Research Helps Set the Stage for Ethanol...Southern Style

With sugar on tap as an ethanol resource for use in the U.S. Gulf Coast region, Agricultural Research Service (ARS) scientists have already taken the next step: custom-breeding new varieties of so-called "energy sugarcane," whose sugar- and fiber-rich stalks could become the complementary feedstocks of tomorrow.

"We're looking at these high-fiber energy canes for further down the road—should the technology for converting cellulose into ethanol become profitable," says Edward P. Richard. He leads research at ARS's Sugarcane Research Unit in Houma, Louisiana. "Right now, raw-sugar processors are just burning the fiber to generate heat to power the stalk-crushing and sugar-crystallization processes."

In anticipation of biorefineries that produce ethanol using both sugar- and cellulosic-conversion platforms, three new cane varieties—one high fiber/low sugar and two high sucrose/high fiber—were released in April 2007. The varieties—L 79-1002, Ho 00-961, and HoCP 91-552—were developed as part of a cooperative breeding and evaluation program with scientists at the ARS Sugarcane Research Unit in Houma, the Louisiana Agricultural Experiment Station at Louisiana State University in Baton Rouge, and the American Sugar Cane League in Thibodaux.

Together, the cane releases serve as benchmarking varieties for a biofuels industry considering a dual platform for converting both sugar and fiber to ethanol. These releases also reflect a push by ARS to make better use of region-specific crops as feedstocks that can sustain localized production and use of biobased fuels and energy.

In 2006, for example, America's heartland accounted for most of the 80 million acres of corn that were planted and the nearly 5 billion gallons of ethanol derived from its starch, which must first be converted to sugars. But in southern Louisiana, soil conditions and climate are more amenable to other sugar-producing crops, notably sweet sorghum and sugarcane. It makes sense to tap them as ethanol feedstocks instead of corn.

"With respect to the soluble solids—the sugars in cane and sorghum—we think the technology is already in place for planting, culturing, harvesting, and processing these feedstocks into ethanol and other biofuels," says Richard.

Aside from the fact that sugarcane is adapted to temperate regions of the U.S. Gulf Coast, the crop offers a key processing advantage over corn-based ethanol production: Cane sugars need not be derived from starch using cooking steps and costly enzymes. Rather, the sugar can be directly fermented into ethanol as soon as the sucrose and related sugars are extracted from the stalks of this tall-growing jointed grass.

PEGGY GREB (K10668-1)

Technician David Verdun transplants sugarcane seedlings into the field. The operation includes annual transplanting of about 8,000 seedlings as candidate varieties for bioenergy use.

The remaining crushed cane stalks, called "bagasse," are composed of the complex carbohydrates cellulose, hemicellulose, and lignin, which make up the cell walls of all plants. But profitably converting these complex carbohydrates to ethanol poses a technological challenge that research is still grappling with today.

PEGGY GREB (K10671-1)

Geneticist Thomas Tew (left) and agronomist Edward Richard inspect transplanted sugarcane seedlings.

"Based on our estimates, the three released energy cane varieties, on average, will produce 4.7 to 6.6 tons of sugar and between 5.8 and 9.3 tons of dry fiber per acre per year," Richard says. "Using an estimate of 125 gallons of ethanol per ton of sugar and 70 gallons per ton of fiber, that equates to production of 1,170 to 1,240 gallons of ethanol per acre."

Taking Off the Chill

"Sugarcane varietal development is a 12- to 13-year process," says Richard. "So, in developing these high-fiber/high-sugar energy canes, we're trying to anticipate what the biofuel industry's needs will be as many as 13 years from now."

One of the problems with sugarcane, he says, is that it can only be grown in a few states, namely Louisiana, Florida, Texas, and Hawaii. Southern Louisiana is the farthest away from the equator that sugarcane can now be grown commercially in the world, Richard adds. Farther north, frosts and freezes can delay the growing season or ruin the crop.

ARS scientists Anna L. Hale and Thomas L. Tew at Houma are seeking to breed cold tolerance into today's sugarcane varieties by crossing them with wild relatives obtained from Asia—specifically from the Himalayan mountain region.

The purpose of developing cold- or freeze-tolerant sugarcane is twofold: to extend the crop's growing and milling season in Louisiana and to expand its production range into other states, such as Alabama, Arkansas, California, Georgia, Mississippi, and Oklahoma.

Small-scale trials of conventionally bred, cold-tolerant canes are now under way in these states, Richard says. As with all varieties released by the Houma lab and its collaborators, the cold-tolerant sugarcane is being thoroughly evaluated for desirable agronomic and processing characteristics and for resistance to insect pests, such as stalk borers, and to diseases, including rust, leaf scald, mosaic, smut, and ratoon stunting disease.

From Theoretical to Actual

To be successful, biorefineries need feedstock for processing virtually year round. Richard's group thinks that by developing a suite of complementary crops, the harvest season can be extended. To that end, the Houma scientists are looking at growing sweet sorghum on fallowed sugarcane fields and on adjacent lands.

"In Louisiana, sugarcane is planted in late summer and harvested from October through January, so a companion crop like sweet sorghum would fit in nicely. It's a short-season crop you can plant in late March to early April and harvest 4 months later," says Richard. "The beauty of sweet sorghum is that it can be harvested and milled using the same equipment and procedures used for sugarcane."

Meanwhile, building the infrastructure for cane-based ethanol production in Louisiana is under way. This fall, Louisiana Green Fuels, LLC, plans on operating the first U.S. sugar-to-

Predicting Sugarcane Conversion to Ethanol

One of the complications of producing ethanol from sugarcane is that conversion rates may swing wildly between batches of juice when they are distilled. The usual culprit is lactic acid bacterial contamination of the sugarcane juice. But contamination can be dealt with economically if its extent can be precisely determined when the juice first arrives.

Unfortunately, there has been no reliable, rapid, easy, and inexpensive test that can be used onsite at the factory—until recently. Chemist Gillian Eggleston at ARS's Southern Regional Research Center in New Orleans and her collaborator Henrique Amorim, president of the Brazilian research company Fermentec, found that the amount of the sugar mannitol in sugarcane juice is a very sensitive indicator of the level of the contaminating lactic acid bacteria, *Leuconostoc mesenteroides.*

Eggleston has developed an enzymatic test that measures mannitol in deteriorated sugarcane juice in just 4 to 7 minutes, using spectrophotometry analysis. The test is not affected by the presence of other sugars such as sucrose, glucose, fructose, or dextran, which are associated with sugarcane deterioration or yeast fermentation, the process that converts the juice to ethanol. Tests are currently underway between Eggleston and Amorim to verify that the method works in industrial fermenting of sugarcane juice to ethanol.

"Because most cane-based ethanol factories already have spectrophotometers, we calculate that the cost of the test could be as little as 60 cents for each analysis," says Eggleston.

PEGGY GREB (D696-1)

Chemist Gillian Eggleston (right) demonstrates the simple, rapid enzymatic mannitol test to Hedgardo M. Centella, a factory laboratory technician at Alma Sugarcane Factory, Lakeland, Louisiana. A spectrophotometer is required for the test.

Knowing the precise bacterial contamination level, Eggleston points out, would also be beneficial because antibiotics to fix the problem are very expensive, and the test will indicate the smallest amount to use to kill the bacteria. In addition, controlling use of antibiotics limits the potential for developing antibiotic resistance.

In Brazil, where 4.7 billion gallons of sugarcane-based ethanol were produced in 2006, solving the contamination issue is important.

Amorim expects that three or four Brazilian factories will start using the test this year, which he says will be very valuable to the sugarcane ethanol industry.—By **J. Kim Kaplan,** ARS.

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ethanol facility, at its Lacassine plant. The principal feedstocks there will be sweet sorghum and sugarcane.

According to the company's website (http://saldefrutas.com/louisiana/index.html), the Lacassine facility is one of three planned for Louisiana that aim to produce 100 million gallons of ethanol per year. The tentative sites of the other two facilities are St. James and Bunkie. Current plans are to burn the bagasse and cogenerate electricity for sale to electricity suppliers.

To further ensure a steady, year-round source of feedstocks for such facilities, Richard's group is examining the possibility of crossing sugarcane with two of its distant relatives—*Miscanthus* and *Erianthus*—with the hopes of developing new sugar-containing crops with more cold tolerance and biomass yields.—By **Jan Suszkiw,** ARS.

This research is part of Bioenergy and Energy Alternatives, an ARS national program (#307) described on the World Wide Web at www.nps.ars.usda.gov.

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RYAN VIATOR (D1243-1)

Geneticist Thomas Tew (left) compares a leading sugarcane variety (known as "L 99-233") to the newly released high-fiber sugarcane variety (called "Ho 00-961") being held by agronomist Robert Cobill at the Sugarcane Research Unit's research farm in Schriever, Louisiana.