Use of Warm-Season Grasses Managed As Bioenergy Crops for Phytoremediation of P in P-Enriched Soil

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INTRODUCTION

Effective options for reducing P losses from P-enriched soils remain a major challenge, particularly in intensive agricultural areas . An alternative to reduce the environmental risks associated with P transport from agricultural lands is the direct use of living plants for in-situ remediation of excess P. The objectives of this study were to i) investigate the potential P removal capacity of bioenergy crops grown on a manure-impacted site, and ii) examine the impacts of crop P uptake on surface ground water quality.

MATERIAL AND METHODS

This 3-yr field study was conducted in south Florida (27°32'N, 81° 48'W) on a private farm that has been continuously occupied by dairy cows (*Bos taurus*) for over 50. Mean annual precipitation is ~ 1650 mm and average maximum/minimum temperatures are 28/17°C. Soil was a Pomona series (sandy, siliceous, hyperthermic Ultic Alaquods).

Treatments consisted of the four grass species: (i) sugarcane cv. 'CP 78-1620', (ii) elephantgrass cv. 'Merkeron', (iii) switchgrass cv. 'Alamo', and (iv) stargrass cv. 'Florona' replicated four times in a completely randomized design for a total of 16 plots. Crop species were selection was based on the criteria of high dry matter production potential, high P uptake rate, seed or planting material availability, and potential for use as a bioenergy crop in the region. Plot size was 10 x 10 m with a 2-m alley between plots.

Crop harvest and N fertilization regimes were designed to maximize crop yields and P removal potential. Stargrass and switchgrass were harvested every 6 wk during the growing season (May to November) and were fertilized with ammonium nitrate at a rate of 90 kg N ha^{-1} after every harvest. Elephantgrass plots were harvested every 12 wk and received 180 kg N ha^{-1} after every harvest. Sugarcane plots were cut every 12 mo and received 200 kg ha^{-1} N after each harvest. No P and K fertilizer was added during the study because soil test levels were adequate.

Experimental plots were isolated hydrologically by berms and ditches. Two suction lysimeters were installed at 60- and 90-cm depths in the center of each plot. Leachate samples were collected from May to November at 14-d intervals.

RESULTS

Dry Matter Yield and P Removal with Harvested Herbage

There was significant ($P < 0.001$) interaction between year and crop species for dry matter yield and P removal (Table 1). The greatest dry matter yields were observed for elephantgrass (average of 46 Mg ha^{-1} yr^{-1}) followed by sugarcane (average of 40 Mg ha^{-1} yr^{-1}). Despite its high yield potential in other regions in the U.S., switchgrass demonstrated poor adaptability to the soil and environmental conditions and only persisted during the first 2 yr of study.

Table 1. Cumulative annual dry matter yield and P removal in harvested herbage of four crop species in the 3 yr study.

Crop species	---------- Dry matter yield (Mg ha^{-1}) ---------			------ Phosphorus removal (kg ha^{-1}) --------		
	2007	2008	2009	2007	2008	2009
Elephantgrass	24aB†	57aA	57aA	70aC	160aB	189aA
Sugarcane	NH‡	39bA	40bA	NH	72cA	79bA
Ona stargrass	9bC	26cA	19cB	36cC	106bA	63cB
Switchgrass	13bA	15dA	NH	53bA	59dA	NH
SE	2	2	2	5	5	5

†Means followed by the same lower case letters within column are not significantly different using the LSMEANS/PDIFF procedure ($P > 0.05$). Means followed by the same capital letter within row and parameter (dry matter or P removal) are not significantly different using the LSMEANS/PDIFF procedure ($P > 0.05$).Values are the means of four replicates.

‡NH = not harvested; sugarcane was not harvested because establishment only occurred in spring 2007; switchgrass did not persist to 2009.

RESULTS (Cont.)

Phosphorus removal followed a similar pattern as dry matter yield (Table 1). Greater annual P removal rates were observed for elephantgrass treatments as compared to the other species (Table 1). Despite the relatively high dry matter yields, P removal rates by sugarcane were less than those observed for stargrass. This occurred because of relatively low tissue P concentrations in sugarcane (1.9 g kg^{-1} for sugarcane vs. 3.2 and 3.9 g kg^{-1} for elephantgrass and stargarss, respectively).

Soil and leachate P concentrations

Mehlich-1, Melich-3, and water-extractable P concentrations in the Ap horizon decreased during the 3-yr study (Table 2) but no effect of crop species on soil P concentrations was observed.

Table 2. Soil P concentrations (0-15 cm depth) as affected by year during the 3-yr study. Data are means across 4 crop entries and 4 replicates (n = 16).

Year	________________ Soil P levels (mg kg^{-1}) ________________		
	Mehlich-1 P	Mehlich-3 P	Water-extractable P
Initial	232a‡	140a	50a
2007	175b	108b	29b
2008	118d	95c	24c
2009	133c	90c	24c
SE	12	14	2

‡Means followed by the same letter within a column are not significantly different using the LSMEANS/PDIFF procedure ($P > 0.05$).

Leachate P concentrations at the 60-cm depth were lower for the elephantgrass as compared to the other species (Fig. 1); however, no difference was observed among the sugarcane, stargrass, and switchgrass treatments. No effect of species was observed at the 90-cm depth.

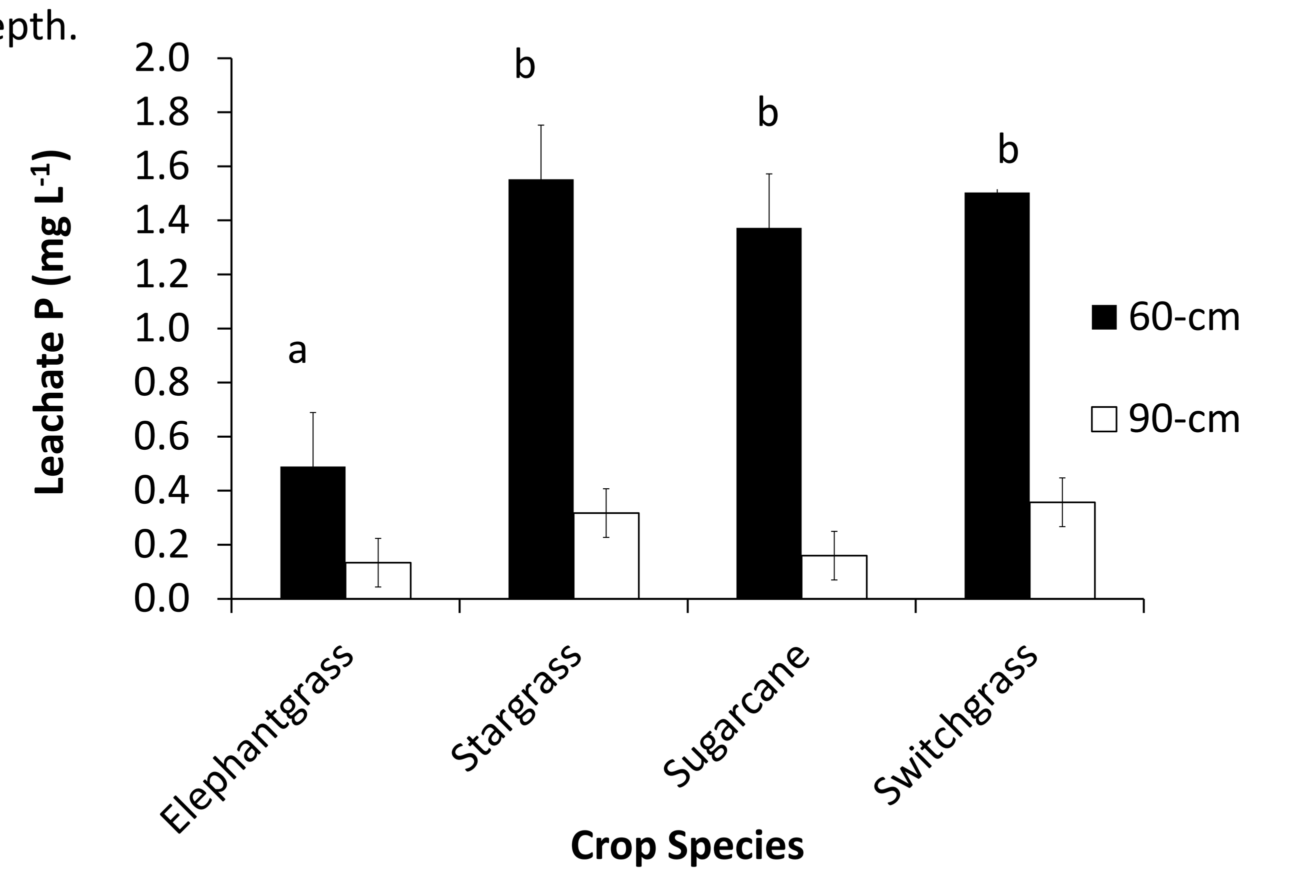

Fig. 1 Average leachate P concentrations at the 60- and 90-cm depths as affected by crop species. Bars represent the mean of sixteen sampling events (2 year * 8 sampling events per year). Means followed by same letter within soil depth are not significantly different in each depth ($P > 0.05$). Error bars indicate one standard error of the mean

CONCLUSIONS

Grasses managed for bioenergy feedstock or hay production represent a viable alternative to remediate excess soil P and improve water quality in areas impacted by excessive livestock waste deposition. Results indicate that the use of elephantgrass may be more effective than stargrass, sugarcane or switchgrass in remediating P in manure-enriched south Florida Spodosols. The greatest P removal rates by elephantgrass resulted in lower leachate P concentrations as compared to the other species. In addition to the environmental benefit associated with soil and water P reductions, the potential of increased demand for cellulosic feedstocks may also provide synergies between elephantgrass production and water quality issues.