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THE ROLE OF THE STATE OF SÃO PAULO RESEARCH CENTERS ON BIOENERGY TECHNOLOGICAL INOVATION

Orlando Melo de Castro

INTRODUCTION

Generation and transference of scientific knowledge are strategic elements for a sustainable development of agribusiness in the state of São Paulo. State government invests money through agencies such as Apta – Agência Paulista de Tecnologia do Agronegócio – São Paulo Agribusiness Technology Agency, in order to amplify the competitive leadership of our state.

São Paulo is leader on bioenergy production in Brazil, and most of industries aiming bioenergy production are settled in the state. It is responsible for more than 60% of Brazilian ethanol production and represents around 30% of the state energetic matrix. In addition:

- São Paulo is responsible for 1/3 of Brazilian agribusiness and for almost 30% of exportations. Foreign sales of agribusiness products have reached a total of US$ 14.47 billions dollars in the year of 2008 (DIÁRIO OFICIAL, 2008).
- Farming and cattle raising production of São Paulo state in 2008 was nearly R$ 37.7 billions, which corresponds to an increase up to 11.6% in comparison with 2007, already discounting inflation (IEA, 2009).
- São Paulo's agriculture bears the greatest yield indexes: 2.3 fold the national average.
- Most part of the technological development on bioenergetic area takes place in public and private institutions of the state.
- Formal training in undergraduation and graduation courses in agro sciences in this state reaches the highest national levels.
- Each R$ 1.00 invested in agriculture and cattle research returns between R$ 10.00 and R$ 15.00 in values of the agricultural production, in the period from 1960 to 2000.
- Bioenergy contributes for the improvement of São Paulo environment. State environmental legislation concerning to the bioenergetic issue is the most modern and efficient among all Brazilian states.
- Agribusiness and familiar agriculture, on their economic, social and environmental dimensions, go on together in São Paulo, generating incomes and employments as well as promoting a regional development.

São Paulo's public policies aim to attend, through diffusion and popularization of science, the insertion of poor populations and also the increase of agriculture yield, as well as keeping State's leadership in the main productive chains of agribusiness. Policy for science, technology and innovation adopted by Apta are consonant with the public policies from São Paulo's Department of Agriculture and Food Supply.

Regional development is considered determinant for the enlargement of the State's economy. Thus, Apta is participant of the importance that science and technology represent nowadays in the process of regional development. Science and generation of technology are considered by Apta as social inclusion factors and, consequently, extension activities of knowledge and spread of new technologies are also considered major aims.

Capacity-building is another prior issue to Apta. It is intended, through the capacitance of agents, to collaborate with the generation of incomes and rural employment; gather value to products; collaborate with the adoption of new technologies and also help on the divulgation of the institutional mission for the society.

A new concept was recently introduced in São Paulo's public policies for the agricultural sector. Add to the generation of incomes, employment and social inclusion, certified quality or traceability is currently essential for the attendance of external market and also to ensure better life quality.

New opportunities and challenges are raised every day. The production of bioenergy and highly-productive biomass respecting the bases of sustainability, added to the avoidance of competition with food production, as well as preserving environments and forest areas, in a way that it is possible to generate jobs, incomes, social inclusion and regional development are major aims to be accomplished by Apta in the following years.

APTA'S INSTITUTIONAL MISSION

Apta's mission is "To generate, adapt and transfer scientific and technological knowledge for agribusiness, aiming for the social-economic development and environmental balance".

This mission is performed by the Research Institutes belonging to the Department of Agriculture and Food Supply in the State of São Paulo. Apta composing units are: Instituto Agronômico – IAC, head office in Campinas; Instituto Bilógico – IB, Instituto de Economia Agrícola – IEA and Instituto de Pesca – IP, all established in São Paulo; Instituto de Zootecnia – IZ located in Nova Odessa; Instituto de Tecnologia de Alimentos – Ital, seat in Campinas and also 15 Regional Poles of Technological Development, which action areas comprises several regions of the state. In addition to the head offices, which are also experimental farms, poles encompass other Research and Development Units, in a total of 34 Research Units (Experimental stations).

Regional poles reinforce Apta its strategically-distributed structure throughout the state, counting with scientific researchers in regions of agronomic frontier and/or close to productive chains which they are integrated in. Add to the programmatic action of Research Institutes (IAC, IEA, ITAL, IZ, IP e IB), the structure found in the Regional Poles confers strategic and competitive advantages ahead other Research Institutes in the State.

Generation of knowledge and technology is concerned to the adding of all actions, procedures and achievements used in a systematic way, linked to the basic knowledge or to applied science.

Transference of know-how and technology consists of actions that aim the dissemination and adoption of technologies. Traditionally, Research Institutes make public their research works in scientific and technical reports. Apta has many well-known scientific periodic magazines, which are under responsibility of the Institutes such as: Revista Bragantia, o Agronômico, Informações Econômicas, O Biológico, Boletim de Indústria Animal, Boletim do Instituto de Pesca and *Brazilian Journal of Food Technology*.

Other major actions for spreading technology is the organization of events, such as Field days, technical seminaries, among others, Apta also plays a role in capacitating people, through graduate courses (MSc at IAC, IP, IB & IZ and Ph.D at IAC), as well as organizing annually many short or long courses and trainings.

In the process of transference of knowledge, it is also relevant the production of strategic goods and specialized services that comprises goods and services derived from knowledge generated during the research process.

APTA AND THE RESEARCH, DEVELOPMENT AND INNOVATION STRATEGIC PROGRAMS

Apta joins government actions (public policies) with institutional goals. Within this perspective, it was defined for the Pluri-annual Plan, which is the government's instrument to the budget management and financial liberation, five great Strategic Programs for the period of 2008-2011. Programs were conceived aiming to orientate

RD&D for themes considered as priority in the present and future agricultural research scenario. This organization propitiates management mechanisms that facilitate programmatic actions of the Agency. Moreover, it is expected to create a more competitive environment in the sense of broadening the capacity of capturing resources and straitening Apta's relations with strategic partnerships.

Different productive chains are inserted in one or more strategic programs, e.g., research projects of sugarcane productive chain may be inserted in bioenergy programs, products and process strategic for agribusiness or even environmental sustainability.

Strategic programs defined for Apta are:

1. bioenergy;
2. environmental sustainability;
3. organization of rural and peri-urban areas;
4. food safety;
5. products and processes strategic for agribusiness.

To attend the strategic programs, Apta counts on with state budget resources, complemented with incentives from state, national and international founding agencies and also from private initiative. It also keeps scientific collaboration with other institutes, universities, private initiative, and agriculturalists, among others.

Apta counts within its dependency of around 20.000 ha of useful area belonging to the Research Institutes, encompassed among poles and some specialized centers under the supervision of the Research Institutes located in Campinas, Jundiaí, Cordeirópolis, Nova Odessa, Ribeirão Preto, Sertãozinho, among others. The sum of all these research units confers Apta its great capillarity in the State and the possibility to execute projects in an experimental network, in which one sole experiment may simultaneously be performed in different edapho-climatic conditions. These aspects consist in incomparable advantages to agronomic research.

Apta Institutes are organized in Research Centers. There are 35 Research Centers, comprised through 6 Institutes. These centers may be thematic or product-specialized, generating and developing most part of the agronomic research of the Institution and, many times, they coordinate or participate in the research performed in the Regional Poles.

Apta counts on its staff board with 2,491 employees, among researchers, administrative assistants or research support assistants, as shown in Table 1.

Scientific qualification of Apta research team is considered high. Around 42% of the technical board has already reached academic titles such as PhD or post-doctoral positions. Table 2 shows the percent distribution regarding the academic titles of Apta research team.

TABLE 1 Apta staff board.

Institute	Number or researchers	Number of assistant employees	Total
IAC	203	361	564
IB	126	116	242
IP	72	94	166
IEA	73	69	142
ITAL	96	108	204
IZ	60	166	226
Regional poles	213	734	947
Total	**843**	**1,648**	**2,491**

TABLE 2 Percent distribution of Apta's research team academic titles.

Researchers	%
PhD and post-doctorates	42
MSc	40
BSc	18
Total	**100**

Major aspects that characterize Apta are:

- Solid Institutes, reference in the history of national agronomic research.
- Well-distributed infrastructure within the state of São Paulo, that enables the assistance of regional demands and the formation of research networks, good capillarity.
- Technical board highly qualified.
- Diversified agenda of RD&I and multidisciplinary.

Some issues either limit or impair many RD&I actions in the Apta ambit and consist, therefore, in aspects to have efforts concentrated on them within the following years:

- Budget and financial resources are not always sufficient.
- Need for modernization of the infrastructure.
- Motivation, training and professional updating for technical and support board.
- Replacement of the support and administrative staff board, modernization and creation of new careers, e.g., professionals in the area of communication, informatics, administrative management, among others.
- New juridical model that ensures more administrative autonomy and self-management of the technological and physical patrimony.

Efforts must be made in order to broaden competence in research, development and innovation; also in the modernization of management, potentialization of opportunities for resources acquisition, improvement of the relationship with the productive sector and finally in transferring technology to the productive sector.

APTA AND BIOENERGY

Within the macro program bioenergy, Apta intends to found, generate research and suggest state actions for the various aspects of bioenergy, comprehending scientific and technological studies, in the areas of plant yield, biomass and residues application and even aspects concerning environmental, social and economic impacts.

Current portfolio in bioenergy projects is composed of 90 research projects comprising the following areas:

- Phytotechny, new cultivars, value aggregation, evaluation and use of wastes in oilseed plants.
- Phytotechny, new cultivars, value aggregation, evaluation and use of wastes in starch plants (manioc for ethanol).
- Phytotechny, new cultivars, value aggregation, evaluation and use of wastes in sugarcane for ethanol.
- Biofuels and agricultural engines functioning.
- Economic evaluations, production costs, competitiveness, food safety.

TABLE 3 Number of researchers directly involved in bioenergy studies and Apta units where they develop research.

Units	Number of researchers
IAC – Centro de cana-de-açúcar – Sugarcane Center	16
IAC – Centro de ecofisiologia – Ecophysiology Center	4
IAC – Centro de solos – Soils Center	3
IAC – Centro de irrigação e drenagem – Irrigation and Drainage Center	2
Polo – Piracicaba	4
Polo – Jaú	5
Polo – Votuporanga	2
Polo – Colina	4
Polo – Ribeirão Preto	5
ITAL	13
Instituto biológico – Biological Institute	7
Total	**65**

TABLE 4 Number of researchers directly involved in bioenergy studies and their major area of actuation.

Areas of actuation	# of researchers
Value aggregation and food engineer	9
Biochemistry, ecophysiology and plant physiology	5
Biotechnology and molecular biology	3
Climatology	1
Biological control of pests	2
Biological control of diseases	3
Pests and diseases control – Phytossanity	6
Conservation, conservationist practices, direct planting	3
Production costs	1
Phytotechny and plant yield	8
Irrigation and drainage	2
Weed management	2
Genetic breeding	6
Plant mineral nutrition and soil fertility	5
Agro environmental planning	1
Wastes, sustainability and environmental issues	4
Zootecny – animal nutrition with biomass production wastes	4
Total	**65**

Research on the bioenergetic area is performed by several Apta units and involves hitherto 65 researchers.

Apta develops research in genetic breeding and phytotechny for biomass yield aiming energy production within the following productive chains: sugarcane, manioc and other starch plants, peanut, soybean, castor oil plant and physic nut.

IAC leads one of the three sugarcane breeding programs in Brazil, performing activities in eleven Brazilian states, yet Mexico, Angola and other South American countries. This fact has allowed high adaptability of IAC's sugarcane cultivars to different edapho-climatic conditions.

Tables 3 and 4 relate the researches directly involved with the bioenergetic issue, Apta units where they can be found and main topics discussed.

EXAMPLES OF PROJETS – BIOENERGY APTA

IAC sugarcane program

The Agronomic Institute (Instituto Agronômico, IAC) initiated sugarcane research in 1892, with the Austrian scientist Franz Wilhelm Dafert, who was hired to establish an Imperial Station in 1887, with an essay of 42 noble cane cultivars in two cultivation conditions. In the 1920´s, a mosaic virus crisis stimulated the creation of genetic breeding programs through the introduction of imported cultivars and their adaptation to the environment. Thus, IAC genetic breeding program started in 1933 along with the creation of the former Seção de Cana-de-açúcar (Sugarcane Section), motivated by the mosaic virus crisis. In the following decades, IAC has developed many researches on phytotechny, which lead to the use of fertilizers, spacing and candidate cultivars to be adopted for São Paulo conditions.

However, from 1970 to 1990, its action was drastically reduced by being considered not essential for the state, since Copersucar program activities were just beginning (current CTC and former Planalsucar). In the year of 1992 IAC Sugarcane Program was reestablished, and in 2005 IAC Sugarcane Center was created, settled in the city of Ribeirão Preto, São Paulo state. Main research line of this center is genetic breeding, aiming for the development of sugarcane cultivars adapted to different environments. IAC Sugarcane Program is virtually managed by a configured network, involving a multidisciplinary research among many Research Centers and State Universities. In the last 10 years, IAC Sugarcane Program has released 17 cultivars develop under the concepts of regional selection exploitation of the particularities of the different production environments mainly within the state of São Paulo.

Add to the release of new cultivars, IAC has provided important advances in phytotechny. As an example, the qualification of production environments, a concept widely used by breeding pro-

gram in which the parameters developed by IAC, are currently adopted either by other research groups or producers. Project Ambicana aims the characterization of production environments using pedology and phytotechny criteria, as well as promoting the socialization of such knowledge, capacitating specialists through training for this aim. Benefit of the project reaches over one million of hectare of Brazil's Center-South region.

This way, pest and nematode management is deeply based on research developed by IAC, which lead to the setting of an integrated management program of some of the most important pests in the Center-South region of the country. Currently, research on such area is focused on the management of sugarcane borer *Diatraea saccharallis* and the beetle *Sphenophorus levis*, which have been shown significant increases in both populations, mainly in sugarcane expansion areas.

IAC also coordinates the Sugarcane Fertilizer and Nutrition Group, responsible for many research works lately, aiming to define a new calibration for crop's nutritional management.

Within the biotechnology area, IAC Sugarcane Center develops research on germplasm characterization for parental selection, genetic mapping, gene expression and genetic transformation of sugarcane. Additionally, the Center also offers a diagnostic analysis of ratoon stunting disease and varietal fingerprinting. Moreover, the center counts with *in vitro* propagation of IAC cultivars.

At present, IAC Sugarcane Center coordinates the organization of a public germplasm collection which will gather efforts from many research institutions (Unicamp, USP and Unesp) on its management and strategy definition.

There are still some research works about physiology of sugarcane involving the evaluation of maturation phase and biomass accumulation. Such studies, in addition to the bioclimatic network coordinated by IAC Ecophysiology Center propitiate the possibility of projecting production scenarios through mathematical models.

The Engineering and Automation Center has been responsible for several studies in the area of mechanization of planting operation, cultivation and harvesting of sugarcane.

The organization of IAC Sugarcane Program is based in a virtual management set as a network of efforts, counting not only with a multidisciplinary vision, but still an organized action that allows a scope of the application of such model in many regions where this crop is very expressive or shows potential to increase.

An important element of this management process is the Sugarcane Phytotechny Group coordinated by IAC since April 1992. This group is a great prospector for sugar-alcohol research demands, used as reference by many researchers from Institutions such as Esalq, Ufscar, Unesp and CTC which participate together with the productive sector of the seven annual meetings that take place in Sugarcane Center in Ribeirão Preto, for the discussion of relevant issues for this crop. Some important projects have been elaborated as a result of these meetings. The creation and consolidation of the Phytotechny Group enabled a closer partnership with the sugar-alcohol sector, since it made possible a bigger participation by the technicians that work for the private sector on the definition and suggestion of paths and phases of IAC's sugarcane research programs, making them acting participants and also co-responsible.

Currently, besides all main regions of São Paulo state and Brazil, where sugarcane cultivation shows or gains expressiveness, IAC Sugarcane Center has widely spread its technologies for countries such as Mexico, Paraguay, Peru and Angola, with high future possibilities of helping other countries such as Mozambique, Sierra Leone, Tanzania etc.

Some technologies developed by IAC Sugarcane Program over the last decade are mentioned below:

- 16 sugarcane cultivars for ethanol and sugar production that are found in the majority of the Brazilian companies.
- One sugarcane cultivar for animal nourishment (forage).
- Training and maps of the production environments in more than 30 Brazilian companies comprising over a million ha.
- Integrated pest control such as nematodes, *Sphenophorus* and spittlebug.

- Innovative varietal management concepts using environmental matrixes.
- Experimental harvesting methodologies via biometrics.
- Methodologies for studying sugarcane root systems.
- Methodologies for harvest predicting through associative climate modeling methods.
- Text book: Sugarcane Services performed by IAC Sugarcane Center are cited below.
- Course: topics in sugarcane cultivation, which has oriented over 200 technicians for phytotechny production during the last three years.
- Performing the diagnosis of ratoon stunting disease.
- Characterization of production environments.
- Strategies for varietal management.

Data bank in bioenergy

Due to the great importance and demand for precise information about bioenergy, the Governor of São Paulo state, José Serra, in 22 of October 2007, through Decree n. 52284, conferred to the Apta's Agronomic Economy Institute the responsibility for creating a bioenergy data bank. Initially, information about the area, productivity and price for sugarcane, grains and oilseed plants of São Paulo are available. Furthermore, there are also laws, decrees, emends and articles available about the bioenergetic issue, as well as the regular publication entitled "Etanol: A experiência paulista", which brings current numbers about ethanol in São Paulo and Brazil, concerning economic, social and environmental aspects.

IEA intends to make available a bioenergy data bank with a fast updating and easy utilization system, in a way to make it a dynamic tool, helpful for the several researchers from different areas interested on this topic. Thus, this data bank will be improved and systematically updated.

Physic nut program

The utilization of physic nut as raw material for oil extraction and biodiesel production is an option to be researched due to some advantages facing others oilseed plants, such as presenting a favorable energetic balance, low input use production, possibility of planting in declivous areas, regional alternative for job generation and social inclusion.

Main focuses are on subjects such as: botanical characterization; phytochemical characterization of present compounds; setting a germplasm collection; genetic characterization of materials obtained from many countries and/or Brazilian regions; evaluation of behavior of native and exotic material from different regions of the state, crop phytotechny management, spacing, fertilization, pests, diseases and seedlings production.

Castor oil plant program

Castor oil plant is distinguished by presenting high oil levels within its seed, and therefore is of interest for biofuel production. IACs intends to morphologically characterize its castor oil plant germplasm collection; obtain progenies and castor oil lines for the development of new cultivars, installing fields for the genetic purification of IAC's castor oil commercial cultivars (IAC-80, IAC-226 e IAC-Guarani); developing new management practices and adapt the ones already existing to the new cultivars, among them: new spacing, plants population, seed and harvest time, spatial array of plants and production of genetic seed s of new cultivars.

Elephant Grass program

Elephant Grass is the ideal raw material for obtaining electricity through biomass burning, because of the high caloric power around 4,500 kcal/kg dry matter and also because it leaves low ashes level after combustion. Hybrids from elephant grass x pearl millet (seed reproduction) as traditional cultivars for elephant grass are excellent to generating energy. It is intended to evaluate the selected genotypes of a hybrid population from elephant grass x pearl millet (PC e P8P) and the inter-varietal hybrid andropogon grass.

Also, it is necessary to optimize the chemical scarification of elephant grass x pearl millet and andropogon hybrid seeds, aiming to efficiently eliminate the aristas without harming the quality of seeds.

Diesel and biodiesel mixes and durability of engines

It aims to study the prolonged use of a mix from castor oil biodiesel in an agricultural engines. The mechanical performance of the agricultural engine is compared, in a dynamometric balcony, using alternatively castor oil diesel and a mix of fuel constituted of 95% diesel and 5% castor oil plant biodiesel (B5). Yet, it is intended to analyze the B5 mix effect in the characteristics of lubricating oil during 1,000 hours of engine functioning as well as analyzing the effect of B5 mix in the inject pump and inside the engine, after 1,000 hours of engine functioning.

Environmental impacts of wastes derived from ethanol production

Vinasse is one of the wastes derived from ethanol production in which the environmental impact comes from the quantity generated. It is produced 13 liters of vinasse for each liter of ethanol, resulting in over 230 billions of liters annually. This residue has some applications such as fertirrigation in the cultivation of sugarcane, where it totally replaces potassium and part of nitrogen necessaries for the crop. Agronomic efficient issues has been researched in detail in the past, and currently research is focused on topics concerned to the monitoring of soils and groundwater, in order to verify the risk of pollution through dragging of ions from soils and vinasse itself. Finally, it is aimed to verify if the recommendation of vinasse doses, that is currently done based on potassium levels (present at vinasse and soil) in a manner that it does not overpass the 5% soil CTC limit (Cetesb, norma 4231) is environmentally suitable.

Program of biological control of sugarcane pests

Spittlebug

Since its publication, in 1997, the state Decree-Law n. 42056/97 legislate that sugarcane harvesting in São Paulo state without burning the straws is a reality. This process, along with the increase of the mechanized harvesting area, has transformed the sugarcane agro-system and, in some cases, has favored the attack of some pest, e.g. sugarcane spittlebug, causing huge damages in agronomic productivity and industrial quality of the raw material.

The Biologic Institute – IB has performed actions to foment the use of the fungus *M. anisopliae* to control the increase of sugarcane spittlebug in the state. For that, IB has selected some isolates of this fungus and obtained in lab and field conditions, virulent products to spittlebug and high-productive in pre-baked rice medium. Such action involved researches for the obtainment of isolates more efficient for the control of this plague, as well as for suitable concentrations of the bi- insecticide and propitious period for its application.

It is important to outline that the isolates, resulting from the selection process, are nowadays used by the majority of fungus-based bio-insecticide producers located in Brazil. Thus, new companies and industry labs have been set up in order to increment the bio-insecticide offer in the market and, therefore, stimulate the use of this fungus.

As an example we can remind that between 2004 and 2008 around 10 thousand tons of bio-insecticide were used to treat an area of about 1,200,000 ha, generating an estimated economy of about R$ 240 millions in control costs. At present, besides the generation of knowledge about the subject, technicians from the Biological Institute assist the sugarcane sector on the development and implementation of plant factory inside and outside the state.

The development of biological control for spittlebug is of extreme importance to the economy of the sector, considering that the cost of this method is much lower than the chemical control, it is non-polluting, it does not cause biological imbalances, it is durable and takes advantage of the biotic potential of the agro-system. Moreover, it is not toxic for man and animal and may be applied with conventional machines with small adaptations.

Sugarcane borer

A biological insecticide capable of combating sugarcane borer (*Sphenophorus levis*), a pest that can destroy as much as 30 tons of plants per ha causing high risks to sugarcane cultivation, is

being developed by the Biological Institute and will soon be able to be industrially produced.

Ground level insects are of hard control through the use of chemical compounds, what makes way for the opportunity of evaluating alternative methods for microbial control through nematodes entomopathogens, with advantages mainly on the economical and environmental order.

In some works developed by IB, nematodes have been presenting potential use in soil control, and many advances have been achieved in researches focus on sugarcane borer control.

To explore nematodes as bioinsectices, IB has been looking also to develop techniques for the industrial production and formulation of these new agents.

In addition to the lower cost of biological product, when compared to chemical one, another advantage is the application of nematodes in sugarcane is the possibility the combat, by these agents, of more than one pest species.

FINAL CONSIDERATIONS

Apta's Institutes are responsible for most part of the technological heritage which supports the tropical agriculture in our country. As major features, we can outline the capacity of performing regional research contemplating an environmental diversity which widely represents São Paulo state and others states of Brazil's Center-South region. This happens due to the significant infrastructure that enables the formation of research network and a good capillarity. Multidisciplinary research favors a more contextual view of the demand, especially when the bioenergy are is considered. Apta technical board is highly qualified and is inserted in main productive chains of agro-energetic crops.

Some actions would stimulate this net to make it more efficient, among them, the re-structuring of the management model, which could make possible to achieve better interaction among actors from public and private sectors.

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