Callus formation on sugarcane leaf roles under sterile tissue culture conditions representing the first step of genetic modification of sugarcane.

BIOTECHNOLOGY INCREASES SUGARCANE YIELDS

Sweet energy

Brazil is the leading producer of biofuel made from sugarcane. Researchers at Bayer CropScience are developing a technology with the potential to increase the sugar yield in sugarcane and thus its energy content, and working together with one of Brazil's leading players in sugarcane to introduce it in commercial sugarcane varieties.

Sweet sugarcane juice contains enough energy for all of Brazil. And it is becoming more important every day because, as well as being central to the South American country's biofuel and sugar production, the plant's fibrous residue, known as "bagasse," can also provide energy for electricity and heat. So much energy, in fact, that Brazilian sugar mills and ethanol distilleries are independent of fossil energy supplies. "Sugarcane has the potential to reduce CO_2 emissions and make us less dependent on petroleum," says Michael Bäuerlein, Project Leader at Bayer CropScience in Monheim. One liter of ethanol distilled from sugarcane provides nine times more energy than is used to produce it. In other words, solar energy is pumped into gasoline tanks very efficiently in Brazil – all thanks to sugarcane. "The bioenergy balance of sugarcane in Brazil cannot be matched by any other agricultural raw material globally," Bäuerlein says. And because high-tech distilleries can generate more electricity from bagasse than they consume, they feed it into the power grid. Experts say that Brazilian sugarcane corporations will soon deliver some 15 percent of the South American country's demand for electric power.

Clearly, bioethanol from sugarcane is an important factor in the development of the Brazilian economy. For this reason, Brazil has put a lot of effort over the last 40 years into expanding its lead in sweet, juicy sugarcane. And surprisingly, all this energy is produced using less than 2 percent of the arable land in Brazil, according to the Brazilian Sugarcane Industry Association (UNICA). To avoid competing with food production in the future, sugarcane experts in Brazil have their sights set on one thing above all: "Our goal is to raise yields without significantly increasing the area of land currently in use," explains William Lee Burnquist, Business Director at the Centro de Tecnologia Canavieira (CTC), near São Paulo.

Expert cuts: Bayer CropScience scientists Dr. Michael Bäuerlein (left) and Dr. Ralf Christian Schmidt take samples from sugarcane plants in the greenhouse. Their experiments in the Bayer CropScience Innovation Center in Ghent ultimately give them a detailed insight into the properties and characteristics of the newly created transgenic plants containing the high-sugar gene.

CTC is recognized as the largest sugarcane technology center in Brazil and one of the most renowned in the world. It conducts innovative research on all aspects of the sugarcane production chain, from breeding to the final production of sugar, ethanol and energy, and therefore has a hand in approximately 60 percent of the sugarcane produced in Brazil. To reach the goal of higher sugar yields in sugarcane, Bayer CropScience and CTC entered into a partnership to take Bayer's "High Sugar technology" into CTC's high-performing sugarcane varieties. "We bring over 30 years of experience with sugarcane into the partnership," Burnquist points out.

CTC and Bayer CropScience researchers want to use biotechnology to increase the plant's sugar content by up to 20 percent. This would increase the sugar yield without increasing the bio-

83 percent

of all newly registered vehicles in Brazil in 2012 were flex-fuel cars that can be powered with both biofuel and gasoline.

Source: ANFAVEA

Photos: Peter Ginter/Bayer AG (5), GBEP (1)

Development potential: these sugarcane seedlings in the research laboratory will grow into stalks as tall as a man. But before the new sugarcane varieties make their way from the lab to the fields of Brazil, Dr. John Lohrenz (photo, left) and his research colleagues analyze the plants closely to determine their genetic modifications, benefits and any potential risks for man and the environment.

mass and would keep the logistics costs to transport the harvested cane to the factories at today's level – a clear advantage over the yield increases achieved through conventional breeding, which also increases biomass and thus the production costs per liter of ethanol. "This technology could increase plantation yields by several thousand liters of fuel per hectare," Bäuerlein explains. And that means lower fuel prices for Brazilian drivers and profitable exports, because what Brazilians consider to be "normal" fuel is actually E25, a fossil fuel mixture containing 25 percent bioethanol. "Pure gasoline is no longer available in Brazil. Fuel stations countrywide also sell what is known as 'etanol' or E100, in addition to E25," Burnquist relates. The flexible-fuel vehicles introduced widely in Brazil since 2003 can run on E25 gasoline or E100 ethanol, or any mixture of the two.

A sugar boom instead of an oil crisis

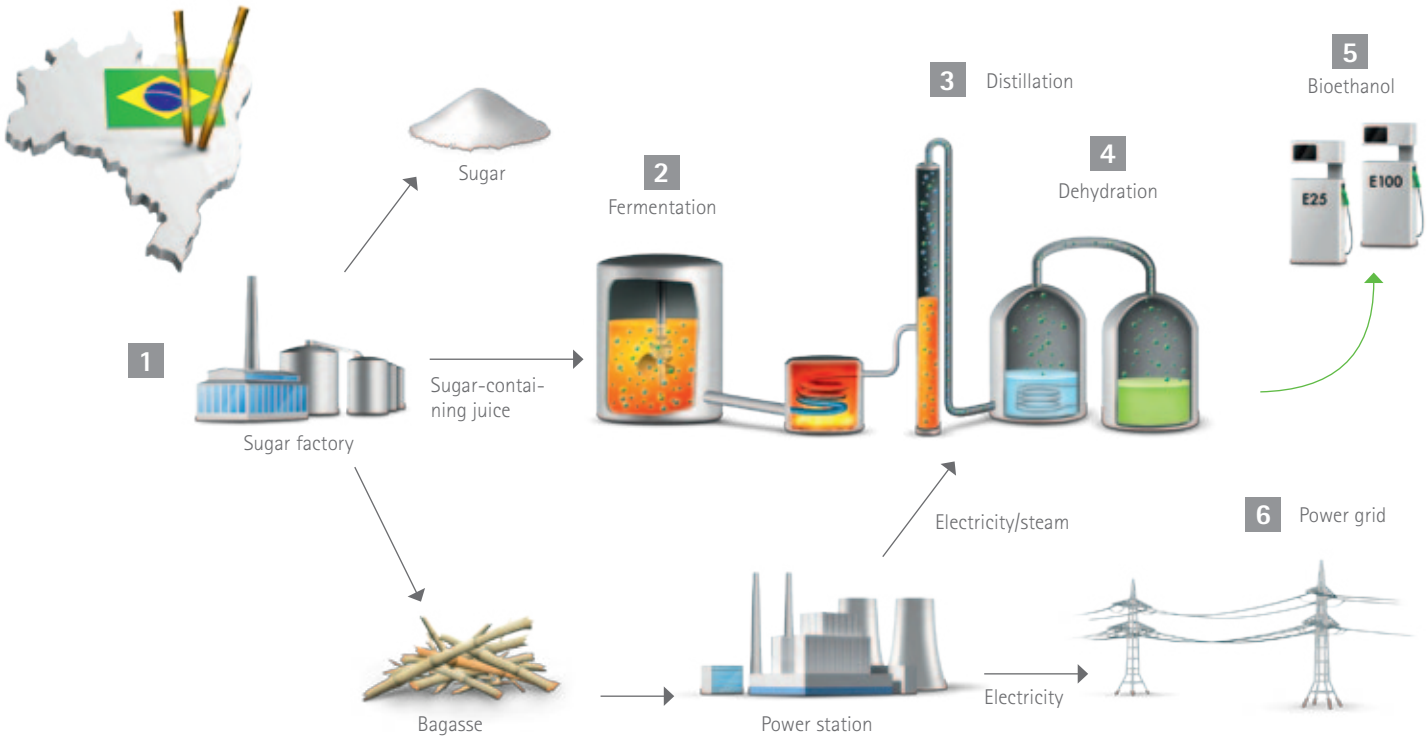
The development of biofuel in Brazil goes back to the oil crisis in the early 1970s, when the Brazilian government began concentrating all its efforts on ethanol as a highly promising alternative. The world's first vehicle to run on 100 percent biofuel (E100) was introduced as early as 1979. By the end of the 1980s, one-third of all Brazilian passenger cars were running on ethanol. Recent introduction of flexible fuel vehicles provided another boom to the ethanol industry. However, increasing production costs and turbulent weather have created challenges for the industry to meet the increasing demand at acceptable prices. Introduction of new technologies to increase yields is considered essential for the sustainable production of ethanol in Brazil.

A gene in many vegetables (e.g. onions) helps trick the sugarcane's metabolism

The Bayer CropScience team now wants to use its expertise in biotechnology to help farmers further increase their crop productivity. Their work actually began back in 2003, when the flex-fuel engine hit Brazil's roads, by which time Bayer CropScience was already studying possibilities for converting the natural sugars in plants. Dr. John Lohrenz, R&D Portfolio Manager at Bayer CropScience, recognized the potential of this scientific work for the sugarcane industry in Brazil. "The plant normally shuts down sugar accumulation above a specific saturation point, but by incorporating a gene into the plant that controls sugar conversion in other healthy food plants, we can trick the sugarcane's metabolism." Sugarcane normally produces sucrose. After the new gene is introduced, the plant switches to producing another type of sugar called kestose. And while the sweet plant fills its storage reservoirs with kestose converted from sucrose, it keeps replenishing the consumed "normal sugar." "It's as if we had built a second storage tank into the sugarcane that increases the overall capacity by up

From the field to the tank: biofuel from sugarcane

The production of sugar yields a juice containing sugar which can be converted in the 1 *sugar factory by means of* 2 *fermentation directly into ethanol. The process of* 3 *distillation separates any residues from the bioethanol/water mixture. As the mixture still does not have the required degree of purity, the water is removed from it by means of* 4 *dehydration. The high-quality* 5 *bioethanol is now ready to be sold at gas stations. However, sugarcane can be used to produce more than just biofuel. The plant residue (bagasse) is also a source of energy and thus makes sugar factories independent of fossil fuel sources and allows them to supply electricity to the grid* 6*.*



to 20 percent," Lohrenz says. What sounds so simple today is based on several years of intense research. "And it undoubtedly will take another decade before the technology will go to market," Lohrenz explains.

"That's because sugarcane is a challenging plant," says Dr. Ralf-Christian Schmidt, Research Program Leader at the Bayer CropScience Innovation center in Ghent, Belgium. "The plant has ten or more copies of its chromosomes, making it hard for us to insert the gene of interest in a suitable position for optimal trait expression. Genetic transformation is therefore considerably more complex than in other crops like corn or oilseed rape." Since the protocols have to be adjusted for each new variety to be transformed, the researchers entered uncharted territory – from incorporating the new gene into the plant's DNA up to the selection of that single new plant - known as a transgenic event - that could be considered for commercial development from hundreds of candidates. "The important thing in gene transfer is not to damage other parts of the DNA, to avoid adverse side effects like poor agronomic performance due to stunted growth, for example," Schmidt says.

With ten and more chromosome pairs, the sugarcane plant is one of nature's challenges

Once the researchers find cells they think have integrated the gene in a favorable genome position, their next step is the greenhouse, where the young plants grow for a year into ten-foot-tall stalks. This is the only way the sugarcane experts can find out if the modified plant does indeed produce more sugar. "We have to see at least 10 percent more sugar before the effort is worthwhile," Burnquist says. In the last step, he and his co-workers study how the plant behaves under normal agronomic conditions. For this, they plant the sugarcane out on a field, testing different locations and different types of soil to monitor the biomass and sugar content of promising events.

Harvest under control: Brazil's state-of-the-art sugarcane harvesting machines are GPS-controlled to prevent unnecessary destruction of soil or yields

The research for this exciting sugar boost is conducted in the Bayer CropScience Innovation Center in Ghent. The team of Bayer CropScience scientists is providing the best genetic constructs to the CTC researchers and helping them optimize their analytical methods. "With our methods, they can select the most promising events with regard to their molecular profile as well as their sugar composition," Schmidt says. A further aspect they are addressing is the improvement of the current technology. "By changing or optimizing gene sequences or corresponding control elements, an even higher sugar yield is possible."

Globally renowned sugarcane experts are working on new, high-yield varieties

"Our best sugarcane varieties will soon contain this new technology," Burnquist says. Researchers at CTC and Bayer CropScience will be spending the next few years closely analyzing and characterizing their new sugarcane events. They still have to answer many questions, such as: How much additional sugar can be produced? How stable is the transferred gene in the DNA? What is the environmental safety profile? Like elsewhere, the legal regulations in Brazil are very strict. "We must document every single step and report every change," Lohrenz says. He and his co-workers expect the work on both sides of the ocean to be completed in the 2020s.

www.research.bayer.com/sugarcane
More information on this subject

"Bioenergy and food security"

research *spoke to Maria Michela Morese, Executive Secretary of the Global Bioenergy Partnership (GBEP). GBEP is an international initiative joining governments, international organizations as well as private and civil society stakeholders in a commitment to promote bioenergy for sustainable development.*

MARIA MORESE

Why is bioenergy an often controversially discussed topic?

Food and energy security are among the most serious challenges faced by developing countries. Sustainable modern bioenergy can promote agricultural, social and economic development that will help address these challenges. While seeking to promote the positive effects that sustainable modern bioenergy can have on food and energy security, GBEP recognizes that there is a complex, multi-faceted relationship between bioenergy and food security.

How are bioenergy and food security compatible?

Investing in and improving agricultural systems could lead to increased production of food, feed, and fiber, and the residues that can provide feedstock for bioenergy, which in turn could promote rural development and improve household welfare. At the same time, bioenergy can create increased demand for certain agricultural commodities, which can increase their price. Moreover, because many of the resources and inputs – such as land, water and fertilizers – that will be used to produce bioenergy are also required for food and feed production, bioenergy projects should be developed in a rational and well-thought-out manner.

How does GBEP's work contribute to these issues?

GBEP has developed a set of 24 sustainability indicators for bioenergy, providing an invaluable resource in helping countries assess and develop sustainable production and use of bioenergy. The indicators seek to measure, among other things, the effects of bioenergy production and use on food and energy security. The GBEP indicators are currently in the implementation phase in several countries to assess their practicality and improve their effectiveness, as well as to inform decision making.