.

Study Area

The study was conducted in Cell 2B of STA 3/4, which is intended to be converted to, and managed as, a SAV marsh. Although once part of the historical Everglades, land within the footprint of STA 3/4 had been drained, and occurs within the Everglades Agricultural Area. Previous land use in Cell 2B included sugar cane production, sod farming and a tree nursery. The former sod farm/tree nursery occurs in the western portion of the cell and was covered by approximately 138 ha of torpedograss prior to initiation of this study. Torpedograss commonly invades sod farms in the southern U.S. because it is tolerant of the selective herbicides that are used on turfgrasses (McCarty et al. 1993).

The cell was first flooded in June 2004 and inoculated with SAV in August 2004. Inoculations consisted primarily of variable proportions of southern naiad (*Najas guadalupensis*)

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and muskgrass (*Chara* spp.) and a smaller amount of Illinois pondweed (*Potamogeton illinoensis*) that was mechanically harvested from another STA and transported via helicopter to 10 drop sites within the study area.

MATERIALS AND METHODS

Torpedograss Treatments

The study was conducted during the startup phase for STA 3/4 when torpedograss control methods could be implemented prior to inundation of the cell. A variety of herbicides have been used to treat torpedograss infestations (Chandrasena 1990b, Hossain et al. 1997, Gettys and Sutton 2004) but recent efforts (Hanlon and Langeland 2000, Hanlon and Brady 2005) suggest that efficacy of the most effective herbicides, imazapyr and glyphosate, can be enhanced by burning torpedograss prior to treatment.

Five treatments employing imazapyr, glyphosate and/or fire (Table 1) were applied to 3 ha (120 m × 250 m) plots within a 53 ha area with dense torpedograss cover, which was located 100-800 m away from SAV inoculation sites. Three replicate plots for each treatment and an experimental control initially were assigned randomly among plots with independent torpedograss cover class distributions (p (Pearson χ^2) = 0.43) (see Monitoring methods below). However, this planned experimental design became unbalanced when one of the assigned plots for treatment 2 did not burn during the initial (April 2004) controlled burn, and fire spread to four plots that were not intended to be burned during the second (May 2004) controlled burn. As a result, treatment 1 had three replicate plots, treatments 3 and 4 had five replicates, treatments 2 and 5 had two replicates, and only one plot remained as a control.

Herbicides were applied from a helicopter and mixed with water to a total application volume of 187 L per ha including the adjuvants Sunwet and Nufilm at the following rates:

1) Imazapyr @ 1.15 kg ai/ha + Sunwet @ 4.6 L/ha + Nufilm @ 0.29 L/ha
2) Imazapyr @ 0.58 kg ai/ha + glyphosate @ 4.68 kg ai/ha + Sunwet @ 5.6 L/ha + Nufilm @ 0.29 L/ha

Monitoring

The spatial extent (coverage) of each burn was described by visual estimates (via ground and helicopter surveys) of the percentage of each plot that burned. Inundation depths were derived from water depth measurements (nearest cm) during baseline and post-treatment vegetation sampling periods. Twenty soil depth measurements (nearest cm) were taken at evenly spaced points along five transects across each plot in November 2004. Soil depths were taken by pushing a graduated steel rod through the soil until the underlying limestone was encountered.

Live torpedograss cover was measured before and after treatments. Baseline (pre-treatment) data were collected between December 2003 and February 2004. Post-treatment sampling was conducted in September-October 2004 and March-April 2005. Plant cover estimates were derived from fifteen 100 m² samples within each of the 18 plots (total of 270 samples). Locations of samples were selected randomly during each sampling period to provide independent, unbiased estimates of cover within each 3 ha plot. Sample data included total live plant cover, cover of torpedograss and cover of other live plant species (if >5%). Total live plant cover was estimated to the nearest percent of the sampled area while cover data for plant species were differentiated into six Daubenmire scale cover classes (i.e., 1-5%, 6-25%, 26-50%, 51-75%, 76-95% and 96-100%). Calculations of mean torpedograss cover were based on midpoints of recorded cover classes and total live plant cover estimates for each sample; torpedograss cover was estimated as 0.5% when total live plant cover was <1%. Parametric statistical analyses of plant cover data were conducted using the arcsine transformation to normalize binomial distributions of sample percentages. A hierarchical ANOVA was used to evaluate differences in total cover and cover of torpedograss among plots assigned to the five herbicide/fire treatments.

Post-inundation colonization of SAV was monitored with point samples from the center and at 1 m inside the corners of each 100 m² vegetation sample. Presence of submerged aquatic plants, including southern naiad, muskgrass, and Illinois pondweed was documented within a 1 m radius of each point sample location by visible observation and bottom grab samples.

Table 1. Experimental treatments of torpedograss plots in Cell 2B of STA 3/4.

Treatment	Herbicide	Herbicide application date	Controlled burn
1	Imazapyr	May 26, 2004	April 23, 2004
2	Imazapyr/glyphosate	May 26, 2004	April 23, 2004
3	—	—	May 26, 2004
4	Imazapyr/glyphosate	April 15, May 26, 2004	May 28, 2004
5	Imazapyr/glyphosate	May 26, 2004	—
Control	—	—	—

RESULTS

Site Conditions

All study plots were dry when baseline data collection began in November-December 2003. Plots were temporarily inundated from January-February 2004, prior to implementation of planned treatments, due to seepage emanating from initial flooding of surrounding cells in STA 3/4. Mean water depths in nine sampled plots ranged from 24-34 cm during January 22-February 17. All plots were dry from March-early June but were inundated continuously after June 13, 2004. Mean water depth during post-treatment data collection in September-October 2004 was 65 cm.

The extent of burn coverage ranged from 15-55% in the five plots that were burned in April 2004 prior to herbicide applications (treatments 1 and 2) and 35-99% in the ten plots that were burned in May 2004. Mean soil depths of plots ranged from 14-41 cm.

Torpedograss Cover

Mean baseline plant cover in replicate plots for the five treatments ranged from 60-75% and was dominated by torpedograss (Figure 1). The most common other plant species, sawgrass (*Cladium jamaicense*), bermudagrass (*Cynodon dactylon*), fogfruit (*Phyla nodiflora*) and cattail (*Typha domingensis*), had cover >5% in only 6-9% of samples. Statistical differences in total baseline plant cover among plots assigned to the five treatments (p (F) < 0.001) were due primarily to significantly lower (p (Bonferroni t) <0.05) mean (± SE) torpedograss cover in the two plots assigned to treatment 5 (30 ± 5%) than in replicate plots for treatment 3 (52 ± 4%) and treatment 4 (57 ± 4%). Mean plant cover in the control plot (66 ± 8%) was similar to treatment plots (Figure 1) and also dominated by torpedograss (39 ± 10%).

Post-flooding cover of emergent plant species was reduced to <1% in all plots that were treated with herbicides and to <15% in plots that were burned but not treated with herbicides (Figure 1). A significant (p(F) < 0.001) decline in mean torpedograss cover in plots that were burned but not treated with herbicides (treatment 3) seemed to be influenced by soil depths and the areal extent of the burn. Torpedograss was eradicated from two plots where the areal extent of the burn was >75% and average soil depths were <27 cm, but persisted in burned plots with the deepest soils (33-34 cm) and in the replicate where only 40% of the plot burned (Figure 2).

Data from the remaining control plot indicate plant cover was not greatly impacted by flooding as mean torpedograss cover was not different (p (F) > 0.5) during the three sampling periods (i.e., before and after flooding). Lower mean live plant cover in the control plot during the initial post-flooding sampling relative to the baseline (unflooded) data collection period (Figure 1) was likely due to underestimated plant cover. Emergent plant species (e.g., torpedograss) remained partly submerged during the September 2004 sampling period, which occurred only three months after the cell was inundated.

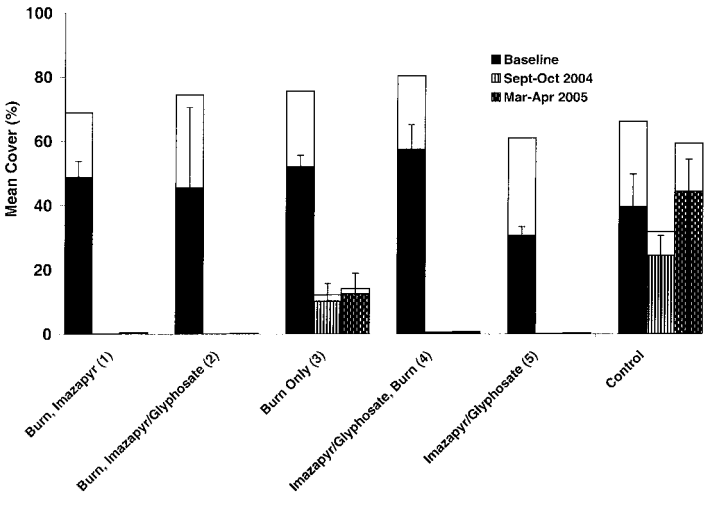

Figure 1. Mean (+ SE) cover of torpedograss (shaded portions of stacked bar graphs) relative to mean total plant cover (unshaded bar) during baseline (December 2003-February 2004) and post-treatment sampling periods. Means and standard errors were based on replicate plots for the five treatments and subplot data for the control plot.

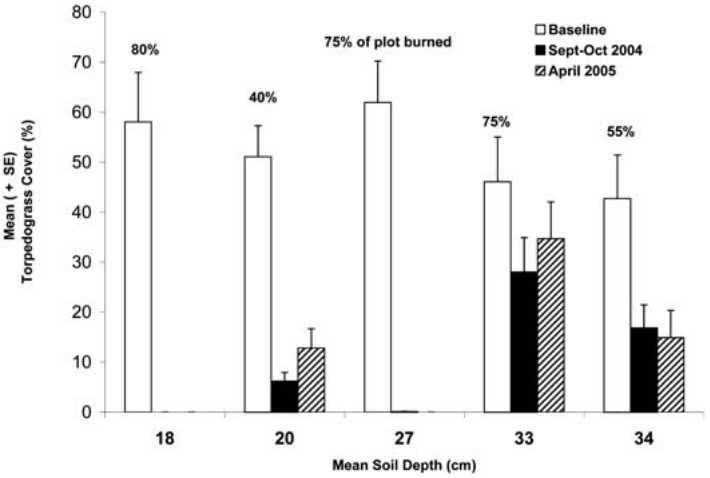

Figure 2. Baseline and post-flooding mean (+ SE) cover of torpedograss in relation to soil depth and the areal extent of the burn (indicated by % above each group of bar graphs) in plots that were burned but not treated with herbicides (treatment 3).

SAV Colonization

Initial colonization of submerged aquatic vegetation occurred in November 2004 when small, scattered patches of southern naiad and muskgrass were observed during soil sampling. During the April 2005 sampling period southern naiad was found at 87% of point samples from plots that were treated with herbicides (Figure 3). Establishment of naiad was lower in plots with substantive remaining emergent plant cover. Naiad was found at 63% of point samples in plots that were burned but not treated with herbicides (14% emergent cover) and at only 25% of point samples within the control plot (59% emergent cover). Muskgrass was found in 8% of all point samples while Illinois pondweed was observed in 4% of cumulative samples.

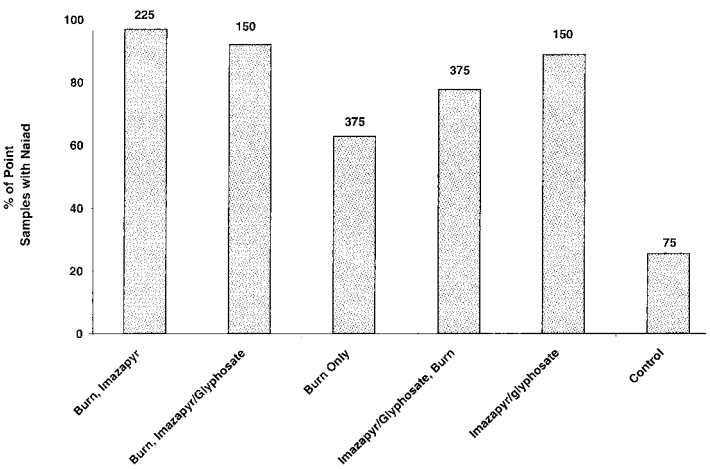

Figure 3. Percent occurrence of southern naiad in point samples from each treatment plot during the April 2005 sampling period. The total number of point samples is shown above each bar.

DISCUSSION

This study was designed to assess the value of vegetation management during STA startup or conversion phases when herbicide treatments and fire can be employed prior to flooding and potentially used to facilitate the establishment of desired plant communities. Results suggest that elimination or reduction of nuisance emergent species like torpedograss prior to flooding can promote subsequent colonization and establishment of submerged aquatic vegetation. Beds of southern naiad established rapidly and most extensively in areas where prior herbicide treatments had reduced cover of torpedograss to <1% and provided conditions conducive for colonization by SAV propagules from adjacent inoculation sites. Colonization of SAV was precluded by the dense growth of torpedograss that occurred in the untreated and unburned control plot following inundation, and was similarly limited by regrowth of torpedograss in plots that were burned but not treated with herbicides. Dense mats of torpedograss prevented establishment of SAV by completely covering the soil and thereby preventing potential propagules from reaching a rooting medium, and by obstructing hydrochoric transport of SAV diaspores from inoculation sites.

Although the planned replication of experimental treatments and control was altered by inability to manipulate fire as intended, the potential for confounding implications was ameliorated by the magnitude of effects of herbicide treatments on torpedograss cover. Both imazapyr and the imazapyr/glyphosate mix were effective in eliminating or greatly reducing torpedograss cover compared to baseline cover in these plots, and relative to post-flooding torpedograss cover in the control plot. The effectiveness of herbicide treatments may have been enhanced by rapid inundation to depths >50 cm. Established torpedograss stands can withstand prolonged flooding with water as deep as 120 cm, but establishment (regrowth) of viable fragments is reduced at depths >25 cm (Smith et al. 2004).

Results did not provide any evidence that antecedent or post-treatment burning increased effectiveness of herbicide applications, but data from plots that were burned and not treated with herbicides suggest that fire may be a useful supplemental management tool for controlling torpedograss in shallow organic soils like the remnant Everglades muck of the STAs. The observed variability in soil depths and associated effects on torpedograss cover could have resulted from burning of muck soils during the controlled burn and concurrent impacts of fire on belowground torpedograss tissues. Effective chemical control of torpedograss is achieved only when herbicides kill belowground tissues (Chandrasena, 1990b); fire could have the same impact as translocated herbicides in highly combustible (Gunderson and Synder, 1994) muck soils. The potential effects of muck fires on soils and subsequent performance should be further evaluated if fire is to be used in STA startup and conversion.

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