SCIENCE

ECOLOGY

Jatoba against pollution

Tropical trees may be an option for cleaning the atmosphere, should the greenhouse effects increase

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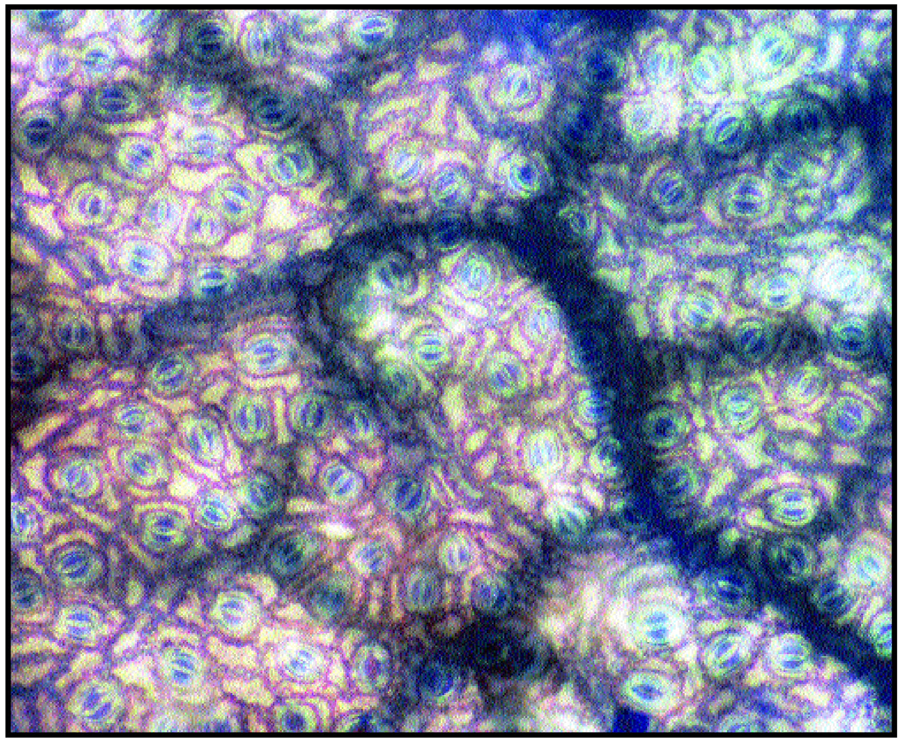
Transforming tropical rain forests into carbon dioxide (CO_2) cleaners and thereby freeing the atmosphere from large quantities of the main gas responsible for increasing the greenhouse effect on Earth is, for the time being, an idea as controversial as it is unattainable. If one day this feat becomes possible, a group of specialists in plant physiology from the São Paulo Institute of Botany believes that the jatoba, a tree that is extremely well adapted to Brazilian ecosystems and present in practically all the latitudes of the Brazilian territory, may be a good candidate for carrying out the role of cleaner of the air – or, at the least, to show how this task may be carried out by other plants. This dream, a still far-fetched reverie, is based on the results of a series of experiments carried out with seedlings of a species of courbaril, *Hymenaea courbaril* (Jatoba), whose growth seems to speed up in environments rich in carbon dioxide, the popular name for CO_2.

Generally speaking, the studies indicate that when they are cultivated for three months in a place with 720 ppm (parts per million) of CO_2 in the air, twice the current concentration in the atmosphere, the Jatoba seedlings double their absorption of carbon dioxide and the production of sugars (carbohydrates), and increase their biomass by as much as 50%, above all in the area of the leaves and in the roots, in the light of the fact that, at this age, the plants are not yet producing trunk (wood). "The work suggests that the courbaril may continue to trap carbon while growing in an environment with high levels of carbon dioxide", says Marcos Silveira Buckeridge, from the Institute of Botany, the coordinator of a project carried out in the ambit of Biota-FAPESP, a program for mapping biodiver

Jatoba: in an environment saturated with carbon dioxide, more photosynthesis

lo. "Our proposal is not to set out planting jatoba forests in the hope of reducing the greenhouse effect. It is, rather, to understand this plant's physiological mechanism, and research into this is at a more advanced stage, to try one day to optimize the assimilation of carbon by the courbaril and other tropical trees that ought to have a similar metabolism".

If the behavior of the adult courbaril in the forest is similar to that of its sapling cultivated in a controlled environment, this tree may be able to get considerably stouter, should the Earth's atmosphere reach those 720 ppm of CO_2 in 2075, as some estimates suggest. In this hypothetical futuristic scenario, to say that the jatoba tree is going to increase its biomass – to have more and/or larger leaves and roots, and, above all, to produce more wood – is equivalent to claiming that this plant is going to trap more carbon from the air. After all, the cellulose in wood is one of the best ways of storing carbon present today in the CO_2 in the atmosphere. "We still do not know, however, how the jatoba tree, in its entirety, responds to the increase of CO_2", comments Marcos Aidar, another biologist from the Institute of Botany involved in the project. "We cannot specify, for example, how much of this extra carbon dioxide that goes into the plant ends up leaving it through its respiration."



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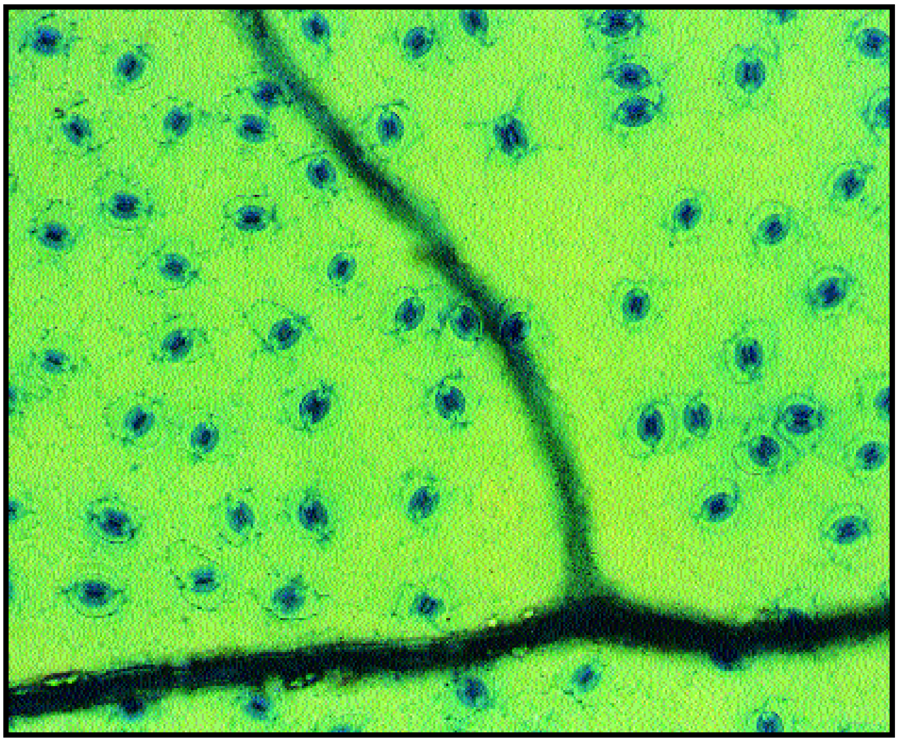
Surface of a leaf from a 1919 jatoba: 40% more stomata (*highlighted*)...

Along with water and light, carbon dioxide is a compound necessary for plants to carry out photosynthesis (energy production). The CO_2 absorbed by a plant can only have two destinations: a part remains held back in the inside of the plant, and the other is sent back to the atmosphere through respiration. The portion that stays in the plant is used in chemical reactions that generate cellulose and other sugars. Altering the mixture of the quantity of CO_2 eliminated by plants, and above all of the fraction used in the production of carbohydrates and wood, is a goal pursued by the paper industry, sectors of agriculture, and scientists like Buckeridge and Aidar.

In the last few decades, the rise in the levels of carbon dioxide in the atmosphere was basically due to changes in the use of the land (slashing and burning of forests) and to the increase in industrial activity, above all because of the accelerated combustion of fossil fuels (coal, oil and gas). Measures at a global level to fight a series of environmental problems, including the stepping up of the greenhouse effect, were discussed at the World Summit on Sustainable Development, the Rio + 10 conference held by the United Nations (UN) in South Africa at the end of August and beginning of September. Theoretically, lowering CO_2 emissions is the simplest and most effective measure to lessen the impact of the greenhouse effect, which is expected to warm up the Earth's climate by a few degrees and change the rainfall pattern at some spots of the globe. However, this objective is one that is difficult to achieve, since the United States, which on its own emits one quarter of the carbon dioxide in the atmosphere, is not willing to take on a commitment like this, as it once again was made clear at the UN meeting (*see the box on page 26*).

Among the proposals that are alternative or complementary to the reduction in the CO_2 emission, one that is frequently pointed out is the maintenance of the tropical forests (and the possible reforestation of new areas), above all due to the potential shown by trees for trapping carbon. Potential, by the way, that is still far from being known, and one that may vary a lot as a result of several factors, such as the age and type of tree being analyzed. As a rule, it is usually said that tropical forests have a great capacity for taking CO_2 from the air. But recent calculations made in the ambit of the Large-Scale Biosphere-Atmosphere Experiment in the Amazon (LBA), an international megaproject led by Brazil, point to the potential for sequestering carbon of this ecosystem possibly being more modest than it used to be thought. This is the context into which the studies of the researchers from the Institute of Botany fit, on the metabolism of courbaril in carbon dioxide rich environments.

The main field experiment with *Jatoba* was carried out last year in collaboration with Carlos Martinez, then at the Federal University of Viçosa (UFV), in Minas Gerais, and today at the University of São Paulo (USP) in Ribeirão Preto. In Viçosa, the cuttings of the plant were cultivated in two kinds of special chambers: one in which the mixture of gases was the same as in today's atmosphere (360 ppm of CO_2), and another with the air kept artifici-



...than today, when the concentration of carbon dioxide is 20% higher (magnified 25 times)

ally with a constant concentration of 720 ppm of CO_2. These devices do not reproduce to perfection the hypothetical environment of 2075 – for example, there is no control over the temperature and humidity, parameters that are likely to change with an increase of the greenhouse effect. Even so, the use of the chambers is universally accepted for this kind of comparative test. "There are more sophisticated and expensive methods, but the majority of work makes use of these chambers", Buckeridge ponders. In the course of the experiment, measurements were taken of several parameters of the plants brought up under different environmental conditions and afterwards collated.

Another methodology used by the researchers was to pump different concentrations of carbon dioxide into only the leaves of the jatoba – and not the whole cutting. With this more targeted approach, concentrated on the part of the plant that absorbs and emits gases, Buckeridge's team discovered that the leaves of the jatoba only reach saturation point in the absorption of CO_2 when the concentration of gas exceeds 1,000 ppm. This is an extremely high saturation point, compared with other tropical plants. The bromeliad *Alcantarea imperialis*, for example, cannot successfully increase the speed with which it assimilates carbon dioxide, if placed in an environment with 600 ppm. With Brazilwood (*Caesalpinia echinata*), the same happens when the level of CO_2 hits 700 ppm. "If our hypothesis is right, the jatoba will still be responding to the change in the concentration of this gas many decades after other plants have reached their utmost point of assimilating carbon", Aidar comments.

Besides showing that the jatoba cuttings behave differently when cultivated in different concentrations of CO_2, the work found alterations in the cellular structure of the leaves of the plants. The team from the Institute of Botany, also made up of Paula Costa, Solange Viveiros and Sonia Dietrich, found that the number of stomata in the courbarils cultivated at 720 ppm of CO_2 was about 15% less than those measured in the saplings kept at 360 ppm. Present fundamentally on the surface of the leaves, where they control the gas coming into and going out of the plants, in particular the absorption of CO_2 and the emission of water vapor, the stomata are sets of cells that perform the role of pores in plants. What does the variation in the number of stomata have to do with the lesser or greater volume of CO_2 in the atmosphere? In environments that are extremely rich in carbon dioxide, plants adapt themselves to the conditions of the atmosphere and reduce the number of stomata in order not to capture an excessive amount of CO_2, which would not be productive or could be even harmful to their organisms. "Changes in the density of stomata are part of the mechanism for regulating plant metabolism", says Buckeridge. "This has now been seen in plants from a temperate climate and in *Arabidopsis thaliana* (a plant model for biology) exposed to high concentrations of CO_2."

Alterations in the level of stomata in plants are not just a phenomenon foreseen for the future, if and when the increase of the greenhouse effect becomes even more intense. Actually, there are strong signs that these changes in the leaf cellular structure have been going on for at least two centuries. Work done in centers abroad have shown that, with the Industrial Revolution and the gradual rise in the emission of toxic gases such as CO_2, today's plants show less stomata than those of the past. Buckeridge's team also corroborated this phenomenon with the courbaril. In the herbarium of the Institute of Botany, they took leaves from a tree dating from 1919, a time when the concentration of CO_2 was around 300 ppm, 20% less than now, and saw that this example of the species had a density of stomata that was 40% greater than in today's *Jatoba*. "If compared with the Jatoba cuttings that we cultivated in Viçosa at 720 ppm, the specimen from the beginning of last century had practically double the number of stomata", says Aidar.

The reader may not have noticed a paradox that pops up from the experiments carried out with the jatoba cuttings in the supposed environment of 2075, rich in CO_2. Under these conditions, the plant shows an increase of 50% in its sugar and doubles the assimilation of carbon dioxide. These last two details lead one to believe that, compared with the current situation, the photosynthesis of the plant also should double, if the levels of CO_2 increase

100% over the next 75 years. So far, it all makes sense. But the reduction in the number of stomata messes up this picture a bit. After all, this alteration is an attempt to adjust downwards – and not upwards, as the earlier data suggests – the current levels of the plant's photosynthesis. "It may be that, in spite of having lowered the number of stomata, there has been an improvement in the cellular structure that were left and are responsible for capturing CO_2", says Buckeridge. This contradiction is an indication that the courbaril's metabolism is waging a kind of inner battle to try to adjust the level of photosynthesis in an environment richer in carbon dioxide.

Many botanists believe that plants have an internal mechanism that allows them to sense the quantity of carbohydrates (sugars), and so to adjust its levels of photosynthesis, to avoid absorbing too much carbon dioxide. According to this theory, when the production of sugars reaches a very high level, above the capacity of the plant for using them, a sensor sends an order to stop photosynthesis and, as a consequence, to lower the assimilation of CO_2 and the synthesis of cellulose. In the opinion of Buckeridge and Aidar, determining the genes that codify proteins that are important for the workings of this natural sugar sensor, such as the enzyme known as rubisco (ribulose-1,5 – bisphosphate Carboxylase) – may be useful for trying to control the entry of carbon dioxide and the production of cellulose in trees.

EDUARDO CESAR

Cuttings: with twice the carbon dioxide in the air, they double the production of sugars

Enthusiastic over the results achieved with the courbaril cuttings at 720 ppm of CO_2, the researchers from the Institute of Botany decided to publicly advocate the idea of researching the use of gene therapy in plants to pursue this intention. In an article published in April in the Biota Neotropica electronic magazine, maintained by the Biota-FAPESP program, the two researchers proposed a few biochemical routes which could be altered in plants with the intent of controlling their photosynthesis, the metabolism of carbohydrates (sugars), and the synthesis of cellulose as well. "We know that this idea is controversial, but we defend approaches that are safe from the environmental point of view", Aidar explains. To be ecologically correct, these interventions into plant genomes must not be handed down to their descendants. In this way, nature is not affected by transgenic species, which could compete and become dominant, with regard to the one unaltered in their DNA.

Russia makes international agreement feasible

If the measure of the success of Rio + 10, the world summit of the UN for sustainable development that ended last month in Johannesburg, is the adhesion of the United States to the commitments laid down in the Kyoto Protocol, the meeting may be considered a failure, at first sight. In South Africa, the George W. Bush administration gave no guarantees to reduce the emission of carbon dioxide, the main culprit for the greenhouse effect. But what seemed to be a victory for the intransigence of the Americans, responsible for one quarter of the global emissions of CO_2, may be a sign of the growing isolation of the country's position.

Although the summit did not produce any bombastic facts, the end of this mega-event, which gathered representatives from 190 countries, may have paved the way for Kyoto to start being put into effect. By 2012, the protocol provides for bringing down the levels of CO_2 emitted by the industrial countries to the levels prior to 1990.

To come into force, the agreement needs to be ratified by at least 55 countries (which has now been achieved), which account for a minimum of 55% of the global emissions of CO_2 – a requirement that is difficult to meet without the United States and of its allies in the environmental field. But the scenario changed at the end of the meeting, as Russia, the second largest emitter of CO_2 on the planet, and Canada, a follower of the Washington recipe book, said that they will ratify the protocol shortly. Australia too is studying compliance with the Kyoto rules. As the 15 countries of the European Union and Japan ratified the agreement at the beginning of the year, with the entry of Russia, and even without the United States, the protocol can take off. Poor and developing countries like Brazil are exempt from complying with the targets.

Brazil, indeed, made news at Rio + 10, by presenting a proposal that called attention: it advocated the idea that by 2010 10% of the energy used globally should come from renewable sources, such as hydroelectricity. The suggestion was however rejected by the United States and the oil producing countries, with the exception of Venezuela.

EDUARDO CESAR

Political deadlock: reduction of the emission of carbonic acid gas depends on international collaboration

For the researchers from the Institute of Botany, two kinds of intervention, both of them theoretically safe from the environmental point of view, could be tried out in plants, with the purpose of increasing their efficiency in ridding the atmosphere of carbon dioxide. One of the possibilities would be to promote alterations in the plants' chloroplasts, in the light of the fact that this part of the genome is not, in the immense majority of plant species, passed on hereditarily to the descendants. Another alternative would be to develop gene vaccines or medicines that could be administered to plants temporarily, just for the time deemed necessary, with the objective of acting on their metabolism, thus leading them to a greater production of photosynthesis and assimilation of carbon.

Not everyone has approved the ideas of Buckeridge and Aidar. In the following issue the Biota Neotropica magazine, two researchers from the Federal University of Rio de Janeiro (UFRJ), Fábio Rubio Scarano and Eduardo Arcoverde de Mattos, published an article criticizing the proposals of their colleagues from São Paulo. "[The proposals] err for not taking into some important ecological and sociopolitical aspects, such as not being ecologically predictable, the fact there is great potential for carbon being sequestered by non-manipulated native plants, and the importance of scientific and political sovereignty as far as the theme of global changes is concerned", wrote Scarano and Arcoverde. Obviously, the knowledge of plant physiology and biotechnology is still not at a level that makes it possible for scientists to go ahead, in the short term, with either one of the two approaches suggested by the two researchers from the Institute of Botany. "But time is running, and if the forecasts are correct, we have only 50 years to decide whether or not we are going to use these methods for manipulating plants", comments Buckeridge.

THE PROJECT

Conservation and Sustainable Usage of the Plant Biodiversity of the Cerrado and the Atlantic Rain Forest: Reserve Carbohydrates and their Role in Establishing and Maintaining Plants in their Natural Habitat

MODALITY
Thematic Project

COORDINATOR
Marcos Silveira Buckeridge – Institute of Botany of the State Secretariat for the Environment

INVESTMENT
R$ 309,845 and US$ 378,726

Even if the studies of jatoba do not open the way for the development of techniques capable of increasing the capacity of tropical forests for sequestering carbon (dioxide) from the atmosphere, the research with *Jatoba* will have served another purpose, just as important or more from the botanical point of view: helping to understand the physiology of plant species and serving as a parameter for the possible rearrangements of the flora that may happen as a result of changes of climate. Many international works, almost always with plants from a temperate climate or farm crops, show that deep alterations may be occurring in the biodiversity of the Earth, due to the increase in the levels of CO_2 and of the greenhouse effect. A study from the University of Florida recently published in the Global Change Biology magazine, showed, for example, that the yield in a crop of beans is one quarter larger when cultivated at 720 ppm. The same thing also seems to happen with soya planted in CO_2 rich environments.

In the case of trees from a temperate climate, there are indications that in an environment with high concentrations of CO_2, the shade species are going to increase their biomass more than the varieties accustomed to sunlight. The data on the growth of jatoba at 720 ppm of carbon dioxide gives weight, for the time being, to this hypothesis. Incidentally: the variety of jatoba studied at the Institute of Botany is a tropical species that grows in the shade when young, protected from the rays of sun by the crowns of larger trees. Buckeridge and Aidar are now planning experiments with other tropical species, like the species of ipe (*Tabebuia* spp), glorybushes (*Tibouchina* spp), pau de jacaré (alligator wood –*Piptadenia gonoacantha*) and Brazilwood, to see their behavior in environments with high levels of CO_2. Another goal is to carry out more complex tests with jatoba, in which, besides the levels of carbon dioxide, temperature and humidity are controlled in the special chambers in which the plants are cultivated. •