



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

18067

BIOTECHNOLOGY IN SENEGAL

by

Raymond A. Zilinskas, Ph.D.
Center for Public Issues in Biotechnology
Maryland Biotechnology Institute

CLT 89/376

20 December 1989

Report to UNIDO of mission undertaken to Senegal during October
29 - November 4, 1989 in accordance with agreement # CLT 89/376.

INTRODUCTION

During October 29 - November 4, 1989 I visited Senegal in order to assess the status of biotechnology in that country. Specifically, in accordance with instructions by UNIDO dated October 25, I sought to elicit information about national biotechnology policies, international cooperation in biotechnology involving Senegal, and biotechnology-related research and industrial activities in Senegal. To accomplish this, I interviewed Senegalese (and other) policy-makers, scientific administrators, and scientists (see Annex I for the list of those interviewed), and personally visited major Senegalese and French research institutes located in Senegal. The sections that follow sum up the information derived from interviews; describe visited institutes and laboratories; discuss the findings from interviews and visits; and concludes with two recommendations for UNIDO action.

BIOTECHNOLOGY IN SENEGAL

1. National Program in Biotechnology.

The Eight National Development Plan for Senegal commenced in January 1989. A copy of the Plan was not available for inspection; the following is therefore based on second-hand information. Reportedly, part of the Plan is devoted to the furtherance of biotechnology. Responsibility for implementing the Plan lies with the Ministry of Planning and Cooperation; its Directorate of Scientific and Technical Research coordinates all work in biotechnology. This is necessary since several ministries sponsor R&D institutes engaged in various areas of biotechnology; for example, the Ministry of Industry sponsors the Institute for Food Technology (ITA), the Ministry of Rural Development sponsors the Senegalese Institute for Agricultural Research (ISRA), while the Ministry of Higher Education is responsible for the research program of the Cheikh Anta Diop University of Dakar (UoD).

Although the Eight Plan has been in force for over nine months, the Ministry of Planning and Cooperation was unable or unwilling to discuss the resources the government was committing to its implementation, or to any of its parts. It was explained that the Plan is being revised; no details were given why or how.

2. National Objectives in Biotechnology.

Spokespersons from the Ministry of Planning and Cooperation explained the national objectives in biotechnology research and applications. The fields of particular importance are agriculture, food, medicine, and industry.

A. Agriculture.

- * Development of biopesticides.
- * Development of improved biofertilizers.
- * Screening of plants for secondary metabolites.
- * Selection and development of efficient mycorrhizae and nitrogen-fixing microorganisms, such as species of Rhizobium and Frankia.

B. Food.

- * Improvement of food fermentation processes.
- * Utilization of slaughterhouse wastes.

C. Medicine.

- * Development and production of human vaccines.
- * Development and production of animal vaccines.

D. Industry.

- * Development and exploitation of carrageenan-producing algae.
- * Improvement of fermentation for alcohol production.

Some problem areas are emphasized; in particular, there is a need to: (1) develop drought-resistant variants of crops important to Senegal, including peanut, millet, and kidney bean; (2) develop tree species that can act as barriers to the movement of sand dunes; (3) treat slaughterhouse wastes that are now dumped raw in the ocean, causing severe pollution; and (4) develop several specific vegetables and fruits for cash crops.

3. Senegalese Research Institutes With Biotechnology-related Activities.

Although several research institutes in Senegal have activities underway in areas that are related to biotechnology, these are mostly done at a low scientific/technical level and thus lie outside the scope of this appraisal. By relying on the opinions of Senegalese government spokespersons and informed observers, four institutes were identified as having the greatest significance to biotechnology in Senegal.

A. Institute of Food Technology (Institut de Technologie Alimentaire or ITA).

The information in the following sections was gleaned from interviews with the ITA's Director and one Department Head, and from a Government booklet.¹ The ITA was established in 1963 in order to promote local food products and develop techniques for biopreservation and bioprocessing. During 1968-1974 a sizeable grant from FAO allowed the ITA to expand its scope of activities to include cereals, fruits, meat, quality control, and to begin pilot plant operations. Since 1974 the Government has been the

major funder of ITA. Thus, the ITA's 1989 annual budget totals approximately 300 million African francs (AFs) or about \$ 1 million; of this 60% is provided by the Government, 30% by international organizations, and 10% is earned (from the providing of training and other services).

The ITA exchanges information and partakes in cooperative projects with institutes in other African countries (including Cameroon, Ghana, Ivory Coast, Nigeria, and Sudan) in R&D related to cereals and fish. It is also in contact with institutes and laboratories in Brazil, Canada, France, and India. One of ITA's goals is for it to become a regional institute in food technology and nutrition for West Africa.

The ITA would like to develop advanced capabilities in biotechnology in order to perform applied research to improve methods for conserving and fermenting fish. In particular, it is desirable to enhance the nutritional quality and improve the flavor of sausages made from fish products. A second and related goal would be to improve present vegetable fermentation processes that are used to produce tempé, pakia, and néré.

It is claimed that the ITA employs about 100 persons, including 20 Ph.D.-level scientists. It is organized in three divisions (Directions), each of which has several departments, as follows:

(i) Technical Division.

a. Department of Nutrition and Crops.

This Department has sections concentrating on research pertaining to cereals and legumes, fruits and vegetables, and nutrition.

b. Department of Animal Products.

This Department has research sections concentrating on fish and fish products, and meat and meat products (mostly beef).

c. Department of Quality Control.

This Department has research sections concentrating on food chemistry, food microbiology, mycotoxins, and testing and analysis.

d. Department of Maintenance.

(ii) Study and Development Division.

This Division has departments that provide linkages between laboratories and industry, coordinates ITA activities with those of other Senegalese institutes, provides information on advanced developments to outside parties, and coordinates ITA's international activities.

(iii) Administrative Division.

My personal inspection of ITA laboratories and facilities indicates that it is a poorly equipped, poorly maintained research institute functioning at the level of about 30% of full capacity. The only laboratories that were operating at anywhere near capacity were those devoted to quality control and mycotoxin analysis. Most equipment, including the pilot plant, appeared to have been unused for many months, possibly years. Chemicals and reagents appear to be in short supply; the library lacks recent books and journals. The equipment being used is of the most basic type, unsuitable for more than rudimentary research in chemistry and microbiology. If the 1985 report of Dr. C. N'Diaye is taken as a departure point,² one can only conclude that the ITA has deteriorated significantly during the last four years.

B. Senegalese Institute for Agricultural Research
(Institut Sénégalais de Recherches Agricoles or ISRA).

The following sections are based on interviews with staff scientists at ISRA in Bambey (located approximately 100 kilometers east of Dakar) and on a joint ISRA-ORSTOM information circular.³ As is seen below, ISRA (Bambey) will have a pivotal role in Senegal's planned biotechnology program. As of now, ISRA (Bambey) consists of one division (Direction) and two centres:

(i) Division of Forestry.

This Division undertakes traditional agricultural research on trees of importance to Senegal, including Acacia, Eucalyptus, and Causarina. A. senegal is of importance to Senegal due to its valuable wood (used in construction), leaves (for animal fodder), and exudate (which is the basis for arabic gum). This tree species is unusual because it has rhizobium root nodules that fix nitrogen (Nif). However, the number of A. senegal is decreasing due to it being susceptible to dryness. For this reason, the Division is heavily involved in attempting to increase the tree's drought resistance through classical breeding techniques; a lengthy process given the slow growth rate of the tree. To help speed up its work, the Division, in cooperation with ORSTOM (see below), is about to begin R&D to micropropagate A. senegal. This work promises to be problematic since the tree possesses great genetic variability. Thus, fundamental research has to be done first in order to clarify the mechanisms for micropropagation growth characteristics.

A second program area for the Division is to investigate and evaluate species of rhizobium and mycorrhizae that are adapted to the dryness of the Sahel zone. Findings from this research may be useful to enhance the resistance to dryness of the rhizobium associated with A. senegal. This work is eventually expected to

utilize genetic engineering techniques such as cloning.

The Division is staffed by one Ph.D.-level scientist, one doctoral candidate, and two technicians. Its funding level was not disclosed.

(ii) Center of Horticulture Development.

This Center has two research sections. The first concentrates on legumes, including potato, manioc, and sweet potato; the second concentrates on fruits, primarily banana and strawberry. In either case, traditional breeding techniques are used to improve plant strains. It is expected that the Center will soon begin employing plant tissue culture techniques.

The Center is staffed by one Ph.D.-level scientist and five technicians. Its funding level was not disclosed.

(iii) Microbiological Resource Center (MIRCEN).

The MIRCEN's work program has three parts. First, it sustains a culture collection, which includes approximately 325 rhizobium strains and many examples of endomycchorizae strains (which are uncatalogued). Second, the Center develops and produces soil inoculum to enrich farm soils. Third, in cooperation with ORSTOM it has a R&D program related to annual legumes (such as soya) and trees (particularly A. senegal and A. albida). The MIRCEN utilizes only traditional agricultural R&D techniques.

MIRCEN is staffed by one Ph.D.-level scientists, four doctoral candidates, and three technicians. For 1989 the Government is funding the MIRCEN's salaries and overhead (about 11 million AFs); in addition, UNESCO provides \$ 10,000, FAO provides \$ 37,000, and BOSTID about \$ 21,000.

MIRCEN has extensive foreign contacts. It is of course a member of the MIRCEN global network, which includes 17 member institutes. It runs training courses related to Nif for West Africa; it has cooperative programs with African institutes in, among others, Freetown, Abidjan, Accra, and Ibadan. Through the NIFTAL program it cooperates with the University of Hawaii and the US Department of Agriculture rhizobium center at Beltsville, Maryland.

Personal inspection of ISRA (Bambey) indicated that facilities were housed in roomy but dilapidated buildings constructed in the 1920s. Several laboratories appeared to be functioning at near capacity; others were unoccupied. The equipment seemed adequate for the tasks; i.e., for researchers to perform traditional agricultural R&D that depends mostly on traditional breeding techniques. Although it was claimed that

tissue culture techniques were employed, this was not in evidence. For example, the large walk-in incubators with artificial lighting and extensive media-making facilities so evident at ORSTOM (below) were not observed. Unlike the ITA, staff morale seemed to be high and the intense level of activities one normally associates with a busy research institute was present.

One laboratory within ISRA (Bambey) was markedly better housed and equipped than others. This is the Regional Research Center for Improvement of Adaptation to Drought (CERAAS). Its work began in March 1989 when it was granted funds by the Commission of the European Communities at 220,000 ECUs per year for the four years. In addition, the French Government pays the salaries of its staff. As its name suggests, CERAAS promotes and coordinates drought-related research, bringing together researchers from African countries directly affected by drought. Its work program has two aspects. First, investigations are to be carried out to clarify the physiological mechanisms of plant adaptation to drought and, second, once these mechanisms have been clarified, a selection program will be undertaken to screen for plants whose physiological characteristics can be improved by breeding. CERAAS research will, for the foreseeable future, utilize only traditional methods used in agricultural research.

In addition to Bambey, ISRA has smaller research units located in several other outlying cities. These could not be visited because of transportation difficulties and lack of time. However, according to reliable sources, these other units are undertaking only traditional R&D; none is utilizing advanced biotechnology.

C. Cheikh Anta Diop University of Dakar (UoD).

The information contained in the following sections came from interviews with researchers at the UoD and from other scientists who have cooperative projects with the University. According to these sources, the UoD's Faculty of Science has two departments that undertake research pertaining to biotechnology; the Department of Plant Biology and the Department of Animal Biology.

(i) Department of Plant Biology.

The Department has three laboratories; the in vitro culture laboratory, the microbiology laboratory, and the phytopathological laboratory. Two projects are proceeding in these laboratories that may be said to be associated with biotechnology. The first project, which is being done in cooperation with ISRA and ORSTOM, is an investigation of Nif nodules that grow on the stem (rather than the root) of two tree species -- Sesbania rostrata and Aeschynomene species. This

research is partially basic (i.e., to investigate the Nif genes of the azorhizobium that make up the nodules), and partially applied (to assess whether the amount of nitrogen fixed by these trees is sufficient to support rice farming without additional fertilizer). This work, which includes tissue culturing, was started by the French professor Duhoux (who has returned to France but still acts as a coordinator); it is being undertaken by a team of two post-doctoral scientists, one technician (who is presently in training in Italy), and 2 - 3 graduate students.

The second project, being done in cooperation with the Faculty of Pharmacy, is to develop culture techniques for growing red marine algae from which commercial quantities of carrageen and other biochemicals may be extracted. This work, relying on traditional techniques, is being performed by a team consisting of two scientists with French doctorates, two Ph.D.-level pharmacists, one doctoral candidate, and two graduate students.

The funding level of the Department Plant Biology is rather low; about 5 million AFs per year is shared by about 20 researchers and support personnel.

My personal inspection of two laboratories belonging to the Department indicated that research was proceeding in roomy but poorly maintained facilities. All equipment seemed in short supply; that which was apparent appeared worn and old. I did not observe equipment sufficient to carry out tissue culture work (it could be taking place elsewhere). Very little research activity was underway during my visit and the number of staff I observed was less than ten. The state of facilities and equipment indicated that Government support of the Department is, to say the least, minimal. This situation may extend to the entire University; for example, the University's telephone system had been disconnected because its telephone bill had not been paid for eight months (this, in turn, made it difficult and time consuming to set up appointments at the University).

(ii) Department of Animal Biology.

Due to constraints of time and the inability to set up appointments, I was unable to visit this Department. However, information from interviews with scientists acquainted with this Department's work program indicates that it is relatively well off in terms of funding, facilities, and equipment. For example, this Department possesses two electron microscopes; the first is an older model donated by the French Government, the second a recent donation from the Japanese Government. These instruments are, reportedly, well maintained and manned.

There is extensive collaboration between this Department and the Pasteur Institute in Dakar in the area of arthropod-borne viral diseases (especially Rift valley fever) and human

immunodeficiency virus (HIV) research. Both sides benefit; Senegal students and researchers receive advanced training at Pasteur (see below), while Pasteur scientists use the Department's electron microscopes and avail themselves of UoD field facilities, especially the veterinary stations.

D. Ecole Nationale Supérieure Universitaire de Technologie (ENSUT).

Most of the information about ENSUT, which I was unable to visit, was elicited from Senegalese and French scientists. Reportedly, the major mission of ENSUT, which is part of UoD, is to train engineers and technicians. Specifically, ENSUT's Department of Chemical Engineering and Applied Biology offers graduate-level courses in food technology and chemical engineering to students who have completed their undergraduate work in one of the natural or physical sciences. This Department also performs low-level applied research to evaluate and improve on certain traditional biotechnology processes, such as food fermentation, biomass utilization, biogas digesters, and post-harvest conservation.

ENSUT's importance to Senegal is that it produces the trained manpower required to staff R&D units and, eventually, biotechnology firms. However, ENSUT offers no training in the advanced biotechnology techniques. Similar to UoD it is in a dire financial condition. In addition, its resources are strained; reportedly, laboratories that 10 - 15 years ago accommodated 30 or so students now house anywhere between 300 - 600 students, with no increase in resources.

4. Non-Senegalese Institutes with Biotechnology-related Activities.

Note should be made of the fact that Dakar hosts several research institutes that are funded by foreign sources and manned by mostly foreign scientists. Within the context of this report, two research institutes and one regional institute need to be discussed.

A. Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM).

ORSTOM, set up in 1949 in Senegal, consists of five departments that are staffed by over 250 scientists, technicians, and administrators. It runs about 45 programs spanning a wide scope of scientific and technical activities. However, in the context of this report, when ORSTOM is mentioned it refers to the Bel Air research center focussing on the biology of trees. Information about this center comes from interviews with its scientists, an informative booklet,⁴ and personal inspection of

facilities.

ORSTOM has a multitude of laboratories; within the context of this report three are pertinent:

(i) Microbiology Laboratory.

Research in this laboratory is proceeding along two directions. First, two symbiotic nitrogen systems are being studied; Acacia-Rhizobium and Casuarina-Frankia. The second system is in particular interesting because it has been imported from Australia. Research methods include quantifying the nitrogen fixing capabilities of each system through the use of radioactive nitrogen uptake; taxonomic studies; studies of the host spectrum; and by propagating shoots via in-vitro culture techniques. Although most of this research is basic, the eventual aim is to develop trees that can grow without artificial fertilizer in the semi-arid zones abutting areas swallowed by sand dunes. In the first instance, the dunes would be "anchored", thus preventing their further migration. As the trees take hold, it is hoped that valuable crops may be planted between them.

The second direction is an applied one; to develop and improve soil inoculants using ectomycorrhizae and endomycorrhizae. Only traditional techniques of selection and breeding are used in this work.

(ii) Genetic Laboratory.

The work of this laboratory, which compliments that of the microbiology laboratory, is to investigate the genetic variability of the Sahalian acacias; to analyze the diversity of Acacia senegal; and to clarify the affinity of specific acacias with strains of Rhizobium. The major research methods used are electrophoresis of proteins and in vitro culturing. As above, the eventual aim of research is to improve on the growing possibilities of acacias in the semi-arid zone.

(iii) Plant Physiology Laboratory.

This laboratory studies the physiology of the plant-nitrogen-fixing bacteria systems (Acacia-Rhizobium), as well as the triple symbiotic system of Acacia-Rhizobium-Endomycorrhizae. Traditional techniques are used, such as the chemical analysis of plants and soils.

Most of the projects mentioned above are done in cooperation with ISRA units; usually the Division of Forestry and, in cases involving rhizobia, MIRCEN. In addition, active cooperation, including joint projects, are maintained with the Max Planck Institute in Cologne, the Universities of Gand and Liège, the

National Botanical Garden of Belgium, and others.

Each of the laboratories appear to be staffed by 2 - 3 Ph.D.-level scientists and 3 - 4 technicians. In addition, ORSTOM provides slots for Senegalese graduate students so they can work on projects related to their dissertations. At present, three such graduate students are completing their work. It may be symptomatic of the times in Senegal (see Discussion, below) that ORSTOM has so far been unable to find qualified new graduate students to replace those about to finish their work.

Personal inspection of ORSTOM laboratories and green houses indicated that the institute is well-equipped, well-housed, amply supplied, and adequately staffed with competent scientists and technicians. It has the large walk-in growth chambers, culture media production facilities, and sterilizers required to propagate in vitro plant shoots in large numbers. Thus, it appears similar to many agricultural research institutes found in developed countries where high quality research takes place. Similar to Pasteur Institute (below), ORSTOM is able to import equipment and supplies as needed, with the full cooperation of Senegalese authorities.

(iv) Future Biotechnologies Center.

To finish up the discussion of ORSTOM, it is important to note that this organization is funding the construction of the future Biotechnologies Center, which will be manned and run jointly by ORSTOM and ISRA. The UoD will also be involved, but at a lesser level. Funding at over 400 million AFs has been committed to the project by ORSTOM; construction is to begin in the spring of 1990. An elaborate work program for the Center has been formulated, spelling out its aims and delineating spheres of responsibilities between participating organizations.

It is envisioned that the Biotechnologies Center will initially have four programs. The first, Molecular Biology and Genetic Engineering, will concentrate on tree species of importance to Senegal (A. senegal, A. albida, and Sesbania rostrata), as well as on their symbionts (Frankia, Rhizobium, and Mycorrhizae). Major emphasis will be placed on an in vitro culture program to prepare for large-scale plant production. This program seeks to exploit the genetic diversity present in acacias to select for clones giving superior growth performance in the semi-arid zone. Eventually, it is expected that advanced biotechnology techniques will be employed in this research, including cloning and molecular hybridization.

The second program, In Vitro Plant Propagation, will be the development of non-tree plants, particularly crops and fruits. Researchers will use techniques such as meristem culture, in vitro tissue culture, and micropropagation to seek to increase

yields of potato, manioc, sweet potato, and strawberry.

The third program, Methane Fermentation, will attempt to improve methane fermentation methods, while the fourth program, Ethanol Production Through the Use of Thermophilic Bacteria, will attempt to optimize the production of ethanol from cellulose using thermophilic bacteria. These two programs, to be carried out by ENSUT and ORSTOM, will use only traditional biotechnology.

The Biotechnologies Center is to be located near to ORSTOM Bel Air; as planned, it will have equally fine facilities and equipment. It will be staffed by mostly Senegalese scientists. Each of the participating ISKA units, UoD, and ENSUT will have a coordinator to coordinate activities with the new Center; the lead coordinator has already been designated (Dr. Mamadou Guéye of ISRA's Division of Forestry).

B. Pasteur Institute.

Information about the Pasteur Institute comes from interviews with its Director and scientists, an information booklet,⁶ and personal inspection of facilities.

The Pasteur Institute is financed mostly by the French Government (via ORSTOM); it is administered and directed by Frenchmen. There is close cooperation between the Institute and the Senegalese Ministry of Health, including the holding of a yearly planning council. This council determines research objectives important to Senegal; it thus has an important influence on the Institute's work program.

On the practical level, there is, as mentioned above, close collaboration between the Pasteur Institute and UoD. The major area of common interest is arthropod-borne viruses (arboviruses - - see below) and, to a lesser extent, HIV. In 1988 the Institute accommodated 35 trainees from Senegal; most stayed for about three months. Some of these trainees were doctoral candidates in pharmacy who used this period to complete work for their thesis.

The Pasteur Institute has extensive international contacts. It is of course an integral part of the network of Pasteur Institutes sited in Africa (7), Iran, and France. Its medical zoology laboratory (below) is a WHO arbovirus reference center for Africa. This laboratory may in fact be the most important research center in the world in regards to the study of the Congo hemorrhagic virus and Rift valley fever virus. In its role as the reference center for arboviruses, the Pasteur Institute interacts, and receives specimens from, hospitals and laboratories from many African countries, including Burkina Faso, Central African Republic, Cameroon, Ivory Coast, Mali, Madagascar, and Mauritania. In addition, close contacts have been established with the Yale University, the US Centers for

Disease Control, and the US Army Medical Research Institute for Infectious Diseases in arbovirus research. In the field of basic immunology pertaining to malaria there is close contacts between the Institute and the Max Planck Institute in Germany

The Pasteur Institute in Dakar has three divisions; public health, vaccine production, and parasite and virus research. The first is not covered here because it consists of several clinical medical laboratories. The second, consists of two vaccine production laboratories wherein are produced and packaged vaccines for yellow fever and rabies. These are widely accepted classical vaccines; no research on genetically engineered vaccines is underway.

The third division, which performs only basic research, has two program areas; parasite research and virus research.

(i) Parasite Research.

Parasite research, focussing in the main on malaria and leprosy, is done in two laboratories. Thus, research at the immunological laboratory attempts to compare the different immunoglobulin isotypes possessed by immune and non-immune subjects and to clarify the mechanisms whereby merozoites invade the red blood cells. At the cellular biology laboratory research is proceeding along four tracks. First, researchers are investigating the molecular biology of Plasmodium falciparum. Second, the human immunological response to P. falciparum is under investigation. Third, research is aimed at clarifying the immunology of leprosy. And fourth, the immunologies of the simian immunodeficiency virus and the virus causing Rift valley fever are being studied.

(ii) Viral Research.

Basic research on viruses is being done in three laboratories. The molecular virology laboratory concentrates on the yellow fever virus. Its researchers have cloned yellow fever antigens and sequenced parts of the virus' genome. In the second laboratory the biological and molecular aspects of the Rift valley fever virus is being investigated. The ORSTOM laboratory of medical zoology (Laboratoire ORSTOM de Zoologie Médicale) has a wide-ranging arbovirus research program, encompassing the arboviruses that cause yellow fever, dengue, Rift valley fever, and Congo hemorrhagic fever. The scope of research activities is wide, including field surveillance in at least seven African countries of arboviruses, the bioecology of the arbovirus vectors, laboratory experimentation to clarify the biochemistry and pathogenicity of viruses, the development of diagnostic methods for arboviral diseases, and so forth.

The parasitology research is being conducted by eight Ph.D.-

level scientists (four French and four Senegalese); the viral research is being done by 12 Ph.D.-level scientists, of whom seven are French and five are Senegalese. All of the 20 technicians are Senegalese. Funding for this division stands at about 300 million AFs per year from research grants and \$ 6,000 from WHO. In addition, the French Government pays for staff salaries, basic equipment, and certain supplies.

My personal inspection of the laboratories in the third division demonstrated that their facilities and equipment are of the highest quality, equal to top laboratories such as those of the Max Planck Institute or University of Maryland. The scientific staff manning Pasteur appears to have excellent credentials. The most advanced techniques of biotechnology are used, including genetic engineering, polymerase chain reaction, and monoclonal antibody construction. The Institute imports whatever equipment and reagents it needs with the full cooperation of the Senegalese customs. It has two generators on standby in case of power failure (something none of the other research institutes that I visited had, including ORSTOM). Remarkably, it has a BL4 level high security laboratory to accommodate research on highly pathogenic viruses (although the work done there is usually at the BL3 level). The many articles published in international journals by the Institute's researchers bears witness to its high scientific stature.

C. African Regional Centre for Technology (ARCT).

Unlike the institutes discussed above, the ARCT is not a scientific research institute. Rather, its objectives is to promote the development and application of technologies indigenous to Africa, especially in the areas of food science and technology and energy technologies.⁷ It was established in 1977 under the auspices of the Organization of African Unity (OAU) and the UN Economic Commission for Africa. At present, it has 30 members consisting of African states. Liaisons between the ARCT and member governments are maintained through ARCT focal points in each country, who usually deal with the local Ministry of Planning and Development. Communications between focal points and ARCT headquarters takes place via telex at UNDP offices.

The ARCT's activities have been documented elsewhere and need not be covered here in detail.⁸ As the ARCT is geared towards low-level technologies, it has so far stressed traditional biotechnology, such as biogas digesters. However, beginning in 1985 it has worked with the UNU to promote the establishment of Chairs in Biotechnology at African universities. Three institutions have been designated as hosts for Chairs: University of Nairobi, Kenya, in nutrition and health; University of Ibadan, Nigeria, in new food technologies; and ENSUT, Senegal, in general biotechnology. The holders of these Chairs are now in the process of preparing a project paper, which will as a first

step delineate their nations' manpower needs in biotechnology.

In 1987 the ARCT commissioned the study "Prospects for the Development of Biotechnologies in African Countries", which focussed on the development of biotechnologies as means for improving the food situation in the African continent. A more substantive step to involve the ARCT in modern biotechnology is its organizing of a workshop on the subject held during November 12 - 16, 1989 (after this mission was completed).

DISCUSSION

By any measure, the economic condition of Senegal has deteriorated over the last ten or more years; this trend is unlikely to be reversed in the near future. One result of this situation is that Government support of higher education and public research institutions is at a very low level, just sufficient to ensure survival. However, as the level of government funding tends to remain the same from year to year, in actuality, given inflation and rising costs of equipment and supplies, research institutes face a steady deterioration of working conditions and capabilities. Practically the only way to escape this downward spiral is for an institute to secure funding from international sources. Those that are successful are able to build new capabilities and to undertake more than low-level R&D in traditional areas of biotechnology, such as beverage and food fermentation and small biogas digesters. The situation is similar in agricultural R&D.

In view of this situation, it is no wonder that every Senegalese research institute is trying very hard to secure funding from outside sources. One major problem for a donor is to assess requests for assistance and determine where necessarily limited funds can be used most efficiently in terms of research results or findings that may be applied to solve national problems or stimulate economic development. The problem is that all institutes require help; how does one choose between the several worthy applicants?

Need is obviously not the only criterium in making the determination who or what to support. Since all candidates need assistance, other criteria have to be considered. Ideally, an analyst should consider the following criteria when assessing an institute and the R&D it proposes:

- * The utility to Senegal of the proposed R&D.
- * The quality of the scientific manpower that will carry out the proposed R&D.
- * The commitment of the institute's leadership to carry to completion the proposed R&D.

- * Past research achievements of an institute that bear on the proposed R&D.
- * The quality of the equipment to be used for the proposed R&D and the adequacy of the facilities where it is to be carried out.
- * The certain availability of chemicals required for the proposed R&D.
- * The availability of certain resources to back up the proposed R&D, including good maintenance and repair facilities, a well-stocked library, adequate communication lines, sufficient computer power, and so forth.

Practically speaking, several of these criteria cannot be fully evaluated during a short visit of a few hours to a candidate institute. In particular, on the strength of short site visit an analyst cannot hope to properly assess the quality of available scientific manpower, dedication of leadership, impacts of past research, and the certain supply of chemicals. Keeping these limitations in mind, the institutes described above are discussed below in terms of applicable criteria.

1. Institute of Food Technology (ITA).

The ITA performs research of importance to Senegal as designated in the national objectives, especially to improve food fermentation processes and to utilize slaughterhouse wastes. However, the institute's equipment and facilities is run down, supply of chemicals inadequate, library out of date, and computer power deficient or lacking. During my visit no more than three or four of the purported 20 or so Ph.D.-level scientists were present. Expensive equipment provided in times past by international donors (for example, pilot plant equipment) now stands unused and appears to be deteriorating. Questions why this is so are not answered; perhaps there are presently no appropriate projects, or the equipment has broken down and remain unfixed, or the qualified personnel to operate them is unavailable. In any case, it does not bode well for the future of any new equipment that may be provided by international donors. The ITA has weak links with the industries that could be expected to utilize results from its work. It is claimed that there are extensive contacts between ITA and foreign research units; however, there are no concrete recent signs evidencing such linkages. Summing up, on the assumption that it has good leadership and well trained researchers (neither of which is certain), substantial financial assistance provided over some years would be required in order to build up ITA's level of scientific excellence to a level acceptable for a regional research center. The amount of this assistance is most probable

in excess of what is envisioned under UNIDO's regional biotechnology program for Africa.

2. Senegalese Institute for Agricultural Research (ISRA).

In the field of agriculture, ISRA undertakes R&D of importance to Senegal as designated under its national objectives. Several of its key scientists appear to have received fine training in agricultural research at French and other European research centers. Although its equipment and facilities seem primitive by developed country standards, they appear adequate for the traditional, low level research done in Senegal. Unlike ITA, equipment is being used and facilities are occupied, demonstrating an active research program. There are concrete signs of international cooperation, especially at MIRCEN and CERAAS. In addition, active wide-ranging cooperation takes place between ISRA and ORSTOM, which seems to benefit both sides. Through this cooperation, ISRA can tap the expertise and resources of ORSTOM; a significant factor for future growth. ISRA appears to have set up an efficient extension service, which is able to deliver results from research to farmers and farm cooperatives through demonstration projects.

In view of ISRA's full and equal participation in the joint project with ORSTOM to establish and operate the new Biotechnologies Center, it appears as if it is poised to build new capabilities in advanced biotechnology on an existing solid base. This should enable its researchers to work more efficiently on problems besetting Senegalese agriculture, in particular, the lengthy time between plant generations can be shortened through the application of tissue culture and genetic engineering.

3. Cheikh Anta Diop University of Dakar (UoD).

Typical to universities everywhere, the UoD has the dual mission of teaching and performing basic research. Similar to other Senegalese research institutes that are dependent on the Government for all or most of its support, it is in a difficult quandary as that support has in fact diminished while the teaching demands have increased several fold during the last ten years. The results are evident; deteriorating facilities, poor or non-existent equipment, inadequate supply of chemicals and supplies, scientist/teachers who have to augment their salaries by taking on additional work, a library with few recent serials or books, and so on. The funds needed to reverse the downward trend and, ultimately, to correct shortcomings would be sizeable, more than those that could under the best of circumstances be made available by UNIDO to one country. Further, it is questionable whether UNIDO should under any circumstances undertake to strengthen a national university dedicated to teaching and basic research, especially when the home Government does not do so.

4. Ecole Nationale Supérieure Universitaire de Technologie (ENSUT).

Although I did not visit ENSUT, information elicited from interviews with knowledgeable persons indicates that ENSUT's situation closely parallels that of UoD. Unlike UoD, ENSUT does perform applied research in biotechnology; however, the technical level of that research is probably below that which is being considered for support by UNIDO. Perhaps the best that can be done for ENSUT at this time is to provide additional training opportunities in advanced biotechnology for its graduates.

5. Pasteur Institute and ORSTOM.

Since the Pasteur Institute and ORSTOM are extra-territorial French institutes that are, comparatively speaking, well-endowed and well-staffed, they are not candidates for UNIDO support. However, the resources they, and their sister institutes elsewhere in Africa, offer should be utilized by UNIDO when constructing a biotechnology network in Africa. Specifically, the Director of Pasteur Institute indicated a willingness to cooperate with UNIDO in the area of cellular immunology pertaining to the malaria parasite and to mycobacteria. For example, Pasteur may be willing to expand its present training program for mainly Senegalese to train additional researchers from African countries in advanced biotechnology techniques, such as cloning, construction of monoclonal antibodies, polymerase chain reaction, and others. Further, Pasteur would consider entering into joint, cooperative research projects to, for example, develop diagnostic kits based on monoclonal antibodies and the polymerase chain reaction.

ORSTOM's situation is different from Pasteur's in that it is entering into partnership with ISRA and, to a lesser degree, UoD and ENSUT to establish and operate the Biotechnologies Center. Nevertheless, ORSTOM may be amenable to taking on additional trainees from African countries at its facilities, to train them in tissue culture, cell culture, and advanced plant biotechnology techniques. Because the pertinent ORSTOM laboratories are staffed by comparatively few Ph.D.-level researchers, it is doubtful whether these scientists would be willing to take on joint, cooperative projects beyond those envisioned at the Biotechnologies Center. However, this is something that could be explored once the Center is up and running.

Summing up the spectrum of biotechnology-related activities in Senegal (i.e., those ranging from education to basic research, applied research, and applications), it is clear from the descriptions provided above that Senegalese research institutes are inadequately supported by the Government. As a result, they deteriorate, unless they are able to secure international funding. Some have managed to do so and therefore prosper. This

situation is likely to prevail for the foreseeable future.

The education system, as exemplified by UoD and ENSUT, is probably in worse shape than the research sector, mainly because its ability to secure international funding is limited. In addition, student and teacher strikes paralyzed universities during most of 1987 and spring 1988. This caused severe disruptions in graduate studies, especially laboratory practicals. There are indications that the Government decided to "punish" the universities by withholding funding. The net result is that the quality of training has gone down, which of course is reflected in the quality of graduates. ORSTOM's difficulty with finding qualified graduate students may have its origin in these problems.

In the applied sector, the Government is attempting to privatize industries that were nationalized after the state of Senegal was constituted in 1960. Privatization is not going well for several reasons. First, there are insufficient numbers of trained managers and administrators to run newly privatized firms. Second, private funds are in short supply in Senegal, thus the ability of investors to purchase or invest in industry is limited. Third, borrowing is expensive because interest rates charged by lending institutions run 18 % and higher. Fourth, the tax structure does not favor entrepreneurship. On the one hand, if the business becomes profitable, profits are taxed very heavily. On the other, no credit is given for losses. Fifth, the cost of doing business is very high because of high utility rates and high duties on imports.

Although foreigners are encouraged to invest in Senegal, in actuality, foreigners owning businesses in Senegal are liquidating them and moving out. Simultaneously, new foreign investments are not being attracted. The reasons for this situation are the largely the same as those in the preceding paragraph. In addition, successful businesses owned by foreigners become targets for takeover attempts by Senegalese nationals under circumstances that favor the latter.

Similar to other developing countries, there is little or no contacts between researchers and industry. The reasons for this situation are many, but generally the research institutes have had little to offer while industry has neither the expertise or means to apply research. Also, industry does not support research, mostly because it has no incentive to do so. For example, no credit in the form of a tax break or subsidy is given by the Government to an industry wishing to perform research.

It can be seen that the future of biotechnology is uncertain because of underlying generic problems having nothing to do with this field *per se*. Yet these problems will have to be corrected before biotechnology, or any other research-based technology, can prosper in Senegal.

RECOMMENDATIONS

It is recommended that the best candidate in Senegal for

UNIDO support is ISRA; specifically, the ISRA component of the new Biotechnologies Center. The reasons for this recommendation are as follows:

* The research it will perform is of importance to Senegal as defined by its national priorities. Specifically, one direction of planned research is to improve the growth characteristics of certain tree species, which can thereafter be used to anchor sand dunes, preventing their further migration. A second objective is to improve crop plants, giving additional options to farmers to grow cash crops.

* The research program of the Biotechnologies Center builds on existing strengths possessed by ISRA (in forestry research, research pertaining to rhizobium and mycorrhizae, and the MIRCEN cell culture collection), as well as ORSTOM (the symbiotic systems of Acacia-Rhizobium and Sesbania-Frankia and strong capabilities in tissue culture).

* Although the involved institutes primary strength is in agriculture, capabilities could relatively quickly be built up in areas more pertinent to UNIDO's purview. For example, from the basis of tissue culture it is only a small step to develop a capability in cell culture. Plants endogenous to Senegal could be screened for physiologically active compounds (which is a national priority); then cell culture systems could be developed to mass produce these compounds for the pharmaceutical industry.

* ISRA's record for transferring the results from its research to consumers appears to be good; this attribute heightens the possibility that its future internationally funded research will in fact be applied.

* ISRA appears to have effective communications and joint programs with counterpart institutes in the region and throughout the world. This ability to communicate internationally should be advantageous if it became part of the proposed biotechnology network in Africa.

The second recommendation concerns the role of the ARCT. Undoubtedly, the ARCT possesses only a limited resident expertise in biotechnology. Further, the organization is in financial difficulties (reportedly, out of its 30 members, only two are up-to-date on their contributions). Nevertheless, it is recommended that the ARCT be given the responsibility for coordinating network activities. For one, it has a communications network in place; it is probably more efficient to augment this network as necessary than to set up a new network (although this hypothesis should be ascertained by experts). Second, for political and social reasons it makes sense that Africans should run a network

for Africa. Further, it makes practical sense, given the distance between the involved countries and Vienna and the difficulties inherent to communications by phone. Other organizations that may be considered for the coordinating role, such as the OAU and ECA, appear to be less technically qualified than the ARCT.

Before the ARCT can be expected to take up the role of coordinator, its level of biotechnology expertise would have to be increased. Possibly funding for the African network should include sufficient moneys to hire a new staff member with the requisite expertise. Also, funding should be available to engage international experts as consultants when necessary. Care should, however, be taken when drawing up the budget for the African network so that administrative costs do not eat up too much of the funds that would otherwise support research.

Cited Documents

1. **Ministere du Developpement Industriel et de L'Artisanat, "Institut de Technologie Alimentaire (ITA)", no date.**
2. **Cheikh N'Diaye, "Mission Report to Various African Countries for Identifying Possible Locations for Chairs in Food Science Technology and Nutrition", report to UNFSSTD and AAU, December 1985.**
3. **ISRA-ORSTOM, "Programme de Centre de Biotechnologies", 1989?.**
4. **ORSTOM, "Éditions de l'ORSTOM: Senegal", 1988?.**
5. **ISRA-ORSTOM, op. cit.**
6. **Instituts Pasteur Outre-Mer, Rapport Sur le Fonctionnement Technique de l'Institut Pasteur de Dakar, 1987.**
7. **African Technodevelopment, Bulletin of the African Regional Centre for Technology, June 1988.**
8. **African Regional Centre for Technology, Annual Report of Activities 1987, December 1988.**

Annex I

Persons Interviewed and Institutes or Organizations Visited

Monday, October 30, 1989

Mr. Norbert G. Mühlenback, SIDFA
UNIDO
Dakar

Mr. Prosper Houeto
Ms Awa Evelyne Cisse
Ministry for Planning and Cooperation
Dakar

Dr. Yousuf Maudarbocus, Director
Division of Human Resource Development
African Regional Centre for Technology (ARCT)
Dakar

Tuesday, October 31, 1989

Dr. Mouhamadou Diop, Director General
Mr. Babacar N'Dir, Chief of the Quality Control Laboratory
Institute of Food Technology (ITA)
Dakar

Dr. J.-P. Digoutte
Director
Pasteur Institute
Dakar

Dr. Jim Bonner
Agricultural Sector
US Agency for International Development
Dakar

Wednesday, November 1, 1989

All Saints' Day -- National holiday

Thursday, November 2, 1989

Dr. Marc Neyra, Acting Director
Dr. Jean Marc LeBlanc, Plant Geneticist
French Institute of Scientific Research for Development and
Cooperation (ORSTOM)
Dakar

Dr. Yvette Parès
Department of Plant Biology
Faculty of Science
Universite Cheik Anta Diop de Dakar (UoD)
Dakar

Mr. Peter Leitenbauer, Ambassador
Embassy of Austria
Dakar

Dr. Cheikh N'Diaye
Consultant
African Regional Centre for Technology

Friday, November 3, 1989

Dr. Mamadou Guéye, Microbiologist
Senagalese Institute for Agricultural Research (ISRA)
Bambey

Dr. Annerose Daniel J.M., Director
Regional Centre for Improvement of Adaptation to Drought (CEERAS)
ISRA
Bambey

Dr. M. L. Thiam, Director
Microbiological Laboratory
UoD and
Councilor
Ministry of Higher Education
Dakar