FESC
Florida Energy Systems Consortium

UNIVERSITY OF FLORIDA

Water-Use Efficiency and Feedstock Composition of Candidate Bioenergy Grasses in Florida

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Description: Florida ranks first in the USA in annual growth of plant biomass because of a large cultivatable land area, high rainfall, and long growing season. The development of high yielding production systems for energy crops that can be grown in Florida is considered essential for establishment of a sustainable biomass to energy industry. This is the case because long-term availability of sufficient amounts of reasonably priced biomass will be an important determinant of if and where new biofuel and bioenergy facilities will be built. Because of its size and large number of climatic zones, there may be large regional differences in what energy crops can be used at various locations in Florida and how they will perform. In this project, we are conducting applied research at locations throughout Florida with sweet sorghum, sugarcane, energycane, giant reed, miscanthus, erianthus, and elephantgrass to provide important agronomic practice, yield, water use, and chemical composition information for Florida growers, bioenergy producers, and policy makers. This information will support decision making regarding which crops are adapted to specific environments, which are best suited to particular management practices (e.g., irrigation or none), and which have the desired chemical composition for the intended bioenergy use.

Investigators in the project include Dr. Lynn Sollenberger and Dr. John Erickson (agronomists at University of Florida), Dr. Joao Vendramini (agronomist at the Range Cattle Research and Education Center at Ona, FL), and Dr. Robert Gilbert (agronomist at the Everglades Research and Education Center at Belle Glade, FL). The five graduate students mentioned above all started their graduate programs in 2009 or 2010. External collaborators include Speedling, Inc., which provided planting material of miscanthus, and Nutri-Turf, Inc. which provided land for testing perennial grasses.

Budget: $191,981
Universities: UF
External Collaborators: Speedling, Inc.; Nutri-Turf, Inc.

Progress Summary

Miscanthus, giant reed, erianthus, sugarcane, elephantgrass, and energycane are being compared in regional trials throughout Florida. All plots were fully established by early summer 2009. Biomass yield of the grasses was quantified at the end of the growing season in December 2009.

Miscanthus yielded least at each location (4-11 metric tons dry biomass/hectare), giant reed was generally intermediate (13-27 tons/hectare), and elephantgrass, energycane, erianthus, and sugarcane yielded the most (29-39 tons/hectare). Nitrogen and phosphorus removal in plant biomass was greatest for elephantgrass and least for miscanthus. Maximum ethanol production was estimated based on carbohydrate content. This ranged from approximately 330-375 liters/metric ton of giant reed, elephantgrass, energycane and erianthus dry biomass, but was 435 liters/ton for sugarcane bagasse. Data show that elephantgrass, energycane, erianthus, and sugarcane outyield giant reed and miscanthus in biomass and potential ethanol per hectare. Analysis of feedstock composition shows that fiber concentration in dry biomass is similar for all perennial grasses except sugarcane which has much less fiber.

Three sweet sorghums varieties including M81-E, Dale, and Topper 76-6 were planted at three dates during 2009 at three locations in Florida to assess the effects of planting date and location on biomass production, sugar composition, and sugar yield. Planting occurred on 13 March, 27 May, and 12 June 2009 at Belle Glade, 31 March, 5 May, and 9 June 2009 at Citra, and 7 April, 12 May, and 16 June 2009 at Ona. Across all sites, plant crop green yields ranged from 48 to 73.2 metric tons ha^{-1}, with M81-E yielding better than Topper 76-6 which yielded better than Dale. The May planting date yielded most. Ratoon crop green yields were affected by all treatments, ranging from 5 to 67 Mg ha^{-1} with greater yields generally associated with earlier initiation of ratoon. Juice brix values ranged from 8 to 19% across all treatments, averaging 14.4 and 13.1% in the plant and ratoon crops, respectively. Brix values were about 20% lower on the muck soil location compared to the sand soil locations and about 20% lower in M81-E compared to Dale and Topper 76-6. Combining plant and ratoon harvests, this translates to estimated ethanol yields of 2350 to 6780 L ha^{-1} yr^{-1}. Our results indicated that sweet sorghum production in Florida can be competitive with corn ethanol yields in the Midwest, but understanding genotype, environment, and management will be critical to optimizing sugar yields from sweet sorghum.

Characterization of water use occurred in sweet sorghum, elephantgrass, energycane, and giant reed during summer of 2009 and will continue in 2010. Measures of plant transpiration allow for direct measurement of crop water use under real-world field conditions. These data will be combined with stem density measurements, leaf area index measurements, and/or stem basal diameter measurements to calculate water use by each species. These daily measurements will be integrated with climate data (measured at the site) to calculate seasonal water use by each crop. Thus, we will be able to directly compare crop water use during the growing season which will assist producers in selecting crops that are most sustainable for Florida. In addition, we will be able to couple seasonal crop water use data with yield data (e.g., biomass, lignocellulose and/or simple sugars) to estimate ethanol produced per unit of water used by the crop during production. Results from 2009 indicate that energycane and elephantgrass produce more biomass per unit of water than does giant reed.

The projects described above are being conducted for a second year in 2010 at all locations.

2010 Annual Report

Perennial Grass Evaluation

Miscanthus, giant reed, erianthus, sugarcane, elephantgrass, and energycane are being compared in regional trials throughout Florida. All plots were fully established by early summer 2009. Biomass yield of the grasses was quantified at the end of the growing season in December 2009. Yields of elephantgrass, energycane, erianthus, and sugarcane were not different, but all were greater than giant reed and miscanthus (Table 1). Giant reed yield was much greater in South Florida than in other regions. Data from a single year are useful, but for perennial species the longer-term performance is more important. This study is being conducted for a second year in 2010 and will continue for a third year in 2011.

Tissue N and P concentration and removal were determined using dry biomass harvested for each species. Tissue N concentration and removal were greater for elephantgrass than most other species (Table 2). Giant reed had comparable tissue N concentration to elephantgrass, but soil N removal by giant reed was much less due to its lower yield. Tissue P concentration was greater for elephantgrass than any other perennial grass in the trial, and this resulted in elephantgrass having greater P removal than any other grass (Table 3).

Table 1. Dry biomass yield of six perennial grasses at three locations in Florida.

Perennial Grass Species	**Total Annual Dry Matter Yield By Location (tons/hectare/year)**		
	North (Gainesville)	Central (Ona)	South (Belle Glade)
Elephantgrass	35.7 a†	31.6 a†	34.4 a†
Energycane	38.7 a	33.7 a	31.4 ab
Erianthus	36.1 a	31.0 a	32.1 ab
Sugarcane	35.1 a	33.5 a	29.1 ab
Arundo	13.5 b	15.1 b	26.5 b
Miscanthus	6.2 c	4.5 c	10.8 c

†Means within a column not followed by the same lower case letter are different.

Table 2. Tissue N concentration, N removal, and apparent N uptake efficiency for six perennial grasses averaged over three locations in Florida during the 2009 growing season.

Perennial Grass Species	**Total N Removal (kg ha^{-1})**	**Tissue N Concentration (%)**	**Apparent N Uptake Efficiency (%)**
Elephantgrass	230 a†	0.71 ab†	82
Energycane	197 ab	0.57 bc	70
Erianthus	161 bc	0.50 c	58
Sugarcane	160 bc	0.49 c	57
Arundo	131 c	0.75 a	47
Miscanthus	48 d	0.46 c	17

†Means within a column not followed by the same lower case letter are different.

Table 3. Tissue P concentration, P removal, and apparent P uptake efficiency for six perennial grasses averaged over three locations in Florida during the 2009 growing season.

Perennial Grass Species	Total P Removal ($kg\ ha^{-1}$)	Tissue P Concentration (%)	Apparent P Uptake Efficiency (%)
Elephantgrass	50.0 a[†]	0.149 a	162%
Energycane	32.6 b	0.094 b	106%
Erianthus	34.4 b	0.105 b	112%
Sugarcane	28.9 b	0.090 b	94%
Arundo	15.2 c	0.081 b	49%
Miscanthus	10.4 c	0.099 b	34%

[†]Means within a column not followed by the same lower case letter are different.

The harvested tissue of the perennial grasses was also subjected to fiber analyses. Except for sugarcane, NDF concentration of the perennials was similar (Table 4). Fiber concentration of sugarcane was more than 20 percentage units lower than the other perennials. Lignin concentrations in NDF varied by only 2 percentage units across perennial species (data not shown). At present, it is not certain what magnitude of difference in plant fiber composition has a significant effect on conversion, but differences among these perennials grasses appear to be relatively small.

Table 4. Tissue neutral (NDF) and acid detergent fiber (ADF) concentration and hemicellulose concentration for six perennial grasses averaged over three locations in Florida during the 2009 growing season.

Perennial Grass Species	%NDF (cellulose, hemi-cellulose and lignin)	%ADF (cellulose and lignin)	% Hemicellulose
Elephantgrass	76.7 b	50.3 a	26.5 b
Energycane	72.6 c	46.8 bc	25.8 c
Erianthus	77.9 ab	49.3 ab	28.6 ab
Sugarcane	51.2 d	30.6 d	21.3 d
Arundo	74.1 c	45.8 c	28.3 c
Miscanthus	79.5 a[†]	48.4 abc	31.1 a

[†]Means within a column not followed by the same lower case letter are different.

Sweet Sorghum

Three varieties of sweet sorghum, Dale (early maturity), Topper 76-6 (medium-late maturity) and M81-E (late maturity), were grown at the three sites used for the perennial grass trial. Sorghum plots were 5-m wide by 6 m in length and included six rows per plot with a 0.76-m row spacing. Plots were established on three planting dates (PD) in spring (PD1 - 1st week of April, PD2 - 2nd week of May, and PD3 - middle of June) from seed. Each plot was fertilized with a total of 130 kg N/hectare for the plant crop, with part applied at planting and the remainder at three to four weeks after seedling emergence. An additional 65 kg N/hectare was applied to the ratoon crop. Plots were irrigated at sign of visual stress (i.e., leaf rolling) by overhead spray irrigation. A 4-m section of one of the inner two rows in each plot was harvested when at least 50% of the plants were determined to be at soft dough stage (i.e., can easily pinch individual grains between your thumb and fore-finger without 'milk' squirting out of the grain). The total 4-m section was immediately weighed in the field and two subsamples were then collected for brix analysis and determination of plant part biomass. Samples for plant part biomass were placed in an oven and dried at 60°C until constant weight was achieved, and this weight was recorded to estimate dry matter percentage and dry matter yields. Dry stem samples were then chipped in a commercial chipper and a representative sample was collected for analysis of total N and P.

Across all sites, plant crop green yields ranged from 48 to 73.2 Mg ha^{-1}, with M81-E yielding better than Topper 76-6 which yielded better than Dale (Fig. 1). Early and late planting dates yielded less. Ratoon crop green yields were affected by all treatments, ranging from 5 to 67 Mg ha^{-1} with greater yields generally associated with earlier initiation of ratoon.

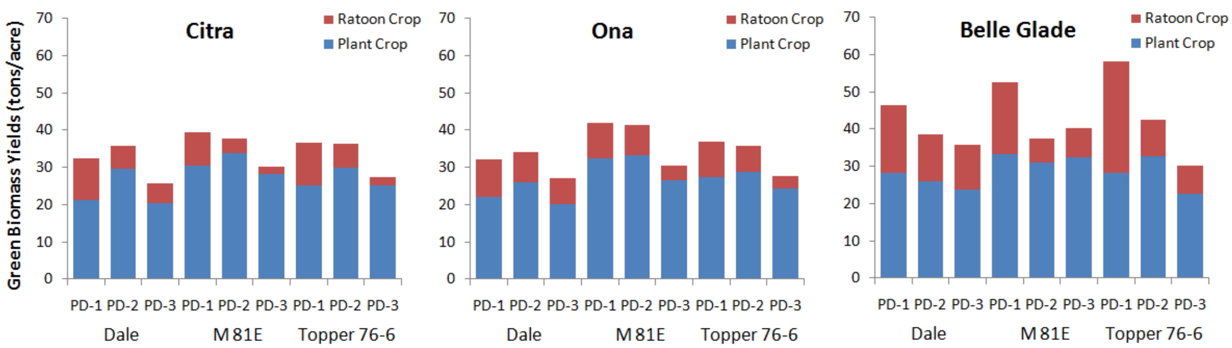

Fig. 1. Sweet sorghum plant and ratoon crop green biomass yields for three cultivars planted on three dates (PD) and at three locations in Florida.

Juice brix values ranged from 8 to 19% across all treatments, averaging 14.4 and 13.1% in the plant and ratoon crops, respectively (Table 5). Brix values were about 20% lower on the muck soil location compared to the sand soil locations and about 20% lower in M81-E compared to Dale and Topper 76-6.

Table 5. Sweet sorghum juice brix for plant and ratoon crops of three cultivars planted on three dates (PD) at three locations in Florida.

		Citra			Ona			Belle Glade		
Crop	Cultivar	PD-1	PD-2	PD-3	PD-1	PD-2	PD-3	PD-1	PD-2	PD-3
Plant	Dale	15.6	15.8	15.9	15.7	16.6	15.9	12.8	13.7	13.0
	Top 76-6	17.1	16.5	15.7	18.8	15.7	17.3	13.1	13.6	13.6
	M81-E	15.2	13.2	9.9	13.5	13.7	15.2	9.5	11.6	10.9
Ratoon	Dale	15.0	15.7	N/A	16.2	14.7	N/A	13.3	13.4	14.3
	Top 76-6	16.8	11.7	N/A	17.6	13.7	N/A	14.4	11.3	11.5
	M81-E	10.1	8.4	N/A	17.6	8.1	N/A	13.0	8.2	9.6

Combining plant and ratoon harvests, estimated ethanol yields were 250 to 725 gal/acre/year (Fig. 2). The two biggest factors affecting annual sugar yields were planting date and cultivar. Overall, earlier planting dates performed better than late planting dates. The medium maturity variety, Topper 76-6, performed better overall compared to the early (Dale) and late (M81-E) varieties, which were comparable. Total N removal was affected by cultivar, with M81-E having greater removal in both plant crop and ratoon crop than Dale (Fig. 3).

Our results indicated that sweet sorghum production in Florida can be competitive with corn ethanol yields in the Midwest, but understanding cultivar, environment, and management interactions will be critical to optimizing sugar yields from sweet sorghum in Florida.

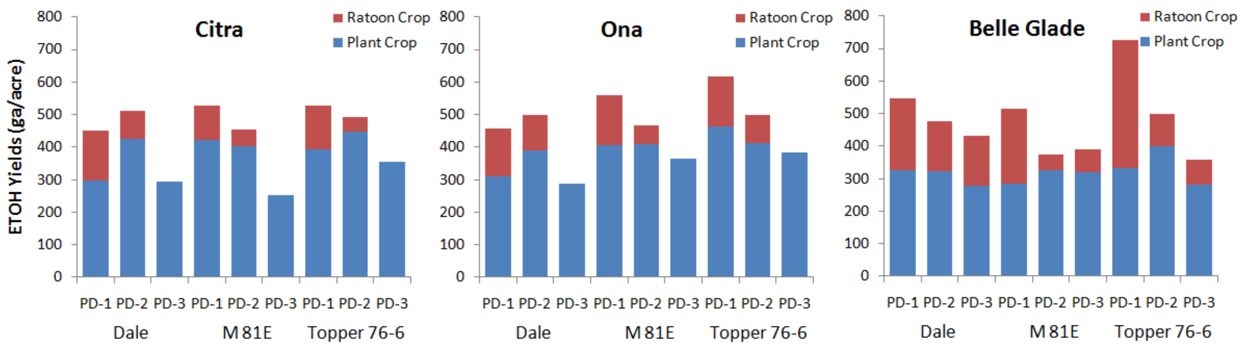

Fig. 2. Estimated sweet sorghum plant and ratoon crop ethanol yields for three cultivars planted on three dates (PD) and at three locations in Florida.

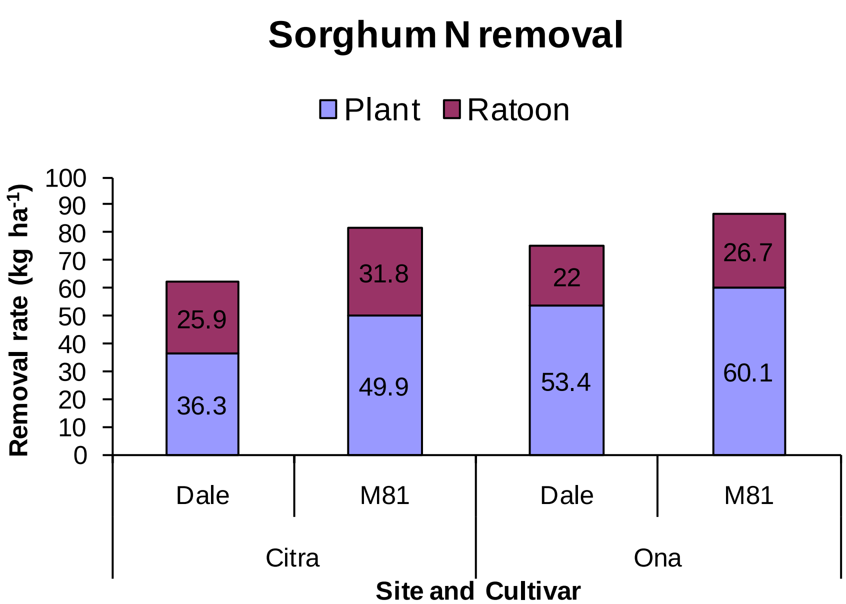

Fig. 3. Average N removal of Dale and M81-E sweet sorghum plant and ratoon crops at two locations in Florida.