PATHS FOR ADVANCEMENT AS ETHANOL LEADER

FAPESP launches a bioenergy research program

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Researchers from the State of São Paulo are being invited to take part in a major research effort designed to improve Brazil's ethanol productivity and to make advances both in basic science and in the technological development of power generation from biomass. The FAPESP Bionergy Research Program (Bioen), launched on the 3rd of the month, aims at encouraging and putting research together at São Paulo institutions and at improving the area's current expertise. "Brazil has clear advantages in the production of first-generation ethanol from the fermentation of sucrose, but many challenges must be overcome to improve productivity," states Carlos Henrique de Brito Cruz, FAPESP's scientific director. "There are also major opportunities for developing second-generation ethanol made from cellulose. This has been a target for research in many countries. Bioen will work on both fronts," he explains.

The program will have five lines of research. One is research into biomass, with a view to improving sugarcane. The second is the biofuel manufacturing process. The third concerns ethanol applications in automotive engines. The fourth regards studies on bio-refineries and alcohol chemistry. And the fifth will examine the social and environmental impact of using biofuels. "The challenge is to establish a new R&D model with real impact on improving cultivars, on increasing the efficiency of ethanol production processes, and on evaluating the effect of using biofuels in several sectors of society," explains Glaucia Mendes Souza, a researcher from the Chemistry Institute at USP (the University of São Paulo) and Bioen coordinator.

The call for projects estimates some R$ 38 million in investments, of which R$19 million will come from FAPESP and rest from CNPq (Brazil's National Council for Scientific and Technological Development), as follows: R$ 10.2 million in grants and R$ 8.8 million from Pronex, the Aid Program for Centers of Excellence. As part of Bioen, agreements were also established to bring together research efforts with companies and other entities. One of them involves the first call for proposals connected to the FAPESP/Dedini Aid Agreement for Research into Industrial Processes of Sugarcane Ethanol Production, which will initially invest R$ 20 million in cooperative projects involving experts from the company as well as from São Paulo research institutions and universities. The FAPESP/Dedini Agreement provides for investments in the order of R$ 100 million over five years, shared equally between the two partners.

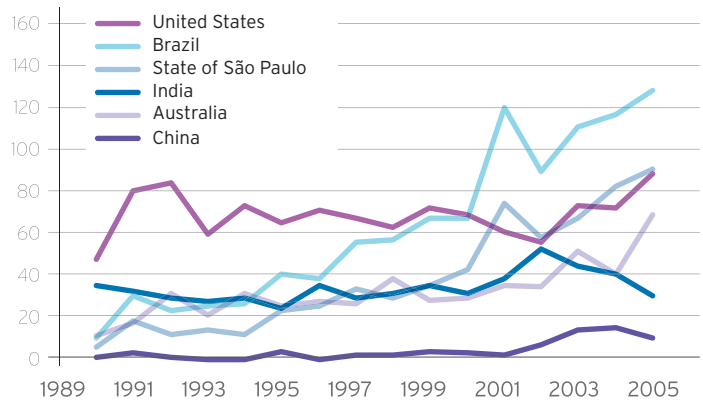
EDUARDO CESAR

Cultivar of hybrid sugar cane grown in Brazil

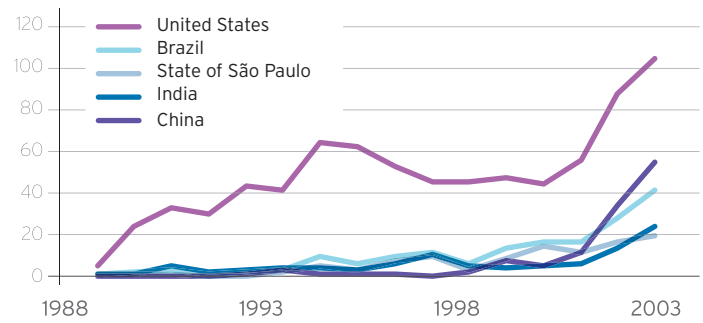
THE COMPETITIVENESS CHALLENGE

Brazil is the sugarcane research leader, but other countries are ahead in studies about 1st and 2nd generation ethanol

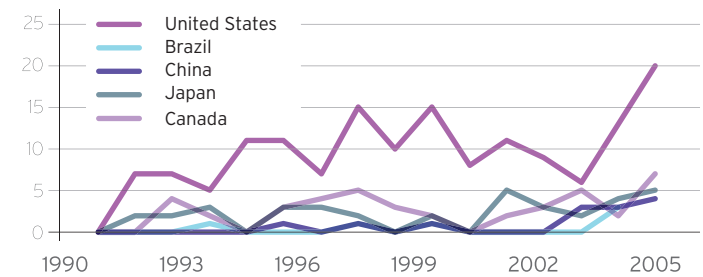
Number of published scientific articles concerning research studies on sugarcane



Number of published scientific articles concerning research studies on ethanol extracted from biomass



Number of published scientific articles concerning research studies on 2nd generation ethanol (lignocellulose)



Sources: ISI/ Web of Science

Dedini is not the only company to enter into a partnership with FAPESP in the biofuel research field. In 2006, the Foundation, together with BNDES [Brazil's National Bank for Economic and Social Development], signed an agreement with Oxiteno, from the Ultra Group, for the development of seven cooperative projects that ranged from investigating the process of enzymatic hydrolysis of sugarcane bagasse for obtaining sugars to the bioproduction of ethanol from cellulose. Early this year, FAPESP and Braskem also established an agreement for the development of biopolymers. Besides the agreements with these three companies, the Bioen Program also encompasses a call for proposals to a total of R$ 5 million; the grants will be funded through an agreement between FAPESP and Fapemig (the Foundation for Research Aid of the State of Minas Gerais) c0vering research into biofuels. Finally, the program will also benefit from R$ 10 million that FAPESP has earmarked for regular aid and forthe Aid to Young Researchers program. The set of calls announced in early June corresponds to R$ 73 million in investment.

The sugarcane agribusiness involves transactions totaling R$ 40 billion a year in Brazil. The 2007/2008 crop is expected to yield 547 million tonnes of sugarcane or 15.2% more than the preceding crop. Half of this will be transformed into ethanol, making Brazil the world's second largest producer of this fuel. The largest producer is the US, which extracts ethanol from corn under heavy subsidies. Two thirds of Brazil's production is in the state of São Paulo. Estimates indicate that Brazil must double its production within the next five to seven years in order to meet local and international demand for ethanol. This will require building new mills, expanding plantations, improving plantation management and, above all, improving productivity.

One of Bioen's chief targets is to create knowledge capable of speeding up the development of new sugarcane varieties that can generate such progress. In São Paulo, productivity improvement may be achieved, for instance, through the advent of cultivars

that are richer in sucrose, as the limited availability of unoccupied land hinders the expansion of plantations. As for the Planalto Central [the large plateau in Brazil's midwest], expansion is more feasible – there are areas with great potential mapped in the north of the state of Tocantins, in the south of the state of Maranhão, in the states of Mato Grosso and Goiás, and in the Triangulo Mineiro area. What is needed, however, is the development of a greater set of varieties adapted to a limited water supply. "The availability of drought-resistant cultivars is necessary to expand sugarcane plantations in this area, because it would enable the use of pastures and might diminish the pressure for expansion on savannas (Cerrado) and forests," says Glaucia Souza. "Producers in the Northeast will also benefit from drought-resistant cultivars, which might significantly increase the region's productivity," she says.

Highly productive sugarcane varieties with high sugar or fiber content and adapted to Brazil's several climates and soil types have been developed for years using traditional genetic improvement techniques. Bioen wants to speed up the development of these varietiesby genetically manipulating the energy metabolism of the farmed plants, thereby generating competitive advantages for Brazilian production.

Bioen's starting point was the interaction of a group of researchers who studied the fragments of sugarcane's functional genes, the so-called Expressed Sequence Tags (ESTs), as part of the FAPESP Sucest (Sugarcane EST) program. Better known as Sugarcane Genome, this project was conducted from 1999 to 2003 by some 240 researchers led by biologist Paulo Arruda; it was financed by FAPESP and Coopersucar (the São Paulo State Cooperative of Sugar and Alcohol Producers). "We got to 238 thousand ESTs, then we moved on to identifying the genes involved; we studied the functions associated with them and did a tissues matrix to help generate more efficient genetically modified plants," sums up Glaucia Souza. "We already have 348 data about genes linked to synthesizing sucrose," she states.

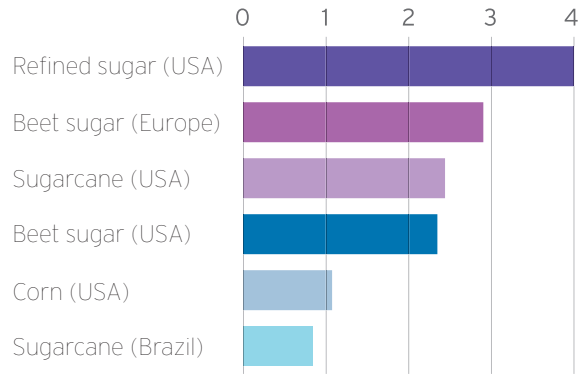
One of the challenges researchers now face is identifying the regions of the sugarcane genome that regulate the expression of the genes mapped by Sucest. An understanding of the physical location of the genes, of the dosage of their variations (alleles), and of their environment will further increase the efficient use of molecular markers to improve the culture and transform the plants. This knowledge should speed up the development of new varieties, also making this process cheaper and more competitive. It currently takes at least ten years. At present, improvement programs start with the selection of future varieties (genotypes) in the field, through the evaluation of the features of interest found in each genotype. This process is conducted on thousands of plants every year, with a view to narrowing them down to a few varieties with great potential. "The idea is to cut the number of plants that are evaluated in the field, using the data of molecular markers to select ahead of time variet-

Hybrid sugar cane

MIGUEL BOYAYAN

THE POWER OF BRAZILIAN ETHANOL

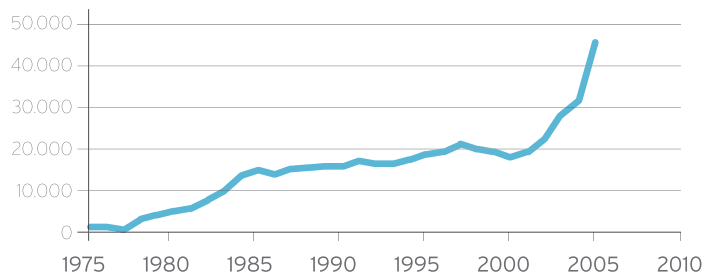
Ethanol production cost, in USD per gallon (4.5 liters), from:



Source: USDA

THE BIOFUEL LEAP

Evolution of global ethanol production – in millions of liters



Source: Worldwatch Institute and World Ethanol and Biofuels Report (2006)

ies linked to genes that are of interest," says agronomical engineer Anete Pereira de Souza, the study's coordinator, who also teaches at the Genetics and Evolution Department of the Biology Institute and does research at Cbmeg, the Molecular Biology and Genetic Engineering Center, both of which are part of Unicamp (the State University of Campinas). "The identification of molecular markers associated with features of interest is extremely important for guiding plant crossbreeding in the sugarcane improvement program," states researcher Marie-Anne Van Sluys, a professor at the Botany Department ofUSP's Biosciences Institute. Both Anete and Marie-Anne will coordinate Bioen research. The task of identifying the molecular markers, incidentally, is far from trivial. The sugarcane genome is as much as three times bigger than the human one, with the added complication that, instead of two copies of each chromosome, there are as many as ten copies that are not all equal.

The Bioen Program will also study sugarcane's defense mechanisms against some of the main pests. The interaction between the plant and the insect is a dynamic system that is subject to continuous variations. "The plants have developed different mechanisms to reduce insect attacks, including specific responses that activate different metabolic paths and that considerably change their chemical and physical characteristics," says Glaucia Souza. On the other hand, the insects have developed strategies to overcome the plants' defense barriers, enabling them to feed off their hosts, as well as to develop and reproduce in them. One of the specific objectives is to study the giant sugarcane borer, one of the plant's main pests in the Northeast of Brazil, also recently identified in parts of the Southeast, besides understanding the function of specific sugarcane defense proteins that fight borer attacks.

Another research focus is how sugarcane will respond to climate change. This knowledge may help the development of varieties that can withstand more rain and heat better, besides the expected advance of pest infestation. It is a known fact that a high concentration of carbon dioxide produces photosynthesis and biomass increases, indicating potential productivity growth. "On the other hand, we know very little about hormone control mechanisms, their relationship with carbon metabolism and the gene transcriptions networks connected to this," says Marcos Buckeridge, a professor at the Department of Botany at the USP Biosciences Institute and Bioen coordinator. "Knowledge of these processes has the potential to show which are the sugarcane metabolism points that might be altered to produce varieties capable of adapting to climate change," states Buckeridge. Sources of biofuel that do not jeopardize nature, such as making ethanol out of polysaccharides from the seeds of native trees grown in the midst of sugarcane plantations, will also be researched. "Agro-forest systems may provide a new model for increasing the production of renewable energy harmoniously and with social benefits, with minimal environmental impact," states Buckeridge.

Sucrose alone, which accounts for one third of sugarcane's biomass, is used to make sugar and fuel alcohol. It is true that Brazil uses sugarcane bagasse to produce energy at mills or for animal feed; this has resulted in an outstanding efficiency gain. The major challenge, however, is to transform the cellulose in the bagasse and straw from the sugarcane into ethanol – enzymatic hydrolysis or physical-chemical processes could enable the carbon units within cellulose and hemicellulose to ferment as well. Knowledge of cellulose utilization technology is at the core of the global race to produce energy from renewable sources. This process is currently very expensive and far from being financially viable. If researchers find ways

to cut costs by using the cellulose that accounts for two thirds of sugarcane, Brazil's ethanol production could dramatically increase in the long run.

The physiology of sugarcane cell walls will be studied as part of the Bioen project. These walls are made of cellulose, hemicellulose and pectins, interwoven in a way that makes it very difficult to efficiently extract energy from their chemical bonds. Investments will be made to understand how the wall is built, in order to perhaps change its structure and create varieties that degrade more easily. "We already have the composition and structure of the polysaccharides of the cell walls of sugarcane leaves, stalks and flowers. Therefore, we know which bonds must be broken to produce sugar," says Buckeridge. "We also have a list of 469 genes connected to the cell walls and we're studying this in greater depth to understand how some of these enzymes work. But this is a protracted task, because we must understand not only how each enzyme operates, but also how they work together. Our long-term aim is to cause the plant, at a certain point in its development, to start degrading its own wall, making it easier to complete hydrolysis after it has been reaped, using enzymes from microorganisms," stated the researcher.

Research on obtaining ethanol from cellulose involves physical, chemical or biological processes; no one knows yet which will be the most efficient. "Up to two years ago, producing large amounts of ethanol was a Brazilian subject. Now, as developed countries have become interested in the issue, we will face competition that will oblige us to use a lot more advanced science," says Brito Cruz, FAPESP's scientific director, who highlights the importance of simultaneously investing in traditional ethanol and in cellulose ethanol. "The idea that second-generation ethanol might be superior is controversial. Undoubtedly it will be advantageous for countries that can't make first-generation ethanol. Research indicates that first-generation ethanol will continue to be superior to the second-generation type for years to come. Still, second-generation ethanol will be very attractive in relation to current oil prices," he states.

Dedini, which has established a partnership with FAPESP, has already developed and patented a process for obtaining ethanol from cellulose and is now trying to perfect it. "It's a great privilege to have access to knowledge from research centers so that together we may solve the technological problems of ethanol production," says José Luiz Olivério, vice-president of Dedini. The call for proposals establishes that over the next three months researchers may submit projects related to improving traditional processes, such as ethanol production or using sugarcane waste for power generation, and with developing innovative processes, such as obtaining ethanol from cellulose through acid or enzymatic hydrolysis at competitive costs. The proposals will be selected by a committee and the chosen projects will be monitored by Dedini's R&D experts.

The discussion about the eventual impact on food production of farming for ethanol production has grown in the last few months and may be studied under program's fifth line of research, which will analyze the social and environmental effects of progress in the production of bioenergy. "It has been clearly shown that this is a misconception; the two main reasons why the cost of food has grown are the increase in the price of oil, which affects transportation, and the increase in the world's consumption , due to the fast economic development in China and India," says Brito Cruz. "Bioen's concern is not tied to the debate about this state of affairs, but to the fact that, to date, agricultural development worldwide has always targeted food production; however, it will now also target producing energy for automobiles. This will probably change the reasoning that governs world agricultural progress and we still know very little about this," he states.

Finally, Bioen also plans to attract and train qualified personnel for bioenergy research. The idea is to create the conditions needed to consolidate the state's leadership in this field, through actions that enable academic research at competitive international standards, an increase in contributions from the institutions and centers that already engage in research in this field, and the establishment of a research network in partnership and collaboration with companies. ■

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