Nutrient Uptake and Allocation in Napiergrass Treated with Swine Lagoon Effluent

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- Napiergrass (*Pennisetum purpureum* Schum.) is a dual-purpose, perennial forage and bioenergy crop candidate for the lower southeastern USA.
- Animal waste in Mississippi is typically disposed of by application on subtropical forage grasses, but yield data using this management on napiergrass is lacking.
- Biofuel crop production on fields treated with swine-lagoon effluent addresses food security concerns at a regional level by not creating competition between biofuel and feed crops

Abstract

Napiergrass var 'Merkeron' was irrigated with swine-lagoon effluent to provide approximately 318, 47, and 470 kg ha^{-1} yr^{-1} N, P, and K, respectively (mean of two yr). Total biomass increased from 41 Mg ha^{-1} in 2011 to 57 Mg ha^{-1} in 2012, accompanied by a 48% increase in tillers plant^{-1}. Estimates for N, P, and K uptake in 2011 were approximately 380, 68, 862 kg ha^{-1}, respectively, and increased in 2012 by 20, 22, and 14%, respectively. Leaf and stem contents of N and K (g tiller^{-1}) reached their maximum levels in late-September to mid-October, when approximately 0.8 to 1.0 g more N and 3.0 to 3.8 g more K were allocated to stems, as compared to leaves. Results are consistent with reports of high K uptake in napiergrass, and the need for regular applications of N-P-K fertilizer to enable rapid growth and high biomass yields. Observations were continued in 2013.

Materials and Methods

Site: Private farm near Crawford in southwestern Lowndes Co., MS (33°17' N, 88°35' W). Plots were located in a swine effluent spray field on a Brooksville silty clay loam. Effluent rates of 10 to 15 cm ha^{-1} yr^{-1} (≈300 to 450 kg N ha^{-1}) had been applied for ≈18 yr before the experiment started.

Effluent: Irrigation amounts and timing were governed by the farm manager. Typically, 0.3 to 0.6 cm ha^{-1} per application, one to three times per week from April through September. Amounts were recorded using three rain gauges.

Plots: Rooted cuttings, plants with 3 to 4 canes, were transplanted in April 2011 at a spacing of 1.5 by 2.0 m using nine plants in each of two blocks (8x12 m). No herbicide or insecticide was used during the study.

Tiller harvests: Every two weeks, a group of three to four tillers was harvested from two plants selected at random in each block (n=4). Leaf and stem (culm plus leaf sheath) tissues were dried separately and the dry weights recorded.

Biomass yield: Four plants in each block were cut at 20-cm stubble height in late-November (n=8). In 2011, plant dry matter (DM) was determined after drying samples to a constant weight at 70 °C. In 2012, plant fresh weight was recorded and a subsample (≈2 kg) was weighed before and after drying to determine DM content.

Nutrient analysis: Leaf and stem samples were ground to pass a 1-mm screen. Tissue N was determined by dry combustion method, and P and K were determined using inductively coupled argon plasma spectrophotometer. Nutrient content was calculated as the product of DM and concentration, and expressed as grams tiller^{-1}. Total plant nutrient uptake was estimated using weighted-average content in leaf and stem tissues.

Regression coefficients for the relationship between total nutrient concentration in lagoon water (Y) and day of the year (X), based on data in 2009 (McLaughlin et al., 2012). Nutrient application rate is derived using the formula and amount of irrigation applied.

Nutrient	Y-intercept	X	X^2	X^3	R^2
N, mg L^{-1}	309.42	4.724	-0.034	6.0 x 10^{-5}	0.98
P, mg L^{-1}	59.29	-0.384	0.004	-8.0 x 10^{-6}	0.96
K, mg L^{-1}	523.58	-0.857	0.005	-8.0 x 10^{-6}	0.08

Multiply mg L^{-1} by 0.225 to convert to lbs. acre-inch^{-1}.

McLaughlin, M.R., J.P. Brooks, and A. Adeli. 2012. Temporal flux and spatial dynamics of nutrients, fecal indicators, and zoonotic pathogens in anaerobic swine lagoon water. Water Res. 46:4949-4960.

Selected production parameters based on individual spaced plants harvested in late-November after first-frost date.

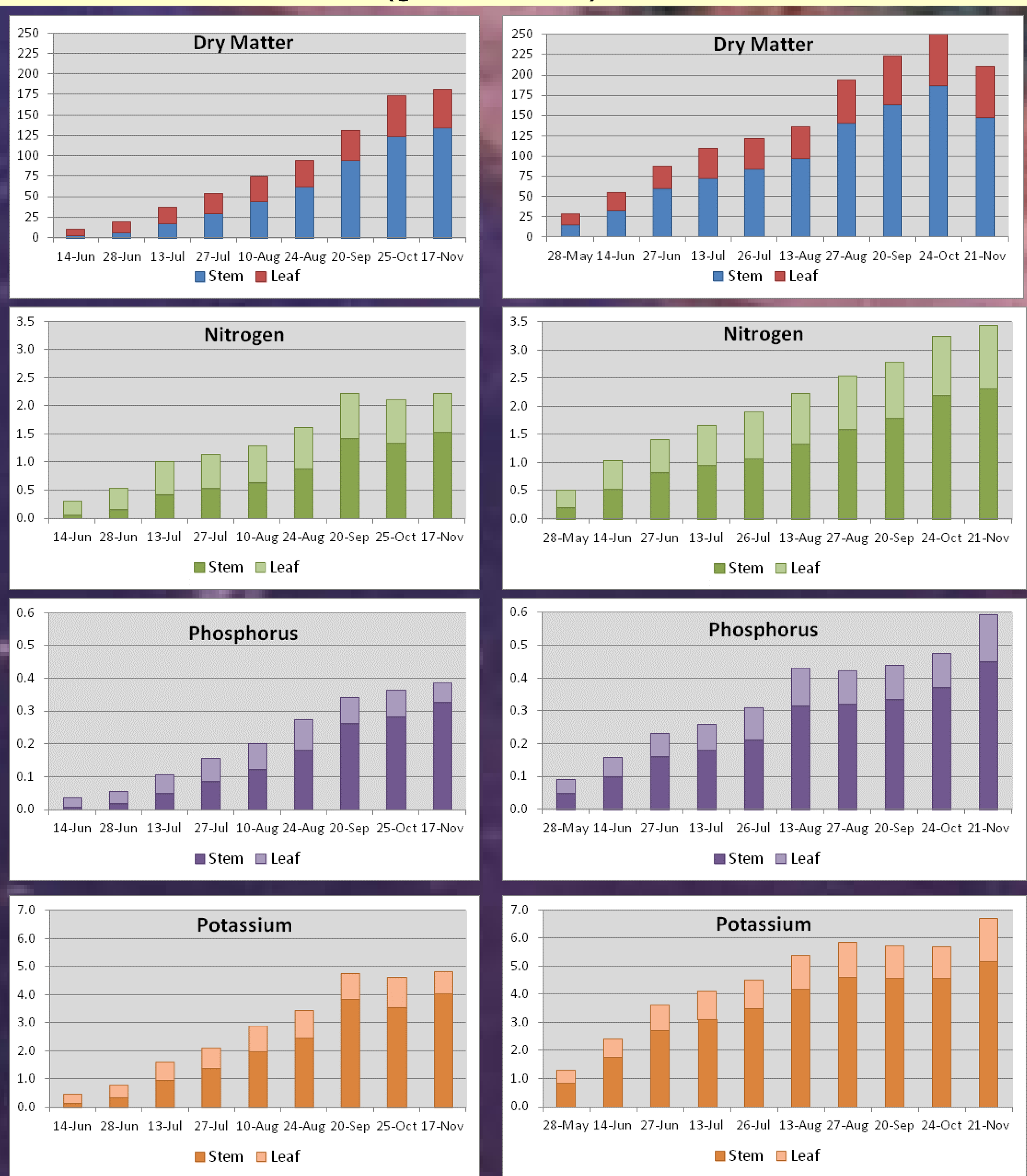
Parameter	2011	2012
Dry biomass†, Mg ha^{-1}	41 ± 8	57 ± 21
Stem height, m	2.4 ± 0.1	3.2 ± 0.1
Tiller number, plant^{-1}	67 ± 13	99 ± 27
N uptake, kg ha^{-1}	380 ± 126	458 ± 217
P uptake, kg ha^{-1}	68 ± 19	83 ± 29
K uptake, kg ha^{-1}	862 ± 254	979 ± 484
Leaf ash, g kg^{-1}	70 ± 7	90 ± 4
Stem ash, g kg^{-1}	74 ± 6	88 ± 23

†Plant dry weight multiplied by 5.379 to convert to Mg biomass ha^{-1}. Dry biomass ranged from 5.7 to 10.4 kg plant^{-1} in 2011 and from 5.4 to 15.6 kg plant^{-1} in 2012. Values in 2012 may be inflated due to estimating yields based on DM content in a subsample of tillers.

Perhaps due to frequent irrigation, biomass production exceeded the range of 31 to 40 Mg ha^{-1} typical for north-central Florida, a region with temperature conditions favorable for napiergrass.

Seasonal changes in stem and leaf contents of dry matter and nutrients.

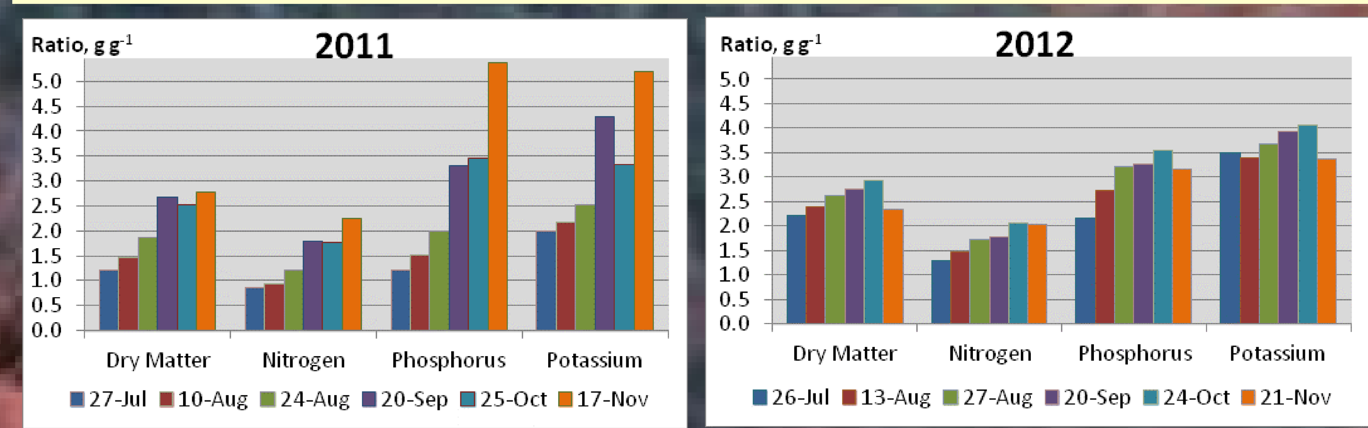
2011 (grams tiller^{-1}) 2012



Average growth season nutrient concentration across tiller sampling dates in 2011 (n=9) and 2012 (n=10).

Year and Nutrient	Leaf	Stem
2011	---------------- g kg^{-1} ----------------	
Nitrogen	22.4 ± 6.1	17.4 ± 6.7
Phosphorus	2.3 ± 0.7	2.9 ± 0.6
Potassium	27.8 ± 7.8	44.8 ± 12.8
Calcium	5.2 ± 1.2	2.3 ± 0.9
2012		
Nitrogen	20.1 ± 2.9	13.8 ± 4.1
Phosphorus	2.4 ± 0.6	2.8 ± 0.8
Potassium	26.8 ± 6.0	40.3 ± 10.7
Calcium	6.3 ± 1.6	1.8 ± 0.4

Stem:leaf content ratio for individual tillers at six sampling dates.



Plant processes apparently favored translocation of assimilates from leaves to stems, particularly P and K in 2011, when stem:leaf content ratios were elevated in Sept., Oct., and Nov..

Conclusions

- Full-season biomass yield increased dramatically in 2012, and this was attributed primarily to increases in both the number and dry weight of individual stalks.
- Correlation between biomass yield and tiller number plant^{-1} was stronger in 2012 (r^2 = 0.85) than 2011 (r^2 = 0.62).
- In general, leaves of individual tillers had much lower K concentration and higher N and Ca, as compared to stems.
- Uptake of K, and to a lesser extent P, appeared to be largely determined by allocation of DM and nutrients to stem tissue.
- Increases in stem:leaf content ratio for DM, N, P, and K as napiergrass matured suggests these assimilates were involved in natural translocation processes.
- Excessive concentrations of nutrients such as P and K in biomass could be undesirable depending on the intended application, for example direct combustion, and this must be considered when fertilizing biomass crops.