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Research paper

Energycane growth dynamics and potential early harvest penalties along the Texas Gulf Coast

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ABSTRACT

The seasonal dynamics of energycane biomass accumulation has major implications in designing optimized cellulosic biomass production and logistics systems. The objectives of this study are to: 1) quantify the growth and biomass dynamics of selected energycane genotypes along the Texas Gulf Coast and 2) estimate the yield penalty and nitrogen removal of different just-in-time harvesting schemes. Field experiments were conducted in three sites along the Texas Gulf Coast with four energycane genotypes. Biomass accumulation varied greatly among genotypes, but relative biomass growth, expressed as a proportion of each genotype's end of season biomass, was similar across years and genotypes for a particular site. On a calendar time basis, relative biomass growth curve became steeper at higher latitudes, indicating a shorter growing season, a narrower harvesting window, and a greater biomass yield penalty for early season harvest. Estimated biomass yield penalties for early August harvest were 60, 44, and 32% of the biomass at crop maturity for the northernmost, intermediate and southernmost site, respectively. Early harvesting of the same amount of biomass tends to remove more nitrogen due to higher organ nitrogen concentration. Combination of organ types harvested also greatly impacts nitrogen removal. Retaining leaf blade materials in the field would remove less nitrogen as compared to harvesting all organs, but will require greater harvesting area. Results from this study highlight the need for a systematic approach to integrate critical time- and site-dependent biomass growth characteristics of energycane in optimizing biomass production and supply logistics.

1. Introduction

Biofuel production in the United States has historically focused on grain-based feedstock concentrated in the Midwestern states [1]. However, the USDA Biofuels Strategic Production Report [2] predicts that the southeast United States will provide nearly half of the estimated 21 billion gallons of advanced biofuels needed per year by 2022, with the large majority from dedicated cellulosic feedstocks, including switchgrass (*Panicum virgatum*), giant miscanthus (*Miscanthus × giganteu*), biomass sorghum (*Sorghum bicolor*), and energycane (*Saccharum* spp. interspecific hybrid) [2].

Switchgrass is a native warm-season perennial grass that can grow over a wide geographical range on diverse agricultural lands and produce moderate yields (9–22 dry Mg/ha) [3], with relatively low fertilizer inputs [4]. Switchgrass production has been extensively studied [3–12]. The single greatest constraint to its commercial production is its erratic germination and slow seedling growth, which delay establishment and prevent effective competition with weeds [13–15]. Giant miscanthus is a high-yielding (30–38 dry Mg/ha) long-living perennial grass [16] that shows promise as a cellulosic feedstock, but has not been extensively studied in the southeast United States.

Biomass sorghum is adapted to a wide range of growing conditions and can yield as high as 45 dry Mg/ha [17–19]. Productivity is affected by genotype, environment, and management [18–21]. If nutrients are not limited, rainfall becomes the primary limiting factor. Energycanes are interspecific hybrids derived from crosses between *Saccharum officinarum* and *S. spontaneum*; they tend to have greater cold tolerance, higher fiber and lower sugar content compared to commercial sugarcane [22,23], and are well-suited for production in the southeast United States, especially in the high-rainfall, low-lying heavy-clay soils on which most crops cannot grow well [23,24].

The productivity of energycane is dependent not only on its intrinsic growth potential but also on site-specific climate and soil conditions. Abiotic factors such as water and nutrient availability vary greatly

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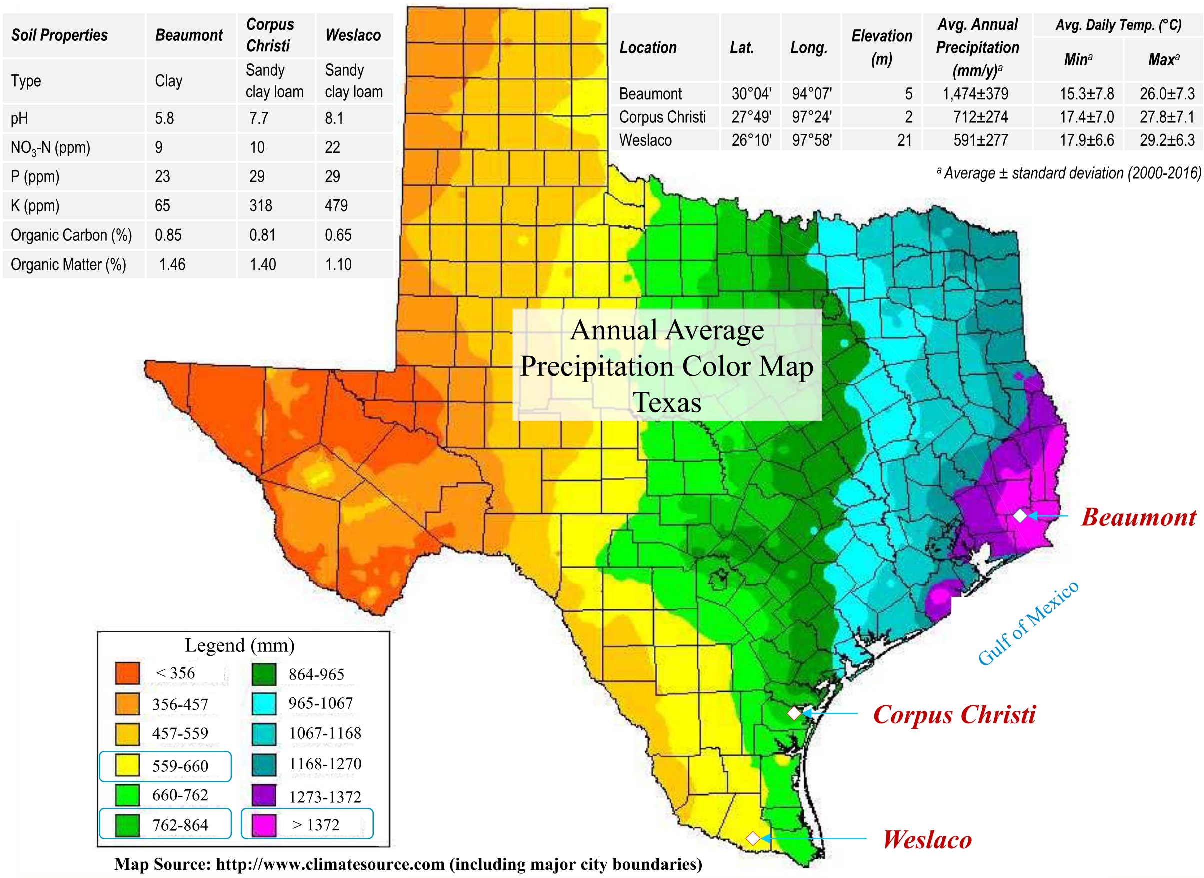

Soil Properties	Beaumont	Corpus Christi	Weslaco
Type	Clay	Sandy clay loam	Sandy clay loam
pH	5.8	7.7	8.1
NO_3-N (ppm)	9	10	22
P (ppm)	23	29	29
K (ppm)	65	318	479
Organic Carbon (%)	0.85	0.81	0.65
Organic Matter (%)	1.46	1.40	1.10

Location	Lat.	Long.	Elevation (m)	Avg. Annual Precipitation (mm/y)[a]	Avg. Daily Temp. (°C)	
					Min[a]	Max[a]
Beaumont	30°04'	94°07'	5	1,474±379	15.3±7.8	26.0±7.3
Corpus Christi	27°49'	97°24'	2	712±274	17.4±7.0	27.8±7.1
Weslaco	26°10'	97°58'	21	591±277	17.9±6.6	29.2±6.3

[a] Average ± standard deviation (2000-2016)

Fig. 1. Soil and weather characteristics of the three experiment sites along the Texas Gulf Coast.

across the range of climatic conditions along the U.S. Gulf Coast, which can result in either profitable or money losing production. Mislevy et al. [25] reported a 4-year average yield of 48 Mg/ha dry weight for energycane cultivar 'US 72-1153' in Florida. In Georgia, Knoll et al. [26] reported significant variation in biomass yield for energycane cultivar 'L79-1002' between years and sites, ranging from ~27 Mg/ha to ~60 Mg/ha. Similar variation is reported in other studies [27–31]. Lee et al. [30] provided a comprehensive report on biomass yields of switchgrass, giant miscanthus, biomass sorghum and energycane from multi-site and multi-year field trials across central and eastern United States.

Most of the biomass feedstock research has focused on end-of-season biomass yield and composition quality. Detailed studies on seasonal growth characteristics and biomass dynamics are lacking, but are needed to optimize biomass production and logistics since biomass harvesting is expected to spread over several months prior to and post maturity to meet the challenge of supplying year-round feedstock to biorefineries.

This expanded harvest window will not only affect harvestable biomass but also removal of nutrients from soil that are critical for sustainable biomass production [32]. It has been reported that leaves contain higher concentrations of nutrients compared with culms across various perennial grass species [33]. Minimizing nutrient removal by recycling the portion of the harvested biomass that is higher in nutrient concentration and lower in biomass (e.g., leaves) could help sustain production systems with minimal nutrient replenishment [34]. Monti et al. [33] provided detailed data on mineral composition of six major energy crops; however, the study did not include energycanes. Knoll et al. [29] estimated N and K removal at the end of the growing season under low input production. Na et al. [31] estimated N and P removal with three harvesting options, including two harvests per year (2×), a fall harvest in early November, and a winter harvest after first freeze. They reported greater dry matter concentration for single harvest treatments when compared to the 2× treatment (34 vs. 25%). The 2× harvest treatment also removed two times more N and P, as compared to one fall or winter harvest. Singh et al. [34] provided detailed results on mineral composition and removal for six perennial grasses, including energycane 'L79-1002'. However, few studies have examined how nitrogen partitioning differs among different plant organs and how different harvesting schemes might affect the removal of nitrogen through biomass harvest.

The objectives of this study are to: 1) quantify the growth and biomass dynamics of selected energycane genotypes along the Texas Gulf Coast and 2) estimate the yield penalty and nitrogen removal of different just-in-time harvesting schemes.

2. Materials and methods

2.1. Energycane genotypes

Four energycane genotypes, TCP06-4772, TCP06-4791, TCP06-4796 and TSP05-46, were evaluated during this study with each classified as Type I energycane [35]. The first three were derived from crosses produced at the USDA Sugarcane Field Station in Canal Point, Florida, and were selected as part of the Texas A&M AgriLife Research sugarcane breeding program in Weslaco, Texas in 2006. The fourth genotype TSP05-46 was created from a cross by the Sugarcane Research Center 'Centro de Tecnologia Canavieira' in São Paulo, Brazil, and was selected in Weslaco, Texas, in 2005. These genotypes were developed as cellulosic feedstocks for biofuel production in the U.S. Gulf Coast