High-Tonnage Dedicated Energy Crops: The Potential of Sorghum and Energy Cane

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The development of viable lignocellulosic-biofuel industries in the United States will require dependable delivery of supplies of feedstocks logistically available to conversion facilities. The selection of feedstocks ultimately will vary with geographical region across the United States. Dedicated bioenergy crops as sources of lignocellulose are likely to be most productive in the southern regions of the United States due to more abundant sunlight and longer growing seasons. Of course, dedicated bioenergy crops in the southwest must tolerate heat and drought, whereas species grown along the Gulf Coast must tolerate heat as well as variable soil moisture and variable soil-oxygen environments associated with different soil types. Dedicated energy crops for the panhandle of Texas and the Midwest will have shorter growing seasons and will need to be more cold tolerant.

Crop Selection

Economically viable bioenergy-production facilities will require the appropriate selection of crops to ensure year-round availability of feedstock tailored to local climatic, biotic, and soil stresses. From a facility manager's perspective, a complement of crops that allows year-round delivery of feedstock is paramount and, in this regard, is a contrast to regional monoculture systems that are predominant across much of the nation. Furthermore, biomass-crop production and management systems must be developed and tailored to each crop and each climatic region to ensure optimal biomass yields. These actions will require a coordinated effort focused on the development of multiple crop-production systems.

The primary limiting factors for sustainable lignocellulosic- and biodiesel-fuel industries in the United States are the reliable supply of economically priced feedstocks and the logistics of the harvesting, transport, storage, and overall supply chain. The current model for ethanol production from feed grains can be significantly augmented by the production technologies associated with high-yielding biomass crops, specifically sorghum, switchgrass, and energy cane. A key to sustaining and enhancing growth of the biofuels industry (combined with environmentally sustainable production systems) is the development of adequate acreage of dedicated feedstocks that produce high tonnage at prices that give producers and biorefineries acceptable profit margins.

Sorghum

Sorghum offers considerable potential as a dedicated lignocellulosic biomass crop. The broad genetic diversity within the genus provides plant breeders the opportunity to develop biomass sorghum adapted to diverse climates with low, and possibly high, water availability, to include many different biotic and abiotic stresses. The development and production of photoperiod-sensitive sorghum will facilitate full-season production of biomass, to maximize yield for significant tonnage. Yields in the range of 15 dry tons per acre have been achieved on the Texas A&M Farm at College Station. Even greater yields are anticipated under optimum conditions. Sorghum is of particular interest because it is the only annual, high-tonnage dedicated energy crop with the potential for being produced on large acreages, and it already has an existing agronomic (*e.g.* seed) infrastructure.

Energy Cane

Sugarcane, particularly the high-tonnage varieties (*i.e.* energy cane), offers the greatest potential as a bioenergy crop for production in much of East Texas and the US Gulf Coast. Sugarcane has a proven track record of producing exceptionally high yields on heavy clay soils in which many other crops are unable to grow well. For the past century, sugarcane varieties have been developed primarily for accumulation of high levels of sucrose. Commercially grown varieties can produce up to 40 dry tons per acre under optimal conditions. Biomass productivity probably could be increased even more if sucrose accumulation were no longer a constraint on breeding programs.

Several other grass species have the potential to produce exceptional biomass yields, including *Arundo, Miscanthus*, and *Miscanthus* crossed with sugarcane hybrids, known as Miscane and developed at Texas A&M AgriLife. The seasonal diversity of biomass production that these species afford may play an important role in ensuring year-round production of feedstock supplies.

Land-Use Changes

The development of sorghum, energy cane, and other biomass crops may require changes in land-use management but should include rotational cropping systems. Research is requisite for identifying which of these species will perform best in each climatic region of the United States. This will include detailed studies on a number of agronomic characteristics necessary to identify optimal performing inbred and hybrid varieties, as well as the identification of best management practices. Each region will require a management package tailored to its unique climatic and soils environments and its slate of biotic stresses. Unlike most conventional production systems, biomass cropping systems must be developed that incorporate appropriate combinations of high-tonnage crops that provide year-round delivery of feedstock at a price and volume that meet the production and financial needs of both the producers and the owners of bioenergy production facilities.

Biomass Priorities

The US Department of Energy has suggested that the delivered cost of biomass to conversion facilities should be in the range of $30 to $40 per dry ton, to hold down the cost of biofuels. However, the production costs for dedicated energy crops range from $50 to $100+ per dry ton. The keys to reducing delivered cost will be high-tonnage crops and highly efficient production systems, but delivering large amounts of biomass (hundreds of millions of tons per year) at rates lower than $50 per dry ton will be difficult; farmers simply will not produce biomass feedstock for returns below what they can receive for current crops. For agriculture to deliver significant, sustainable supplies of lignocellulose from crop sources, a thorough evaluation must be conducted to assure producer buy-in. Table 1 shows a comparison of various delivered biomass costs.

Table 1. Productivity and cost of delivered biomass.

	Residue	Woody biomass	Switch-grass	Forage sorghum	Bioenergy sorghum
Biomass per acre per year (dry tons)	2	5–10	8	10	15–20
Estimated cost delivered to converter (per dry ton)	$60+	$50–75	$60–90+	$65	$50–60

A successful, sustainable biofuels economy must be based on diverse biomass resources available consistently throughout the year that will include appropriate storage measures. Forest resources, municipal solid waste, urban construction residue, energy cane, switchgrass, energy sorghums, and algae will be important in a diversified portfolio. To develop this bioenergy portfolio several guiding principles should apply:

- protect the environment,
- assure economic viability,
- minimize water demand,
- minimize competition for food and feed production, and
- minimize disruptions in the marketplace.

Texas AgriLife Research

Texas AgriLife Research has funding exceeding $26 million for more than thirty projects supported by the Texas legislature, the federal government, and corporate partners to develop sustainable bioenergy production that addresses diverse feedstock development, agronomic practices, logistics, production modeling, and conversion technologies, as well as economic, policy and environmental assessments. Key faculty members with international experience in plant science, agronomy, agricultural engineering, biochemistry, biophysics, and economics are leading these research initiatives.

Since April 2006, **Bill McCutchen** has served as associate director of Texas AgriLife Research, within the Texas A&M University System. His mission includes developing and implementing strategic research initiatives across the biological sciences, with facilitation of university-industry relationships. He also assists in developing intellectual property from R&D.

He earned BS and MS degrees in entomology from Texas A&M, where he was recipient of the Distinguished Graduate Student Research Award in 1989. He received his PhD from the University of California Davis in 1993, having won the Young Scientist Award from the American Chemical Society in 1992.

Dr. McCutchen joined Texas AgriLife Research from DuPont Agriculture & Nutrition, where his responsibilities included crop-protection R&D across agricultural biotechnology and chemistry programs. He was named a DuPont Research Fellow in 2002. In 2007, he was presented with the Henry Wallace Agricultural Revolution Impact Award, DuPont's and Pioneer's most prestigious research award for agriculture. He has more than thirty patents and pending-patent applications. McCutchen provided the vision, innovation, and leadership that propelled a new generation of dual-herbicide-tolerant transgenic crops—corn, soybean, and cotton—and a new-generation weed-management solution, trademarked as Optimum GAT™.