NITROGEN REQUIREMENTS OF SORGHUMS FOR BIOFUEL FEEDSTOCK PRODUCTION IN THE SOUTHERN HIGH PLAINS

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ABSTRACT

Sorghums are a logical crop choice for biofuel feedstock in semiarid West Texas. The declining Ogallala aquifer means that "renewable" biofuel production must be on limited irrigation. Nutrient requirements, primarily N, become the next constraint. We looked at total biomass yields, grain yields, estimated ethanol production, and brix content of forage sorghums, grain sorghums, and sweet sorghums from 2004 to 2007 in Bushland, Texas. Biomass averaged 20 t (65% moisture)/ac for all sorghums. Nitrogen uptake was similar among the sorghums in all years, averaging 154 lb N/ac. Nitrogen fertilizer rate studies were begun in 2007 to determine optimal N rates for ethanol production from sorghums. Sweet sorghums have the advantage of three products; grain, sugar and bagasse. Estimated ethanol production from grain sorghum was similar to forage and sweet sorghums, with similar nitrogen requirements. Assuming cellulosic conversion comes on line soon, grain sorghum production will still be competitive with forage sorghums for ethanol yields. Soil organic matter levels need monitoring to avert declines when harvesting sorghum stover.

INTRODUCTION

Expected increases in biofuel production in the next 30 years will likely have significant regional impacts related to changing irrigation water use, and hence local water availability. The long-term sustainability of the ground water resources used for biofuel feedstocks will be tied to the use of both energy and water efficient crops and cropping practices (National Academy of Sciences, 2007). Crops that support the production of biofuel feedstocks with lower inputs of energy, nutrients, and water will be paramount to maximizing energy efficiency and reducing the trend for increased pumping from the Ogallala Aquifer.

Sorghums have many important advantages over other biofuel crops in the Southern High Plains. In general, sorghums are more water-use efficient than corn and typically require less water to produce a certain level of dry matter (Martin et al., 1976). Even when water use efficiencies of corn and sorghum are similar, the water requirements of corn are greater because of earlier planting dates and longer growing seasons (Howell et al., 1997). Moreover, sorghums are able to maintain high yields under water stress and resume growth after prolonged periods of drought (Sanderson et al., 1992). A final advantage of sorghums is that they can be alternatively used for feed and forage crops in the beef and dairy industry of the region.

Sorghums offer several pathways to produce ethanol: i) starch to ethanol from grain sorghum, ii) sugar to ethanol from stalks of sweet sorghum, and iii) cellulosic ethanol from bagasse (stalks after sugar extraction). The stalks of sweet sorghum harvested just before flowering contain almost as much sugar as sugarcane (16-23% Brix). However, when grown to maturity, stem sugar content declines by about 25% (Reddy et al., 2007). Photoperiod sensitive (PS) sorghum is characterized by tall growth and large dry matter yields. It differs from conventional sorghums in that it requires a day length of less than about 12 hours to initiate flowering. Consequently, plants will remain in the vegetative stage for longer periods during the growing season and could potentially increase ethanol output from sugar and celluosic conversion. In contrast to sorghum produced for hay, seeding rates of sorghum dedicated to ethanol production from sugars may need to be low to increase stem diameters.

Because nitrogen-based fertilizers are commonly synthesized using the Haber-Bosch process, which produces ammonia by reacting natural gas-derived hydrogen and nitrogen, they can be a represent significant energy input for crop production. Recent studies indicate that energy inputs are dominated by nitrogen fertilizer inputs rather than tillage and other field operations (Wienhold et al., 2006; Rathke and Diepenbrock, 2006; Rathke et al. 2007). Rathke amd Diepenbrock (2006) found that 48% of all the energy inputs used to cultivate rapeseed (*Brassica napus*) and 25% of the total energy inputs of the finished biofuel could be traced back to fertilizer nitrogen. The energy used to produce in nitrogen fertilizer inputs represented nearly 10% of the energy output of rainfed corn (Wienhold et al., 2006). This relatively large influence nitrogen fertilizer inputs have on the overall energy balance should be an important consideration in the biofuel crop production system. Moreover, available soil nitrogen to the crop will also influence water use efficiency (grain and forage yield). Given the above considerations and the high cost of fossil-fuel derive nitrogen fertilizer, research is sorely need to evaluate nitrogen requirements for sorghum biofuel production, especially under deficit or limited irrigation.

METHODS

We tested grain sorghums, forage sorghums (both photoperiod sensitive and photoperiod insensitive) and sorghum-sudangrass hybrids from 2004 to 2007 on a Pullman clay loam at Bushland, Texas. Testing of sweet sorghums began in 2006. Planting was in May of each year on 30-inch spaced raised beds at a seeding rate of 120,000/ac. Harvest was in September or October. Nitrogen fertilizer rates ranged from 0 in 2006 to 200 lb N/ac in 2005. Furrow irrigations totaling 13 inches were applied each year. Nitrogen concentration of grain and stover was analyzed at harvest. Brix content was measured on extract from sweet sorghums and forage sorghums starting in 2006. We estimated ethanol yields by assuming 3 gallons of ethanol per bushel of grain and 75 gallons of ethanol per dry ton of stover or bagasse. We performed ANOVA for biomass yields, grain yields, total N uptake, and ethanol yields using sorghum type and maturity as the class variable.

RESULTS

Biomass yields were similar among sorghum types and among years, averaging about 20 t (65 % moisture)/ac (Table 1). Grain sorghum yields averaged 6900 lb/ac (Table 2). Grain yields of photoperiod insensitive forage sorghums ranged from 873 to 4414 lb/ac. No grain was produced from the photoperiod sensitive forage sorghums or the sorghum-sudangrass hybrids.

Total N uptake was similar among sorghum types and among the years 2004 to 2006 (Table 3). In 2007, sweet sorghum had lower N uptake than the other sorghums, and photo-period insensitive forage sorghum had lower N uptake than photo-period sensitive forage sorghum. Grain sorghum grain N concentrations of 1.5 to 2 % were similar to that reported by Booker et al. (2007). Estimated ethanol yields were similar among sorghum types and among years, averaging 573 ga/ac (Table 4).

Assuming cellulosic conversion comes on line soon, grain sorghum production will still be competitive with forage sorghums for ethanol yields. Grain sorghum has the advantage that half of the biomass is in the low volume grain, making transport easier. Sixty five % of the estimated ethanol production was from the grain. Therefore, research is needed to determine if it is a sustainable practice to harvest stover for cellulosic conversion to ethanol in grain sorghum fields. Likewise in forage sorghum systems, a fraction of the aboveground biomass may be best left un-harvested. Soil organic matter levels need monitoring to avert declines when harvesting sorghum stover. Similar nitrogen requirements among these sorghum types mean that soil carbon considerations can be prioritized.

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Table 1. Biomass yields (65 % Moisture) from different sorghum types, Bushland, TX, 2004-2007.

	Photoperiod sensitive	2004	2005	2006	2007
		---------------------------- t/ac	-------------------------		
Forage sorghum	No	24 a	20 a	21 a	17 a
Forage sorghum	Yes	23 a	19 a	23 a	19 a
Grain sorghum	No	17 a	16 a	21 a	16 a
Sorghum/sudangrass	Yes	21 a	20 a	29 a	23 a
Sweet sorghum	No	--	--	23 a	15 a

Means in a column followed by the same letter are not significantly different at *P* = 0.05.

Table 2. Grain yields from different sorghum types, Bushland, TX, 2004-2007.

	Photoperiod sensitive	2004	2005	2006	2007
		---------------------------- lb/ac	-------------------------		
Forage sorghum	No	4414 b	3361 a	1052 b	873 b
Forage sorghum	Yes	0 c	0 b	0 c	0 b
Grain sorghum	No	8408 a	6713 a	7367 a	5011 a
Sorghum/sudangrass	Yes	0 a	0 b	0 c	0 b
Sweet sorghum	No	--	--	1311 b	458 b

Means in a column followed by the same letter are not significantly different at *P* = 0.05.

Table 3. Total nitrogen uptake from different sorghum types, Bushland, TX, 2004-2007.

	Photoperiod sensitive	2004	2005	2006	2007
		---------------------------- lb N/ac	-------------------------		
Forage sorghum	No	194 a	161 a	158 a	137 b
Forage sorghum	Yes	139 a	145 a	187 a	169 a
Grain sorghum	No	145 a	135 a	182 a	170 a
Sorghum/sudangrass	Yes	155 a	128 a	177 a	181 a
Sweet sorghum	No	--	--	128 a	82 c

Means in a column followed by the same letter are not significantly different at *P* = 0.05.

Table 4. Estimated ethanol yields from different sorghum types, Bushland, TX, 2004-2007.

	Photoperiod sensitive	2004	2005	2006	2007
		---------------------------- ga/ac	-------------------------		
Forage sorghum	No	699 a	581 a	586 a	460 a
Forage sorghum	Yes	608 a	503 a	611 a	500 a
Grain sorghum	No	578 a	533 a	667 a	503 a
Sorghum/sudangrass	Yes	562 a	524 a	767 a	605 a
Sweet sorghum	No	--	--	623 a	415 a

Means in a column followed by the same letter are not significantly different at *P* = 0.05.