NUCLEAR AGRICULTURE IN THE FRENCH SPEAKING PART OF AFRICA AND MADAGASCAR

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My purpose is not to present an exhaustive account of nuclear research carried out in all fields of tropical agronomy. On the one hand, the time allowed to me is limited and, on the other hand, I would not like to try your patience. Therefore I will make a rapid review by showing how French organizations have dealt in different regions with the research fields taken into account. Then, quoting some results, I shall draw a few conclusions, not only from the knowledge acquired but, even more, from the way it has been realized.

Many years before 1960, scientific literature mentioned nuclear techniques in African tropical agronomy, particularly in the fields of radiogenetics (work on millet, for example) and of soil fertility and plant mineral nutrition by means of ^{32}P. Experiments concerning the utilization of soil moisture probes were also carried out in Madagascar and Tunisia. In general, maybe with the exception of plant improvement, these experiments as far as French scientists were concerned consisted of very limited research, more or less dispersed, following personal contacts between scientists and international organizations.

With the foundation of CEA and, especially of the agronomy department, the endeavours became more numerous, more constant and better coordinated, while in the fields of genetics and plant physiology the programmes remained partially dispersed between university departments.

I shall devote here little attention to the endeavours of Euratom and to those of IAEA, even though I am quite aware of their importance.

In French speaking Africa and in Madagascar, the use of nuclear methods is still developing in the already existing framework: for example, GERDAT, which regrouped the nine Institutes or Research Centers specialized in tropical produce and ORSTOM, a French public institute whose function is among others "to undertake and to develop fundamental research directed towards vegetal and animal production outside temperate regions".

The cooperation processes between CEA, GERDAT and ORSTOM are diverse and adapted to the conditions imposed by a variety of circumstances and by the rapid evolution of local structures. There are research contracts for the adjustment or, at the opposite, for the popularization of nuclear techniques; the instruction or recycling of scientists and technicians; expert dispatching during a limited or unlimited time for operations involving technical cooperation; a logistic support in certain programmes by supplying scientific equipment and radioactive tracers; the maintenance of material etc.

From 1964 an original formula has been the introduction by CEA of nuclear methods into some countries such as Ivory Coast, Madagascar and, more recently, Niger. In Ivory Coast, the radionuclide laboratory or LRI has been set up within the existing structures of ORSTOM at Adiopodoumé. Its aim is the study of radioagronomy in the most extended meaning of the word. The Tananarive University in Madagascar with the participation of ORSTOM, has most willingly opened a laboratory, serving a double purpose: nuclear agronomy and medical research. In Niger, LRI of Niamey is

managed according to an agreement with IRAT aiming at the establishment of a National Institute for multiple research.

In a general way, these laboratories regroup all the means indispensable for the use of nuclear techniques in agronomy and biology: experts, execution staff, equipment and documentation. Researchers of all origins are welcome to these laboratories, staying over there from a few days up to several months, in order to receive a training on the use of nuclear techniques in their future research. These laboratories can also loan, and maintain equipment for trained researchers, for example nuclear probes, counting equipment, etc. Finally these laboratories are giving advices when it comes to the collection, manipulation and sifting of data. Therefore, they mostly supply services whereas nuclear technique integration remains dependent on the programmes proposed by the scientists themselves. Within this framework, these laboratories have enabled a number of agronomists to become familiar with nuclear techniques, advancing in this way various fields of tropical research.

These diverse formulas have been successful because of the opportunities offered to these institutes by the tropical countries. Most of the time these countries exhibit extreme environmental conditions: dryness or, inversely, excessive wetness; high average or large differences in temperature; hydrological and thermal regimes rapidly varying in the Sahel regions or at the opposite keeping constant in humid equatorial forest, as regards for example thermo- and photoperiodism etc. These well contrasted regions are privileged places for conducting numerous and varied research projects. To these environmental conditions one must add the presence of structures altogether new, dynamic and relatively free from all restrictive traditionalism and therefore open to new methods. Finally, the difficulties involved in adapting too strictly these techniques, first meant to solve the same problems in temperate countries, have led to less classical methods in which nuclear techniques naturally were integrated. This for example explains the very early interest in moisture probes for water movement studies.

Results

It is not easy to give an exhaustive list of work dealing more or less with radioagronomical techniques in the tropics, because in many disciplines the application fields are not so clearly separated as in chemistry, for example, where the use of radiotracers is very common. Therefore I shall give a short review of the research already undertaken, just as did Mr. Guérin de Montgareuil during his lecture at the fifth annual meeting of ESNA in Bucharest, in the fields of gamma radiation, neutrons and, finally, tracers.

Radiomutagenesis and plant improvement

On the whole this topic consists of research work initiated in 1957 by ORSTOM in order to improve groundnut, millet and rice. Work on millet was then carried out at the initiative of Euratom with funds supplied by F.E.D. Work on rice was resumed and until now has been included in the common programmes of INRA and IRAT.

From the practical view point the results have been diverse. They are disappointing with respect to millet for which the morphologically interesting mutants (aristate, with short straws) show deficiencies in the grain filling.

Yet, the results are more positive with groundnut (pod and grain size, and oil yield). However, it is for rice that the improvements, by induced mutations, have been and still are the most promising. From the practical point of view the most interesting modifications obtained concern the duration of the growth cycle, the plant length and height, and the grain texture. Promising mutants are now being tested in the Cameroons and in Ivory Coast by IRAT.

Irradiation of food-stuffs

Irradiation is a promising process for the preservation of products, and Africa offers immense possibilities in this field, as the preservation methods used there are still very rudimentary. Nevertheless, less work has been achieved in this field except for experiments — which have been conclusive — on the disinsectization of smoked and dried fish in Dahomey, performed in 1965 by CTFT.

Neutronagronomy

This is a dynamic field which is rapidly expanding. For a very long time a number of studies have dealt with the *in situ* measurements of soil-moisture content in tropical regions. But traditional methods have shown how difficult it is to follow the water balance, particularly as a result of its extreme variability. This very quickly drew attention to the benefit of using neutronic methods. This explains the increasing use of moisture probes.

As a first approximation there must be about 60 moisture probes of various origin in the whole of French speaking Africa and Madagascar. The experiments involving their utilization mostly took place in Ivory Coast, Madagascar, Niger, Senegal and Tunisia on very different soils: alluvial, subarid, leached ferruginous, ferrallitic and ando-soils.

Their use led to several types of studies:

- Determination of the hydrological and hydrodynamical properties of soils.
- Studies on the amount of water absorbed by crops whether fertilized or not under various kinds and rates of management.
- Determination of irrigation parameters and of the conditions for using water reserves of the soil.
- Studies on the hydrological regime of natural environments on transects, on water sheds or on particular ecological areas.

Enclosed are two tables (Appendices 1 and 2) showing for the year 1974, the different programmes on the use of moisture probes in Ivory Coast and Madagascar.

For the present time important studies may also be pointed out. They have been carried out by IRAT on the terraces of the river Niger, in order to determine the kinetics of seepage and water redistribution. Similar work is conducted by ORSTOM in Tunisia in the watershed of the Oued Sidi ben Nasseur.

The results obtained are important. These field measurements have modified a number of erroneous ideas, resulting from the misinterpretation of laboratory data obtained from sample manipulations. These measurements have made it possible to specify a number of constraints which determine the circulation and availability of soil water; for example, the influence of the compactness difference between pedologic horizons on the medium

permeability. They brought out different behaviours according to the plant cover, particularly between *Graminaceae,* which rapidly use the superficial water reserves of the soil, and leguminous plants which progressively utilize small quantities of water from greater depths. These different experiments have been carried out on a whole range of tropical plants: citrus fruits, pine-apples, groundnuts, cacao trees, coffee shrubs, sugar cane, cotton plants, *Graminaceae* and leguminous fodder plants, maize, cassava, millet, rice etc.

These experiments have also specified the role played by the different natural covers in the processes of erosion and lateral flow and the consequences resulting from their transformation by man. On this subject one can cite: methodological, as well as practical studies, conducted on watersheds in Madagascar and Ivory Coast; studies on the contact zone between forest and savanna in tropical Africa, and the desiccation and desertification of the Sahel regions.

Nuclear tracers

I shall devote a much shorter time to this subject, as the use of radiotracers has become a familiar technique, in a number of fields of agronomy. Therefore, I shall mention without any definite order a whole series of studies dealing with plant physiology, so as to give you an idea of the diversity of the problems:

- Physiology of hevea-latex by IRCA.
- Sulfur, phosphorus and carbon metabolism in the groundnut and millet by IRAT and ORSTOM.
- Photosynthesis in the banada tree and in the papaya by IFAC.
- Root-hair absorption by the cacao tree by IFCC.
- Activity of the oil palm root system in the Cameroons and Ivory Coast by IRHO.
- Pollination problems on Malagasy coffee shrubs by IFCC and ORSTOM etc.

In *agricultural hydrology,* research work involving tracers is practically non-existent. Yet, it is interesting to mention two studies carried out with the aid of tritium-enriched water: one aimed at following water level fluctuations under a cotton culture and, in hydrology, in a catchment basin in Madagascar; the other at precisely determining the percolation rate of water in sandy soils (in Senegal).

With regard to *fertilization,* although some programmes have dealt with the study of calcium, potassium and sulfur, most of them concerned, in the first place, phosphorus and more recently, nitrogen. The method of isotopic dilution with ^{32}P began in Africa long before 1960, particularly in Senegal at the Bambey station. The very numerous results obtained did not succeed, however, in superseding those obtained by more conventional methods. This explains why the experiments with ^{32}P have been relatively unimpressive until recent times, when they received a new impetus thanks to the work of the Cadarache Center, particularly on the E, L and A values. One may regret, perhaps, that cooperation in the field remains still too limited and too personal.

Work with ^{15}N, which has been increasing since 1970, was the starting point of a cooperation programme between IAEA, CEA, IRAT and ISRA in Senegal. This cooperation extends to Ivory Coast at Bouaké under the auspices of IRAT by a planned research supported by DGRST and organized by IAEA. This cooperation concerns field experiments aiming at better

defining the influence of organic matter form upon the crop yield and the use of nitrogenous fertilizers on millet, groundnut, maize and rice cultures. These studies are now extended by a scheduled action of GERDAT in order to study the fate of the nitrogen absorbed from fertilizers in different plant soil systems. These experiments will be carried out in Ivory Coast by IFAC under banana and pine-apple trees, by IRHO under oil palms and coconut-palms, by IRAT, in northern Cameroons, under sorghum and by IRCT under cotton plants. The mass spectrometer analyses are carried out by GERDAT at Montpellier.

In a parallel direction, the installation of an optical emission spectrometer with the financial and technical assistance of CEA is presently being studied at ORSTOM - Adiopodoumé (Ivory Coast).

The use of radiochemical methods has also been developed for pedological studies. In this connection, research was carried out as regards the evolution of biological remodelling and the estimation of the humification processes in tropical forest soils, studies conducted jointly by ORSTOM and the "Centre Scientifique de Monaco". Likewise, recent progress has been made in the study of organo-mineral complexes in ferrallitic regions using ^{14}C, ^{55}Fe and ^{59}Fe, work conducted jointly by CEA Cadarache and ORSTOM. Finally, it is necessary to take into account the use of radio-elements in soil dating which allowed calculating soil evolution rate and which are of great importance for any management project.

In *entomology* insect labelling up to now has supplied important results but the endeavours are rather scattered. One can rapidly point out studies carried out on millet and sorghum predators in Niger, or insect spreading zone from specific sites in the post-forest savannas of Ivory Coast, on the localization of penetration points of nematodes, and studies conducted by IEMVPT on tsetse flies in RCA, Cameroons and Chad.

Finally, one should mention a whole series of diverse studies using radiotracers, e.g. the primary production of a tropical lagoon environment; the uptake of pesticides by plants and their persistence; the autotrophic assimilation by phytobenthos, phytoplankton; the grazing of zooplankton, etc. In order to give an idea of the problem diversity you will find here enclosed, in Appendix 3, the different programmes using tracers carried out at LRI of Adiopodoumé in 1974.

As a conclusion, let me here express my opinion.

The Agronomy Department of Cadarache has devoted a lot of energy in order to stimulate the use of nuclear techniques by tropical agronomists. It has also contributed to their instruction and recycling. But it seems to me that it has brought a new technique rather than a new approach of the problem, for which it is not quite blameworthy, as it had to answer rapidly requests for services. Yet as a consequence both partners did not consider long enough the possibility offered to them as to this newer approach.

Therefore, I believe, it would be necessary to reverse the movement and to ask agronomists to expose their problems in their own way to the CEA experts. The creation of an office of ORSTOM in Cadarache would put that idea in concrete form.

On the other hand, there seems to be too often an unbalance between the large financial means used for the application of nuclear techniques and those of the more "common" substructure necessary to complete it. One example will put this idea into a concrete form. Experiments with ^{15}N do not only require the use of a mass spectrometer which only can operate within a centralized structure, but also require in the close vicinity of the

experimentation site some laboratories for conventional nitrogen analysis. However, the accuracy of soil nitrogen serial analysis is insufficient for isotopic analysis. It is then necessary to put into practice an ad hoc organization with its own staff, which in Africa is not always an easy problem to solve.

Finally I believe we did not fully profit by past experience. For example, I notice that some experiments carried out in pots or in lysimeters were successful whereas in the field they were not conclusive: this difference is sometimes caused by lateral contamination. Indeed, there is often a lack of preciseness when considering the set-up of experimental conventions. On the other hand the accuracy of nuclear methods is relevant with the overall knowledge the agronomist is expecting to draw from his experiments, and are techniques well adapted to the scale of the problems to be solved?

I would like to draw your attention towards these points which perhaps may look elementary but which too often induce misunderstandings and therefore may slow down the development of radioagronomy.

Appendix 1 **RADIONUCLIDE LABORATORY OF TANANARIVE - MADAGASCAR**

Title of the study	Institution	Responsible scientist	Financing	Situation
Neutron probe				
Study of the influence of starting cultivation in a field on its water balance	ORSTOM	D. Ibiza (Hydrology)	DGRST	Ambatolampy
Study of the influence of starting a cultivation in a sloping field on its water balance	CTFT	Benoit de Coignac	DGRST	Manankajo
Influence of the water regime of soils on the utilization of nitrogen fertilizers	IRAM/CNRA	Arrivets	LRI/CNRA	Ampangabe
Water need and irrigation control of rotating crops: cotton, maize and Cape peas	IRCT/IRAT/CNRA	Cretenet	LRI/IRCT	Tulear
Variation of water profiles under various vegetative covers in the low Mandrare valley	ORSTOM	Danloux	ORSTOM/LRI	Amboasary
Water consumption of cotton-plants in the irrigated area of Samangoky. Study of the evolution of the level and saltness of the underground water-level	LRI/IRCT	Marini/Kaiser	IAEA	Tanandava
Control of irrigations of the Samangoky area with a neutron probe. Adjusting of the neutron probe.	LRI/IRCT	Marini/Kaiser	IAEA	Tanandava
Determination of the hydrodynamical properties of the main soils in the area of Samangoky	LRI	Marini/Villemin	IAEA	Tanandava
Determination of the physical hydrodynamical properties of the soils at the experimental station of Sodemo	LRI/Sodemo	Marini/Baran	Sodemo	Morondava
Study of the water consumption of sugar-cane and tobacco in irrigated cultures	LRI/Sodemo	Marini/Baran	Sodemo	Morondava
Determination of the physical hydrodynamical properties of the main types of soils of the Citrus-cultivating State Farm of Bezezika (1,000 ha). Control of the water-level and of the irrigations	LRI	Marini/Villemin	Bezezika	near Morondava
Set-up and adjustment of the neutron probe	LRI	Roulot/Marini	LRI	LRI-Tananarive
Standardization of the soils at the trial points of Morondava, Tulear, Tanandava and Bezezika	LRI	Marini/Villemin	LRI	LRI

Appendix 2 **RADIONUCLIDE LABORATORY OF ADIOPODOUME - IVORY COAST**

Title of the study	Institution	Scientist	Situation	Type of work	State of progress
Study of the savanna in low Ivory Coast	ORSTOM Geography	Winckell	Dabou	Standardization of routine measurements	In progress
Compared ETRM of *Panicum* and *Paspalum*	ORSTOM Bioclimatology	Cardon	Adiopodoumé	Routine measurements	Interrupted
Water consumption of pine-apple	IFAC	Combres	Anguededou	Calibration and positioning of measuring tubes	In progress
Irrigation experiment under cacao-trees	IFCC	Jadin	Bingerville	Standardization	In progress
Water consumption of sugar-cane	IRAT	Langellier	Ferkessedougou	Standardization, density	Starting
Water consumption of rice	IRAT	Kalms	Bouake	Standardization	Starting
Hydrological study of the sloping bed of Sakassou	ORSTOM Hydrology	Lafforgue Camus	Sakassou	Setting up the experiments Standardization-Density-Kinetics	Starting
Water balance under banana-plantations	ORSTOM Pedology	Roose	Azaguie	Standardization Kinetics	Ended
Laboratory standardization of soils using the neutron absorption method	ORSTOM LRI	Bois	Adiopodoumé	Routine measurements	In progress

Appendix 3 **UTILIZATION OF RADIOTRACERS - LRI ADIOPODOUME - IVORY COAST**

Title of the study	Institution	Responsible scientist	Situation	Type of work	Nuclides	State of progress
Biology of a rice-parasiting nematod	ORSTOM Nematology	Reversat	Adiopodoumé	Autoradiography	^{35}S	Ending
Biology of the queen-termite	CNRS	Bordereau	Dijon Adiopodoumé	Liquid scintillation	^{3}H	Ended
Permeability of the latex cells	ORSTOM Physiology	Hanover	Adiopodoumé	Liquid scintillation	^{14}C	In progress
Protein malnutrition and immunological deficiency	Foundation NESTLE	Shopfer	Adiopodoumé	Liquid scintillation Autoradiography	^{14}C ^{125}I ^{131}I	In progress
Study of the phytoplankton of the ocean	CRO	Dufour	Abidjan	Liquid scintillation	^{14}C	In progress
Study of the zooplankton of the ocean	CRO	Leborgne	Abidjan	Liquid scintillation	^{14}C	In progress
Paraprimary production of the ocean	CRO	Herbland	Abidjan	Liquid scintillation	^{14}C	In progress
Pollination of the cacao-tree	IFCC	Lucas	Bingerville	GM couting	^{32}P	In progress
Labelling of tsetse flies	ORSTOM Medical entomology	Challier	Bobo Dioulasso	Labelling and detection in the field	^{59}Fe	Interrupted
Physiology of *Hevea*	Faculty	Lambert Coupe	Abidjan	Routine counting	^{32}P ^{14}C	In progress