

CIRAD

1995



CIRAD 1995

Centre de coopération
internationale en recherche
agricole pour le développement

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The Centre de coopération internationale en recherche agronomique pour le développement (CIRAD) is a French research organization that specializes in agriculture in the tropics and subtropics. It is a state-owned body and it was established in 1984 following the consolidation of French agricultural, veterinary, forestry, and food technology research organizations for the tropics and subtropics.

CIRAD's mission is to contribute to the economic development of these regions through research, experiments, training, and dissemination of scientific and technical information.

The Centre employs 1800 persons, including 900 senior staff, who work in about 50 countries. Its budget amounts to approximately 1 billion French francs, more than half of which is derived from public funds.

CIRAD is made up of seven departments: CIRAD-CA (annual crops), CIRAD-CP (tree crops), CIRAD-FLHOR (fruit and horticultural crops), CIRAD-EMVT (livestock production and veterinary medicine), CIRAD-Forêt (forestry), CIRAD-SAR (food technology and rural systems), and CIRAD-GERDAT (management, common services and laboratories, documentation). CIRAD operates through its own research centres, national agricultural research systems, or development projects.


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The President's Message

1995 was highlighted by CIRAD's discussions with French Ministries on the terms of the agreement on objectives. This 4-year agreement sets out the main development commitments for CIRAD within the context of current government trends.

This contractual approach to interactions between a state-owned research body and ministries implicated in its activities — i.e. research, cooperation, foreign affairs, agriculture, overseas territories, and finance — reflects the admirable, in my opinion, government conviction to modernize its agencies and public policies.

This agreement, set up on the initiative of the former Minister of Higher Education and Research, addresses many concerns that were not adequately taken into account in the past. It provides a forum for ideas and discussions, beyond the framework of annual budgetary negotiations, between the Centre and Ministries on the medium-term outlook.

The negotiations reviewed CIRAD's missions and professional profiles from different viewpoints — providing an overview of its institutional status within the national scientific community. Guidelines were also set which should enable CIRAD to meet the needs of its Southern partners, while promoting synergies with development-oriented research organizations worldwide.

The research priorities will have positive effects on CIRAD's development only if they are fully understood and adopted by its agents, as they are responsible for applying CIRAD policies in the field.

I am delighted by the fact that preparation for this agreement provided an opportunity for in-depth discussions with staff representatives. Despite legitimate differences of opinion on various terms of the agreement, these discussions highlighted the shared desire for a strong state commitment in drawing up guidelines for CIRAD's future programmes, while respecting its operational autonomy. The discussions also confirmed and enhanced what I consider to be one of CIRAD's great assets — its organizational style, based on economically- and socially-oriented scientific activities.

Negotiations on the agreement on objectives have ended and it should soon be signed. This agreement paves the way to a very promising future for CIRAD, bolstered by government approval of the Centre's expertise and importance in development-oriented agricultural research.

A handwritten signature in black ink, appearing to read 'G. Paillotin', with a small horizontal line underneath.

Guy Paillotin
CIRAD President

INNOVATIONS IN COOPERATION



Farmers' Organizations, Partners in Agricultural Research

The withdrawal of government support from agricultural sectors in developing countries has led to a progressive collaborative takeover by producers of activities formerly controlled by the public sector.

CIRAD, prompted by the increasing importance of this highly diversified movement, launched a study 4 years ago on farmers' organizations and their potential role in rural development. This involved working side-by-side with farmers' organizations in six African and Latin American countries and with NGOs. A CIRAD workshop held in Mèze (France), from 20 to 24 March 1995, provided an opportunity to review

the results of this study, and identify changes needed to enhance close collaboration between research agencies and farming communities in Southern countries.

Farmers' organizations have a broad range of economic and technical functions. They represent local vehicles of innovation, serving as mediators between farmers' often highly-varied demand and external technological supply. In addition, these groups often take their own initiatives, such as creating communal services of general interest, developing farmers' savings and credit systems, and managing natural resources. Some are also involved in structuring production

and processing subsectors (*filières*), thus securing markets and enabling a fairer distribution of profits between the different parties involved.

Achievements remain modest, generally due to an unfavourable legal and economic climate, but these farmers' organizations have built on previous experience and are now endowed with all of the skills required to achieve success in their initiatives. They are becoming full partners in negotiations with other development players.

Producers' Involvement in Research

If farming communities are to be able to modernize their agricultural technology and improve productivity, they must have access to technical and economic innovations that are adapted to a wide range of situations and meet their requirements. The research sector can provide them with methodological and technical support in these activities.

In 1995, these priorities were tabled in discussions on the ecoregional concept, held at the request of the French Ministère de la recherche, and involving CIRAD, the French Institut national de la recherche agronomique (INRA), and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM). A new generation of ecoregional projects, to be conducted jointly with national research institutions of Southern countries (another important priority),

was proposed by the French agricultural organizations which emphasize the role that the rural community can play in development-oriented research activities.

Farmers' organizations should be involved in research projects from the outset, i.e. when the regional implications and research needs are being assessed, to complement the intrinsically-partial viewpoints of scientists and experts. Overall analyses of regional situations will also be more accurate when they include consultation with farmers. Indeed, synergy between research supply (that has to be developed) and social demand (that has to be recognized and fully defined) is essential to obtain pertinent diagnoses of agronomic situations. In an ecoregional approach, all regional participants are thus invited to be directly involved in research planning and institutional arrangements.

Users also should be closely involved in the subsequent experimental phase, for on-farm evaluation of research data. Once the results are verified, concerned rural communities can be provided access to these new technological innovations. CIRAD and partners are currently conducting this type of regionally-oriented research in Brazil on newly-cultivated land, with the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), in Santo Domingo, with cocoa producers, and in the French overseas departments and territories. For instance, in Hauts de la Réunion area, CIRAD, in collaboration with farmers' organizations, has developed sustainable cropping systems with permanent plant cover. These farm-tested systems produce higher crop

yields, while controlling soil erosion — farms devoted to rose geraniums were found to be more stable with these cropping technologies.

Exchanges of Information and Know-How

Farmers' organizations require information on markets and on the interplay of operators in the subsector — to help them in negotiating, defending their interests, and adapting their strategies to economic realities.

CIRAD has undertaken to collect and circulate this information by creating an international market monitoring system that analyses agricultural subsectors and publishes technical brochures on each commodity. The latter are updated yearly and distributed to partners. In 1995, CIRAD, upon the request of the French Ministère de la coopération, analysed the effects of the devaluation of the CFA franc on the irrigated rice subsector in three Sahelian countries, i.e. Mali, Senegal, and Niger. The results of this analysis have been enriched with information on the subsector provided by rice growers and their organizations.

Research can also be useful for convincing private representatives of a subsector (producers, processors, and retailers) and political decision-makers to join forces for drawing up national policies concerning their specific subsector. This will provide a forum for exchanges of information throughout the subsector. Sectoral

participants will have access to all elements needed to make their own decisions — research thus serves as a mediator between farmers' organizations and the public sector. In Latin America, for instance, CIRAD, in conjunction with the Instituto Interamericano de Cooperación para la Agricultura (IICA), managed to initiate discussions between all parties involved in the subsector, including government officials, through ad hoc commissions. They led to mutual agreement on subsequent policies. This original institutional model was adopted in Costa Rica for some unorganized subsectors.

It is also essential to train coordinators and members of professional organizations in ways of fulfilling their new responsibilities. A multifaceted system is required to handle the diversity of situations. In support of this type of system, CIRAD has for several years been developing training modules on producer organization planning and local development dynamics. In 1995, CIRAD went one step further in its development-oriented activities by becoming involved in a European master's degree course, entitled "Agricultural extension and professional farming organizations", created by the French Centre national d'études agronomiques des régions chaudes (CNEARC), which is aimed at training future professional staff for farmers' organizations.

In addition, scientists are beginning to focus on analysis of farming practices. CIRAD, in collaboration with the Institut d'études et de recherches agricoles (INERA), Burkina, held a training workshop on "Farming practices and sustainability" in Bobo-Dioulasso (Burkina) from

8 to 14 October 1995. This workshop highlighted the wide diversity of producers' practices and strategies, their rationale and impact. Field visits gave workshop participants a clearer view of factors that guide farmers in their choices, and evaluated the effects of these choices on the sustainability of farming systems.

Taking farmers' motives and choices into account was also an important concern in discussions on the topic of fertility, brought up during a CIRAD seminar entitled "Fertility of humid tropical environments", held in Montpellier (France) in November 1995. Fertility was defined as the capacity to sustainably fulfil the needs of rural communities through their farming systems, i.e. the result of human/environment interactions and an open-ended social structure. Moreover, fertility obviously depends on the physical and biological features of the environment, and on the dietary, monetary, and social strategies of social groups utilizing and modifying the environment to meet their ultimate requirements.

Redefining Partnerships

Agricultural research is undergoing a major institutional shift due to the appearance and increasing importance of professional farmers' organizations in Southern countries. In the light of this situation, Northern institutions are redefining their partnerships and overhauling their cooperation policies. Furthermore, the overwhelming global challenges on the horizon at the onset of the third millennium

— food shortages, environmental degradation, impoverishment of a large portion of the world population — are prompting research institutions to pool their material/human resources. It seems clear that a global network is required to suitably deal with the ecological, economic, and social imbalances that threaten the planet.

CIRAD is thus increasing its collaboration with other French research organizations.

Many established links with ORSTOM have been strengthened, especially in plant improvement. In addition to the already existing joint laboratories, i.e. in-vitro oil palm culture, tropical plant virology, forest symbioses, and aquaculture, ORSTOM research scientists are now working with CIRAD teams in their Crop Physiology and Ecophysiology Research Unit. This determination to work together is also evident in CIRAD's funded thematic research programmes, with collaboration on genetic resources and quality, and joint comparative genome mapping studies on Gramineae species that are under way in the Bureau des ressources génétiques. CIRAD, along with the French Centre national de la recherche scientifique (CNRS), are also involved in ORSTOM soil biology studies. CIRAD-ORSTOM relations should soon be formalized through a signed agreement.

CIRAD has joined forces with INRA to conduct research on livestock production, especially in genetic areas, to identify disease resistance markers, characterize breeds, and evaluate livestock biodiversity. This collaboration is also extended to plant material: citrus improvement, genetic transformation of cotton and, more

CIRAD in the French Overseas Departments and Territories

CIRAD's activities in the French DOM-TOM — French West Indies, French Guiana, Réunion, and New Caledonia — were extended to French Polynesia and Mayotte in 1995.

In Papeete, the Polynesian Ministère de l'agriculture et de la recherche asked CIRAD to contribute to the development of the archipelago through its research skills. CIRAD is analysing the main agricultural subsectors, i.e. citrus, other fruit, vanilla, and forestry, in order to define pertinent research and development projects in these fields.

In Mayotte, local officials are hoping to be able to restimulate the agricultural sector. CIRAD has set up a research programme with three main thrusts: characterization and improvement of production systems; improvement of cropping systems and food-crop diversification; and providing support for fruit, vegetable, and aromatic plant production.

In both Polynesia and Mayotte, tripartite committees have been formed, with the government, local communities, and CIRAD; they are responsible for planning and following up the research.

In other French overseas departments and territories, CIRAD and its partners are setting up specialized pôles, as defined in the 10-year programming plan approved by the the Centre's Board of Trustees in 1994.*

Réunion also has a steering committee that includes representatives of the Region, the Department, and CIRAD. The committee held its first meeting in December 1995, and members expressed a wish to strengthen plant protection initiatives, especially via the transfer of some research activities from metropolitan France to Réunion. The committee also asked CIRAD to study the possibility of creating an aromatic and medicinal plant subsector.

In French Guiana, the scientific interest group Silvolab, which is investigating the physical and

biological bases of humid forest ecosystem functioning and management, now has a reception centre for foreign scientists. Silvolab first included CIRAD, the French Ecole nationale du génie rural, des eaux et des forêts (ENGREF), the French Office national des forêts (ONF) and ORSTOM, and then decided to open its doors to new partners, i.e. the Université Antilles-Guyane, CNRS, and the French Muséum national d'histoire naturelle.

*CIRAD prepared several research projects, as part of an overall economic and social development plan for the French West Indies, and requested EU funding. Three of these projects — animal genetics and pathology, improving sugarcane production, and banana genetics, pathology, and production improvement — presented by Guadeloupe, received a 4-year funding package from the European Agriculture Guidance and Guarantee Fund (EAGGF). In Martinique, which has been hard-hit by cyclones, CIRAD aims to develop the ornamental plant subsector — studies have begun on dieback of galangal (*Alpinia* sp.), a tropical flower for potential export.*

In New Caledonia, CIRAD is conducting research under a mandate signed with the three provinces to promote rural development, as part of the French Matignon Agreements. CIRAD participated in discussions, along with ORSTOM and the Université française du Pacifique, to set up a research programme for 1998 and thereafter. The programme guidelines should be useful for deciding on future development contracts, and planning CIRAD activities for the next 5 years. In addition, CIRAD is committed to establishing regional linkages, in agreement with the policies of the High Commissariat. Research missions on livestock production, vegetable, fruit and food cropping, and coconut-oil development, were conducted in Vanuatu. They should lead into research projects on these topics, and specialists will be sent to Fiji and to Wallis and Futuna Islands.

* Collaborative and multidisciplinary research organizations.

recently, mapping the eucalyptus genome. Moreover, a joint CIRAD-INRA tree and forest-stand modelling laboratory was created in 1995.

CIRAD has also strengthened its relations with other regional and international research centres. Cooperation with the Asian Vegetable Research and Development Center (AVRDC) materialized in 1995, with the posting of a CIRAD scientist in Taiwan to study bacterial wilt of tomato. CIRAD also signed a contract with the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), the international maize research centre, concerning genetic transformation of maize plants for resistance to pest insects. In addition to these two new linkages, there are many other collaborations under way in various regional centres in Africa, Asia, and Latin America, and with most of the international centres of the Consultative Group on International Agricultural Research (CGIAR).

The Doubly-Green Revolution, a Common Goal

Both CIRAD and CGIAR are determined to achieve sustainable development through progress in ecological, economic, and social research. An international seminar on the “doubly-green revolution”, organized by CIRAD in Poitiers in November 1995, in collaboration with the Fondation prospective et innovation, provided an important international forum on sustainability and equity-based agricultural development. At this meeting, research scientists

tabled a set of methods, models, and theories aimed at renewing the sustainable agriculture concept.

According to this agricultural concept, as compared with intensive cropping practices that induce major environmental modifications, the whole ecosystem is managed, and transformations occur progressively. Indeed, existing ecosystems should be tapped for their agricultural potential without altering the natural balances, instead of replacing an ecosystem with a productive cropping system.

The function of research in innovation processes is also being reconsidered. The set of questions addressed by the doubly-green revolution contrasts with the traditional pattern, i.e. information is provided by research, circulated by extension services, and applied by farmers. Technological innovation is now considered to be a complex process with farmers having a key role. Farmers and their organizations must henceforth be involved in the creation of global agricultural research systems, in order to combat poverty, boost food production, and limit environmental stress.

Ecoregionality in Practice

CIRAD is actively designing and setting up ecoregional projects. These will provide a useful testing ground for new development-oriented agricultural research concepts, and lead to novel means of cooperation.

The Pôle régional de recherche sur les systèmes irrigués soudano-sahéliens (PSI), a pôle on irrigated systems in the Sudano-Sahelian zone, was launched in 1995 on the initiative of CIRAD. It brings together, under the aegis of the Conférence des responsables de recherche agronomique africains (CORAF), national agricultural research systems of four African countries (Mali, Mauritania, Niger, and Senegal), and their partners (CIRAD, ORSTOM, and the University of Wageningen), involving around 50 scientists. It receives funding support from the French Ministère de la coopération.

This project focuses on developing irrigated agriculture based on environmental resource management guidelines. Four main research topics were defined, each coordinated by a participating country: controlling soil degradation under irrigation (Mali), intensification of irrigated rice cropping (Mauritania), technical, social, and land-use management related to irrigation (Niger), and irrigated crop diversification (Senegal).

In collaboration with CIRAD, Cameroon, the Central African Republic, and Chad founded the Pôle régional de recherches appliquées au développement des savanes d'Afrique centrale (PRASAC), a regional research pôle for savanna development in central Africa, which is now being set up. The savanna zone of Central Africa represents a relatively homogeneous ecological and economic unit — i.e. a single rainy season, comparable natural vegetation, landscape suitable for both herding and food cropping, an economy closely linked with cotton cropping, and a wildlife-based tourist potential.

Within this context, three main PRASAC objectives were set out. The first involves sustainable management of the natural environment and farming systems which strives to limit competition between herders and farmers for land access. In a zone where climatic, phytosanitary, and marketing risks are a considerable threat to agricultural production, research will focus on strengthening food security, increasing farmers' incomes, while improving and protecting crops and herds, developing agricultural products, and organizing distribution networks. Finally, attempts will be made to improve the competitiveness and productivity of the cotton subsector, the main driving-force of the region.

Nigeria has expressed an interest in participating in PRASAC. CIRAD and ORSTOM are partners, while European universities and international centres of CGIAR could soon become involved in this CORAF-backed project.

CIRAD has also signed a contract with the Center for International Forestry Research (CIFOR) to set up (in 1995) a regional project to provide full access to research results on African tropical rain forests. This project is being carried out in collaboration with Cameroon, the Congo, Côte d'Ivoire, Gabon, and the Central African Republic. Many environment-friendly sylviculture techniques have now been devised which improve ecosystem productivity while preserving the specific diversity of natural forests. Scientists have proposed to summarize the results for the use of those who manage the forests, i.e. forestry services, companies, and rural communities. The final aim is to promote

a regional network for operations and communications on forest management, involving consultation with all economic operators.

Finally, there are ongoing discussions about creating an ecoregional project on humid and subhumid zones of Africa, which could be of interest for Cameroon, Côte d'Ivoire, Gabon, Ghana, Nigeria, and Zaire. CIRAD and the International Institute of Tropical Agriculture (IITA) plan to be involved in this project, with CIRAD providing experience on tree crops, agriculture/food production, and sectoral analysis, and IITA on the improvement of food-crop systems. Other international research centres could also become affiliated, e.g. the International Centre for Research in Agroforestry (ICRAF), the West Africa Rice Development Association (WARDA), and the International Livestock Research Institute (ILRI).

The ecoregional approach is not solely limited to Africa; such projects are also being developed in Asia. The International Rice Research Institute (IRRI) has set up a project on humid and subhumid zones in six countries: India, Indonesia, Laos, the Philippines, Thailand, and Vietnam. CIRAD and ORSTOM, on the basis of their broad experience with respect to cropping

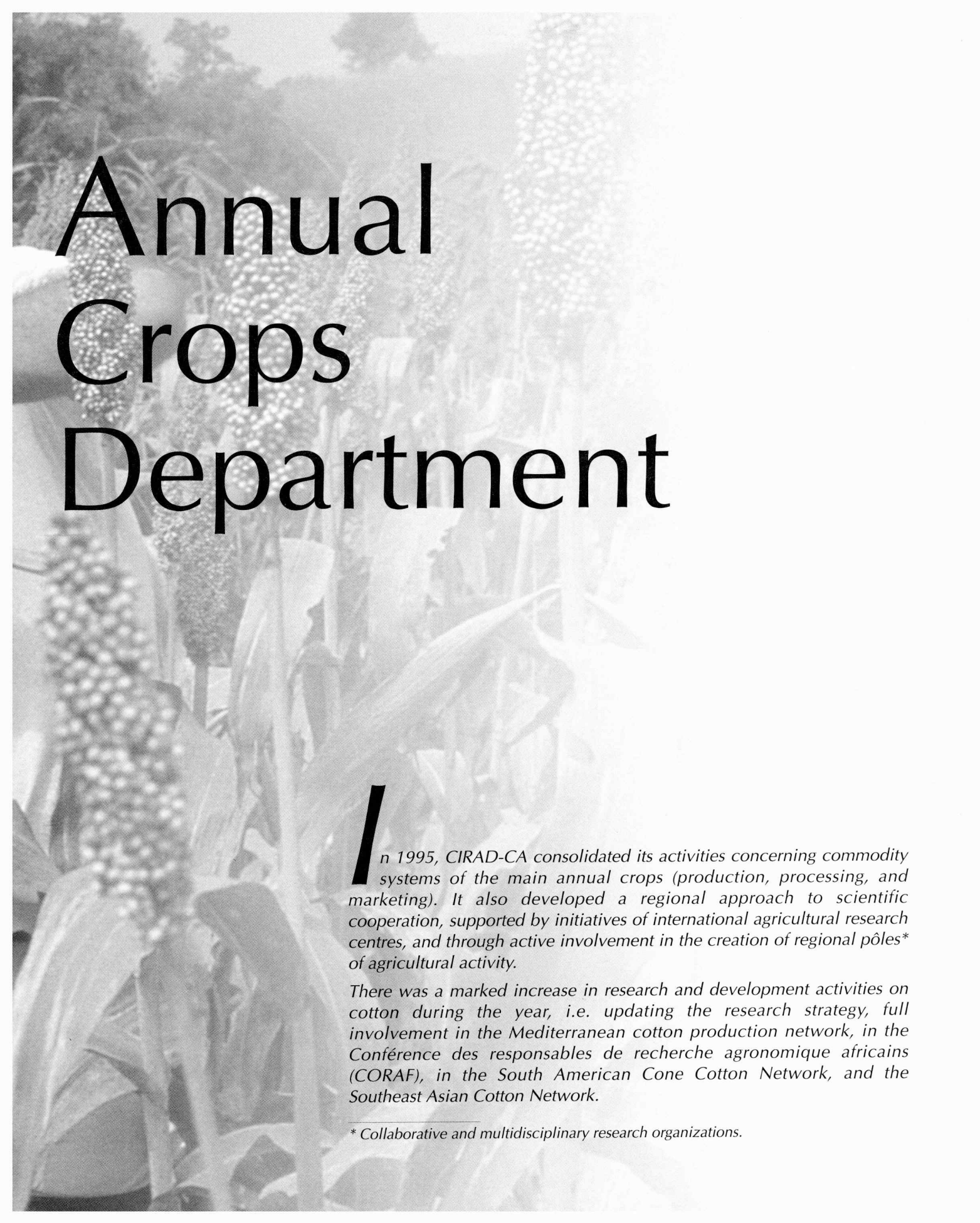
systems in hilly and plateau areas, have offered to participate in the project alongside national agricultural research systems in the host countries. Research organizations from Australia and the Netherlands, as well as other international centres such as CIMMYT (for maize), ICRAF (for agroforestry), and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (for legumes) could also be included in the project.

Through these projects, regional priorities can be defined, tasks shared between countries, and synergies developed, while strengthening national proficiencies.

Research studies conducted within the framework of these projects are designed on the basis of social demand and function through partnerships with funding or commercial agents, i.e. governments, development enterprises, retailers, craftsmen, and, of course, farmers' organizations, and crop and livestock producers.

CIRAD, through its active involvement in these initiatives, is promoting a global open-ended research system that strives to fulfil farmers' needs. The success of the doubly-green revolution will partially depend on whether scientists can establish a fruitful dialogue with farmers' organizations.





Annual Crops Department

In 1995, CIRAD-CA consolidated its activities concerning commodity systems of the main annual crops (production, processing, and marketing). It also developed a regional approach to scientific cooperation, supported by initiatives of international agricultural research centres, and through active involvement in the creation of regional pôles* of agricultural activity.

There was a marked increase in research and development activities on cotton during the year, i.e. updating the research strategy, full involvement in the Mediterranean cotton production network, in the *Conférence des responsables de recherche agronomique africains* (CORAF), in the South American Cone Cotton Network, and the Southeast Asian Cotton Network.

* Collaborative and multidisciplinary research organizations.

The Department promoted cooperative regional research through its involvement with CORAF in setting up the *Pôle régional de recherche sur les systèmes irrigués soudano-sahéliens (PSI)*, and development of the *Pôle régional de recherches appliquées au développement des savanes d'Afrique centrale (PRASAC)*. The creation of PSI was requested by Mali, Mauritania, Niger, and Senegal; PRASAC was set up on the initiative of Cameroon, the Central African Republic, and Chad. These pôles bring together research teams of member countries, and of international and Northern partners, at a limited number of locations. The studies are aimed at addressing the development imperatives of concerned regions.

There will undoubtedly be an increase in the organization of scientific research pôles in the South. Several are currently being developed: the *Pôle régional de recherche appliquée au développement des savanes d'Afrique de l'Ouest (PRASAO)*; a highland research pôle in the Indian ocean region, in conjunction with the International Centre for Research in Agroforestry (ICRAF); and a humid zone research pôle in western Africa, with the International Institute of Tropical Agriculture (IITA). In addition, potential regional cooperation is being discussed: the *Initiative pour la recherche écorégionale en Asie humide (IREAH)*, with the International Rice Research Institute (IRRI) and the Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific (CGPRT); and the *Programme coopératif de recherche et de transfert de technologie pour les tropiques sud-américains (Procitropicos)*, on humid savanna lands, with the Instituto Interamericano de Cooperación para la Agricultura (IICA). The Annual Crops Department intends to become fully involved in scientific cooperation through partnerships established in various regional programmes. ■

Smallholder Farming in Savanna Areas

Through this Programme, CIRAD is currently involved in six different

dry tropical African countries (rainfall: 600–1 200 mm/annum): Mali, Burkina, Côte d'Ivoire, Cameroon, Chad, and Madagascar. The main aim is to promote efficient and sustainable cropping and farming systems through activities carried out in collaboration with national agricultural research services of host countries and with the Institut

ANNUAL CROPS DEPARTMENT

CIRAD-CA

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Jacques Lefort

Research Director
Jean-Claude Follin

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Léandre Mas

Ecoregional Research Programmes

Smallholder farming in
savanna areas
Guy Faure

Smallholder farming in
irrigated areas
Jean-Claude Legoupil

Smallholder farming in
highlands and newly cultivated areas
Alain Leplaideur

Sustainability and
environmental resources
Francis Forest

Commodity Subsector Research Programmes

Rice
Henri Feyt

Other cereals
Jean-Leu Marchand

Cotton
Michel Déat

Protein-oil crops
Robert Schilling

Sugarcane
Jacques Marquette

Research Units

Plant improvement
Jean-Christophe Glaszmann

Crop physiology
Pierre Siband

Farming systems
Michel Crétenet

Soil and land-use management
Francis Ganry

Water management
Florent Maraax

Plant pathology,
weed management
Jean-Loup Notteghem

Applied entomology
Maurice Vaissaye

Biometrics, computer services
Alain Joly

Cotton technology
Eric Héquet

Cereal technology
Jacques Faure

Commodity economics
Claude Freud

Support Services

Publications, information,
documentation
Hervé Saint Macary

Technology transfer
Jean-Luc Khalfoui

français de recherche scientifique pour le développement en coopération (ORSTOM).

SUSTAINABLE CROPPING SYSTEMS IN CÔTE D'IVOIRE

An experiment was conducted in Côte d'Ivoire, in collaboration with the Institut des savanes (IDESSA) and other development partners, with the aim of improving the efficiency of traditional cropping systems. It was set up on farms in the northern part of the country, in a cotton-growing zone, where environmental degradation is occurring (reduced soil fertility, growing scarcity of rangelands and firewood).

Bench terraces were built following the land contours to control erosion. They were consolidated by planting trees (cash crops, forage and shrub species) or quick-growing hedges. Inside these protected areas, various cropping systems have been developed, with different degrees of intensification, often associated with livestock production.

With these more efficient systems, farm incomes and labour productivity had doubled after 6 years of experiments. These systems include soil management techniques to reduce runoff, soil-specific fertilization, and better management of crop

NETWORKS

The Creation of PRASAC

PRASAC, the regional research pôle for savanna development in central Africa, was founded in 1995, upon the initiative of Cameroon (IRA and the Institut de recherches zootechniques et vétérinaires [IRZV]), the Central African Republic (the Institut centrafricain de recherche agronomique [ICRA]), and Chad (the Bébedjia research station, the Direction de la recherche technologique agricole [DRTA] and the Laboratoire de recherches vétérinaires et zootechniques [LRVZ]). CIRAD and ORSTOM are partners of this research pôle, which is also supported by the French Ministère de la coopération. In the zone covered by the PRASAC research centre, cotton cropping is highly developed, with substantial cereal and livestock production.

Rural development imperatives and sponsors' demands are priorities of the research pôle. PRASAC regional activities are backed by national scientific research teams through studies focusing on problems specific to the participating countries.

The research programme was drawn up following consultation with development agents; basic needs were reviewed by national committees, and coordinated by a steering committee. Three objectives were set out: promote sustainable development; strengthen food security; and improve the competitiveness and productivity of the cotton subsector.

rotations. The focus is now on trying to eliminate the need for tillage by growing a permanent mulch plant cover of *Pueraria phaseoloides*. The results should enable savings on labour and inputs, while controlling erosion.

CROPPING SYSTEMS IN A COTTON-GROWING ZONE

From 1992 to 1995, farming practices and decisions made by Cameroonian farmers were jointly analysed, with the Cameroonian Institut de la recherche agronomique (IRA) and ORSTOM, within the framework of the Garoua Project.

The study was conducted in an area south of Garoua with high in-migration, where the cotton production company has been encouraging intensive use of inputs and animal traction. However, these cropping systems are still not very intensified. In practice, farmers often combine intensively cropped cotton and maize with hardy crops such as sorghum and groundnut. The latter staple crops thus partially benefit through a residual effect of chemical fertilizers applied to the intensively-grown crops. Five different production system practices were identified on the basis of crop rotations, extent of cotton and maize crop intensification, and the cropped area/farm ratio. There is a general

trend towards expanding cropland areas in zones where land for farming is still not limited; the devaluation of the CFA franc reinforced this trend. In overpopulated zones, out-migration is an alternative to intensification.

Smallholder Farming in Irrigated Areas

Partial (lowlands) or complete (irrigated farmland) water management projects are the focus of this CIRAD programme. When possible, research staff monitor and advise on irrigation developments with the aim of improving farmers' productivity.

Projects carried out in western Africa, in conjunction with the CORAF PSI research pôle and the Inland Valley pôle hosted by the West Africa Rice Development Association (WARDA), are associated with agricultural water control, cropping and production systems, and irrigation/environment interactions. Further projects are currently being developed for South America, southern Africa, and Asia.

In sub-Saharan Africa, there are 1.3 million km² of inland valleys, representing 5% of the total agricultural area; most of this land is concentrated in the intertropical zone, where precipitation is higher than 700 mm/annum. Traditional cultivation on these lands is characterized by low labour productivity and crop yields. Rice is the most common crop, but vegetable, fruit, and forage crops are also widely grown.

The general aim of lowland water management is to reduce water shortages, not to fully control floods or accurately regulate irrigation. The EBBF model was developed by CIRAD, the Savanna Agricultural Research Institute (SARI), the Malian Institut d'économie rurale (IER), in collaboration with the French Ecole nationale supérieure agronomique (ENSA) in Rennes, for quick analysis of hydrological functioning in a given lowland area. This model simulates basic runoff for lowlands in the Sudano-Sahelian zone, based on daily rainfall, soil, and hydrogeological input data. It was calibrated and validated in two watersheds of the Sudanian zone (southern Mali and northern Ghana). These EBBF simulations, along with agricultural and socioeconomic data, are useful for water management planning adapted to various environmental situations.

INTERNATIONAL COOPERATION

Launching the PSI Research Pôle

A funding agreement between the French Ministère de la coopération and CORAF was signed in July 1995, which marked the official launching of the PSI regional research pôle on irrigated systems in the Sudano-Sahelian zone. It was created on the incentive of several governments of the region, with the aim of coordinating their research efforts towards the development of irrigated agriculture.

The four main research topics drawn up by the partner countries and developed by the corresponding research organizations are: irrigated crop diversification (the Institut sénégalais de recherches agricoles [ISRA], Senegal); intensification of irrigated rice cropping (the Centre national de recherche agronomique et de développement agricole [CNRADA], Mauritania); technical, social, and land-use management related to irrigation (the Institut national de recherches agronomiques du Niger [INRAN], Niger); and soil degradation under irrigation (IER, Mali).

Each member country, in addition to coordinating specific research activities, conducts projects related to the other topics. A regional coordination unit, based close to the CORAF executive secretariat, and supported by a supervisory board, coordinates all of the PSI's activities.

Smallholder Farming in Highlands and Newly Cultivated Areas

In this CIRAD Programme, new technical guidelines and reproducible cropping systems are being developed, with farmer involvement, for tropical humid and highland zones. Projects and activities are under way in five different regions worldwide: South America, tropical humid western and central Africa, the Indian Ocean, and Asia.

NEWLY CULTIVATED AREAS IN MATO GROSSO

CIRAD, in collaboration with two Brazilian research services, i.e. the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) and the Empresa Matogrossense de Pesquisa, Assistência e Extensão Rural (EMPAER), and with a Rhône-Poulenc subsidiary, is conducting studies on newly cultivated areas in the *cerrados* of western Mato Grosso (Brazil). Acidic soils monocropped with soybean have been severely degraded as a result of poorly-adapted cropping technologies.

New diversified cropping systems, based solely on annual crops (soybean, upland rice, millet, sorghum, and maize) or annual crop/grazingland rotations, are being tested on farms in Mato Grosso. These no-till direct sowing systems are more productive, cost-effective, and sustainable than the best diversified systems involving tillage; on an annual basis, 50–100% more surface area can be cultivated, with 40% motor-fuel savings.

This biological crop management technology has restored soil fertility on hundreds of thousands of hectares of land. It also provides farmers with a steady income, despite the overall difficult economic situation.

PLANT COVER FOR SUSTAINABLE SYSTEMS

The rose geranium was grown for a century in the Hauts de la Réunion province — then yields dropped, land erosion increased, and growers had to give up bush fallows. The land-use management commissariat and chamber of agriculture of the province, along with the French Société d'aménagement foncier et d'établissement rural (SAFER) and Association pour la promotion en milieu rural (APR), are trying to determine sustainable means for upgrading this volcanic highland (1 000 m) region, with steep

slopes, and 1 400 mm/annum of rainfall.

An agrotechnology and economic assessment, based on 10-year results from test plots on farms, revealed that cropping systems with widespread plant cover were more stable than those with bare soil. Kikuyu grass (*Pennisetum clandestinum*) and greater bird's-foot-trefoil (*Lotus uliginosus*), provide total plant cover and thus reduce weeds and the necessity of weed control. When bird's-foot-trefoil is present, the rose geranium produces more aromatic oil, and yields of other crops, such as tomato, can be fivefold higher than on bare soil.

These cropping technologies are also useful for controlling erosion and protecting existing infrastructures.

Sustainability and Environmental Resources

Making optimum use of water, biomass, and energy resources and developing recycling and processing techniques are some of the targets of this CIRAD Programme. Two major

INTERNATIONAL MEETING

Farming Practices and Sustainability

The "Farming Practices and Sustainability" workshop, organized by CIRAD and the Centre national de la recherche scientifique et technologique (CNRST), Burkina, with the support of the French Ministère de la coopération, was held in Bobo-Dioulasso (Burkina) in October 1995. Seventy African and French research scientists and agricultural engineers attended.

This workshop was aimed at introducing participants to new terms of reference for the dissemination of technologies and sectoral strategies. The surveys focused on five villages in the Burkina cotton-growing zone; around 10 different types of farms were assessed for each village.

For the survey, participants were divided into multidisciplinary groups, briefed on the region, and they jointly drew up a survey procedure. Subsequently, they analysed situations, defined farmers' strategies, and evaluated the effects of these strategies on sustainability of the systems. Finally, everyone presented their results and discussed their experiences. The new reference framework developed through this workshop will be useful in setting up a network for joint research projects.

achievements in 1995 were the creation of sorghum varieties adapted to the Sudano-Sahelian climate, and the use of Transfiltre, a patented process for the treatment of domestic and agro-industrial effluents, for slurry purification.

IMPROVED SORGHUM VARIETIES FOR THE SUDANO-SAHELIAN CLIMATE

The results of an agroclimatic study in Mali, carried out jointly with IER and supported by the European Union (EU), confirmed that traditional photoperiod-sensitive sorghums are superior to improved photoperiod-insensitive varieties. The conditional photoperiod sensitivity of traditional varieties, which becomes active after the sorghum crop is sown in May, is responsible for high, stable crop yields, with very little fertilizer input.

A map of agroclimatological zones was drawn up for the main sorghum varieties, based on a historical agroclimatic analysis — with water balance and phenological phases of photoperiod-sensitive sorghums as variables. The map outlines the acceptable risk boundaries for drought in the north and mildew in the south. In addition, a "photoperiodism" module was integrated in the SARRA water-

balance model; it will be used to forecast crop harvests and as an aid for agricultural advisers.

CIRAD, in collaboration with IER and the Institut d'études et de recherches agricoles (INERA), Burkina, have begun a study to determine the general reactions of 100 local ecotypes to photoperiod variations. The aim is to create varieties that are more photoperiod-sensitive than currently-available varieties. Hence, in the *caudatum* race, which has many agronomically interesting qualities but is not very photoperiod-sensitive, unusual photoperiod-sensitive ecotypes were identified and used in breeding schemes. Dominance of the photoperiod-sensitive character was detected, especially in *guinea* ecotypes, which are 100% photoperiod-sensitive. Photoperiodism was found to be under polygenic control in a study on more than 200 F₅ progeny of crosses between a photoperiod-insensitive line (IS 2807) and two *guinea* ecotypes (SSM 78 and SSM 1075).

TRANSFILTRE PROCESS FOR SLURRY PURIFICATION

The Transfiltre process, designed to process domestic and agro-industrial effluents with low pollutant levels, was patented in 1986. It was found to be able to purify slurries with nitrogen and

organic matter levels as much as 150-fold higher than domestic effluents. A Transfiltre prototype with a 2.3 m³ holding capacity is being used for a pig-slurry purification study in Brittany. This involves pouring the sieved slurry into the Transfiltre unit, where it is processed by filtration-methanization on a renewable straw substrate (15 kg straw/m³ slurry). The nitrogen can be nitrified, then denitrified and released into the atmosphere, depending on wastewater spreading constraints.

The residue, obtained after processing a slurry with high organic matter and nitrogen loads through the Transfiltre purifier, has markedly lower pollutant levels, i.e. 73% lower organic matter and 45% lower nitrogen — both components can be reduced by 95% when the treatment is followed by a nitrification-denitrification process. In terms of energy production, enough biogas is recovered to power the unit, when only the Transfiltre process is used; very little power is required for nitrifying-denitrifying the organic residue.

The first industrial-scale Transfiltre unit will be installed in 1996, with a processing output of 3 000 m³/annum. Transfiltre processing costs are less than 35 FFr/m³, making it accessible to smallholders with small- to medium-sized livestock farms.

Rice

The diversity of rice-production systems and research issues on this cereal crop can be illustrated by a few examples drawn from the activities of this CIRAD Programme.

Rice was chosen as the model plant for a genetic study on grasses. The small genome of this species facilitates genetic mapping and molecular marking. Moreover, the results of such analyses can be extrapolated for other species with more complex or profuse genomes, e.g. wheat, maize, sorghum, and sugarcane.

DEVALUATION OF THE CFA FRANC AND THE IRRIGATED RICE SUBSECTOR

A study on the irrigated rice subsector in the Sahel, funded by the French Ministère de la coopération, was carried out in Senegal in conjunction with the Société nationale d'aménagement et d'exploitation des terres du delta du fleuve Sénégal et de la Falémé (SAED), in Mali with IER, and in Niger with the Office national des aménagements hydroagricoles (ONAHA). In 1994-95, the results indicated that the devaluation of the CFA franc strengthened existing dynamics.

INTERNATIONAL MEETING

Rice Celebration

"La Science en fête", a science exhibition held in Montpellier (France) in 1995, included an event for the general public and an international scientific conference on rice. The rice research exhibits were presented by Agropolis (Montpellier), CIRAD, the French Institut national de la recherche agronomique (INRA), IRRI, and ORSTOM. The Centre français du riz, and rice growers'/processors' federations were present. On the incentive of the Délégation régionale à la recherche et à la technologie (DRRT), regional and municipal authorities offered their support.

Conference participants discussed the challenges that have to be addressed by tropical agronomic research, the extent of cropland extension and intensification needed to meet demand, and the policies required to deal with the situation.

Cropping systems, landscapes, and rice-preparation techniques, illustrated with free pamphlets, were presented for the general public in the exhibit stands. People were also given access to crop decision-making software aids, and to remote-sensing and radar images of rice fields and image-processing procedures.

In Mali, where liberalization of this subsector has been under way for a long time, the currency devaluation had a positive effect on farmers' incomes. Local rice gained a competitive edge over

imported rice following isolation of the country, and through maintenance of a 46% tax on the import price.

In contrast, imported rice is still in close competition with local rice in Senegal. The currency devaluation occurred just at the time when the sector was being liberalized; and local rice production systems are still not very cost-effective (high costs for inputs and imported irrigation equipment).

The major constraints in Niger include organizational problems and a shortage of commercial rice mills. The reduction of tax on imports almost nullified the effect of the change in the parity ratio, and imported rice is therefore still competitive.

HIGHLAND FARMING SYSTEMS IN TRANSITION IN THAILAND

In highland regions of Thailand, a systemic approach was found to be appropriate for assessing the impact of farming intensification on the sustainability of farms and on soil conservation. In farm holdings with sufficient assets, i.e. irrigated rice fields, livestock herds, or plantations, diversification favours farming intensification, while preserving natural resources. However, on other farms, living conditions are not even improved when farmers' erosion-control practices

are efficient. These rice production farms are threatened by increased weed infestation in upland rice fields, and by fluctuations in the selling price for this main cash crop.

This multidisciplinary project, carried out in collaboration with IRRI, two regional universities, and the Centre national d'études agronomiques des régions chaudes (CNEARC), includes: an agricultural survey in smallholders' fields, highlighting risk-prone cropping situations; an analysis of recent farming transformations, explaining the current wide range of different farming situations; a technological/economic analysis of farming operations, revealing the three main types and trends; a map, drawn up from geographical information system (GIS) data, showing the dynamics of agricultural utilization of watersheds, and the spatial distribution of zones where farming conflicts with natural resource conservation priorities — all of these designed for use as a decision-making aid.



Other Cereals

This Programme is currently conducting research on maize and sorghum, focusing on grain quality

and plant resistance to stress. Root and tuber crops are also being investigated. In 1995, the most striking results included the quality of traditional maize products and insect pest resistance factors.

MAIZE BREEDING AND EATING QUALITY

In the Guinean zone of Africa, improved maize cultivars are better than local cultivars in terms of agronomic performance, but the kernels are harder — porridges and doughs made from these improved cultivars thus do not meet farmers' and consumers' culinary quality requirements.

A study, carried out in collaboration with an agricultural science university in Benin, compared the biochemical, physical, technological, and organoleptic qualities of kernels from five local ecotypes and 16 improved cultivars. The biochemical characters of maize kernels were not correlated with the organoleptic quality (consistency) of porridges. The amylose content was constant in all maize samples tested, whereas very marked amylose variations were noted in other cereals such as rice and sorghum, thus accounting for their cooking qualities.

In contrast, the physical traits of maize kernels varied. Local varieties have very crumbly

kernels, producing fine flours and consistent porridges; improved cultivars have more solid kernels, producing coarser flours and relatively inconsistent porridges. There was a close correlation between kernel crumbliness and organoleptic quality. A kernel crumbliness test was developed by CIRAD's cereal technology laboratory; it should be included in future maize breeding programmes for this zone.

TOXINS FOR PEST CONTROL

CIRAD and the Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT) have carried out many tests to determine the activity of Cry1 toxins from *Bacillus thuringiensis* against lepidopteran pests of maize. Further tests focused on pests of other crops.

The results showed that the efficiency of a toxin against lepidopterans can vary as much as 100-fold between species; and lepidopteran susceptibility differed with different toxins. Although there were some differences in interpretation, the results revealed four toxins of major interest for pest control. Cry1A(b) was very efficient against *Helicoverpa armigera*, *Ostrinia nubilalis* and *Plutella xylostella*, and against the *Cryptophlebia leucotreta*-*Pectinophora*

gossypiella species complex, on cotton crops. Cry1A(c) induced high mortality in the maize pests *H. armigera*, *Sesamia calamistis*, *Chilo suppressalis* and *Perileucoptera coffeella*, and in the cotton pests *H. armigera* and *P. gossypiella*. Cry1B was toxic to *H. armigera*, *S. calamistis* and *C. suppressalis*, but its toxicity against *P. gossypiella* has not yet been confirmed. Cry1C was efficient in controlling *Spodoptera frugiperda* and *Plutella xylostella*, and was the most efficient against *Spodoptera littoralis*. The results of these bioassays should be useful for focusing crop improvement programmes.

Cotton

The world cotton market has tightened as a result of reduced cotton production in the main producing countries (China, India, Pakistan, and Uzbekistan). In 1995, market prices for cotton reached the highest levels ever, since the American Civil War — 130 years ago. The uncertainty of cotton policies and cultural problems in these cotton-producing countries have created a favourable situation for countries that are structurally set up to export cotton.

ASSESSMENT OF PEST RESISTANCE TO PESTICIDES

Pyrethrinoids are the only efficient pesticides against lepidopterans, the main cotton pests; however, insect resistance to these compounds has now been reported on all four continents.

There is a high risk that pyrethrinoid-resistant strains will quite soon appear as a result of selection, especially since these pesticides are also used on vegetable crops that harbour some cotton pests, e.g. *Helicoverpa armigera* and *Cryptophlebia leucotreta*.

Since 1985, CIRAD, along with agricultural research institutions, cotton-producing companies, training services, producers' groups, and crop-protection industries, have been investigating the pesticide susceptibility of the main cotton insect pests, and developing pesticide-treatment strategies. Research staff have been collaborating with the French Centre national de la recherche scientifique (CNRS), INRA, and the Universities of Toulouse (France) and Reading (UK); and the Cotton Programme is involved in setting up laboratories in France, western Africa, Nicaragua, and Thailand.

Generally, in French-speaking Africa, insect pests are still quite susceptible to pyrethrinoids, as the LD₅₀ (the amount of this pesticide that will elicit a lethal

NETWORKS

Cotton Research

CIRAD helped in founding a Mediterranean cotton network in 1988, and the CORAF Cotton Network in 1989 — it is still very involved in the activities of these networks. With the same dedication, it launched the South American Cone Cotton Network in 1992, which includes Argentina, Brazil, Bolivia, and Paraguay; and the Southeast Asian Cotton Network in 1994, involving Burma, Cambodia, Laos, Vietnam, and Thailand.

Workshops on different topics, training programmes, scientific and technology exchanges are currently being formalized and increased. Joint experiments are under way, especially in the fields of cotton breeding and plant physiology. In addition, research projects involving various participants are being developed, with possible organization of internetwork activities.

In 1995, cotton network meetings focused on plant improvement (Mediterranean and South American Cone) and technology (Mediterranean); the Southeast Asian Cotton Network defined its operational cotton-cropping priorities.

response in 50% of the entire insect population) has been stable for 10 years. Nevertheless, there has been a slight decrease in *Helicoverpa armigera* mortality obtained at regular doses in Chad and Côte d'Ivoire.

BREEDING TO IMPROVE COTTON YIELDS

Wide genetic variability can be obtained through multiple crossing. The considerable amount of work required to monitor the progeny of all of these crosses can be reduced through early detection of the best crosses. However, early evaluation is difficult with respect to yield characters, since there can be marked interactions between alleles, genes, and with the environment. Hence, this complexity has to be taken into consideration when assessing the yield potential of cotton hybrids.

In studies carried out in Côte d'Ivoire in collaboration with IDESSA, the best mean yield estimates for crosses were obtained with the formula $2F_{31} - F_2$, where F_{31} represents the mean value for a sample of lines derived from the F_3 generation, and F_2 is the mean value of the F_2 generation. However, the mean yield variance estimates were not realistic.

In the same studies, between-plant competition was found to have an influence on individual or familial genotype evaluations. Early evaluations should therefore be conducted at normal plant densities, with conditions as close as possible to those found in the field.

Protein-Oil Crops

The Grand Prize of the President of the Republic of Senegal for Scientific Achievement was awarded to a joint ISRA/CIRAD team conducting studies at the Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse (CERAAS), in Bambey, for its agricultural development modelling research. The studies are focused on monitoring groundnut crops and forecasting crop yields.

The Arabhy ("arachide bilan hydrique" or groundnut water balance) model facilitates setting up systems to harvest, finance, store, and process groundnut crops. The research results are also important for commercial-scale groundnut production, especially in semiarid zones, providing a warning system and reliable forecasts.

Since 1989, input data on the development of groundnut cropping in dry zones have been included in this plant — and crop — function simulation model. Arabhy integrates daily data on the physiological responses of various groundnut cultivars to drought. The effects of water stress, cropping techniques and fertilizers

on plant root and aerial systems, and on meeting crop water needs, are simulated for different cultivars.

The latest versions of Arabhy are being used in several important development projects. In Senegal, it supplies reliable production forecasts a month before crops are harvested. Linking the model with climatic and agricultural databases would make it useful throughout the territory. It will help the Senegalese Comité national interprofessionnel de l'arachide (CNIA) optimize management of a relief fund for farmers, through accurate identification of zones affected by drought. In addition, Arabhy was used to simulate groundnut development in Argentinian conditions, to monitor the plant's water status. Research is currently under way on applying the model to simulate cereal crop development and production.

Sugarcane

In 1995, there were significant advances in the fields of sugarcane molecular biology, pathology, agronomy, and economics, in addition to important floral biology, water management, and remote sensing results.

CONTROLLED HYBRIDIZATION OF SUGARCANE

In Guadeloupe and Réunion, breeders have developed a sugarcane database to help them in choosing parents to be crossed — in terms of flowering synchronization, available inflorescences, and pollen fertility. Crosses can also be controlled by choosing inflorescences, and testing the fertilization potential of pollen and stigma receptivity.

The database also includes several years of data on bolting, heading, as well as flowering dates and intensity for all varieties in CIRAD collections in Guadeloupe and Réunion (1 300 and 400 varieties, respectively). Since these traits are relatively stable, the database helps in planning crosses long before flowering.

Control is also efficient in synchronizing the release of fertilizing pollen and stigma receptivity in 90% of sugarcane crosses. Alexander staining was found to be the most accurate and easy-to-use cytological technique, of four standard techniques tested, for assessing pollen fertilization potential. The aniline blue test, according to Martin's technique, is recommended for assessing pollen tube germination in situ.

A histocytological study of microsporogenesis in *Saccharum spontaneum*, which is completely male-fertile, highlighted factors

PRODUCTS FOR DEVELOPMENT

The Irricanne Software Package

Irricanne is a decision-making software aid on sugarcane irrigation. It was developed in Réunion through studies aimed at optimizing water supplies, and a farming development and assistance project, conducted in collaboration with the French Service d'utilité agricole pour le développement (SUAD) and the Société d'aménagement des périmètres hydroagriques de la Réunion (SAPHIR). At the present time, 300 ha of an overall irrigated surface area of 4 000 ha are being monitored by Irricanne. It is predicted that, with the extension of irrigation, an additional 4 000–5 000 ha will be monitored by 2005.

Irricanne calculates the water balance for each sprinkler, and provides advice on water input, according to soil conditions, equipment, and discharge constraints; it also integrates irrigation strategies as a function of forecasted rainfall, the growth stage of the crop, and farmers' objectives. Annual results for each operator are summarized and discussed, thus enforcing group dynamics and enabling adaptation of the programme to farmers' and technicians' needs.

A study of 20 sugarcane estates in Réunion indicated that mean water savings of 1 700 m³/ha, and up to 8 000 m³/ha in some estates, could be obtained when Irricanne is used. In addition, a mean sugarcane yield increase of 28 t/ha was obtained simply through rational water management, without any additional inputs.

that should help in detecting sterility during the breeding process.

REMOTE-SENSING MAPS OF SUGARCANE CROPLAND

A project was launched in Guadeloupe, in 1995, to pinpoint and follow-up sugarcane cropland using remote-sensing technology. This includes digital mapping of the overall area under sugarcane, and determining the area ready for harvest, with an annual data update.

Aerial photographs (1/15 000), SPOT satellite images, and data from ground surveys carried out with the Chambre d'agriculture, SAFER, and the sugarcane-based Société d'intérêts collectifs agricoles (SICA), are compiled to obtain a mapping accuracy within 1.5 m, and are included in the data updates. For the fourth quarter 1995, the maps (one at 1/75 000, five at 1/25 000) highlight the area under sugarcane in each sugarcane area in continental Guadeloupe and Marie-Galante. The hydrogeographical system and communication routes are also shown.

In late 1995, a statistical analysis provided an estimate of the area upon which sugarcane could be harvested in 1996, with 98% accuracy, i.e. an overall area of 12 250 ha, with 45% of the crop

fields smaller than 0.5 ha.

Sugarcane cropland is increasing in Basse-Terre, while decreasing in southern Grande-Terre and Marie-Galante.

This database can be included in an information system, established on the basis of cadastral surveys, with reference to remote-sensing data.



THESES COMPLETED IN 1995

CIRAD Scientists

Transformation génétique de protoplastes haploïdes de variétés méditerranéennes de riz (*Oryza sativa* L.) [Genetic transformation of haploid protoplasts of Mediterranean rice varieties (*Oryza sativa* L.)] by Hâna Chaïr; Université des sciences et techniques du Languedoc, Montpellier II.

Le rôle des institutions dans l'évolution de la filière canne à sucre à la Réunion [The role of institutions in developing the sugarcane commodity chain in Réunion] by Jean-Marc Chastel; Ecole nationale supérieure agronomique de Montpellier.

Bioécologie et épidémiologie du puceron *Aphis gossypii* Glover, 1877 (Hemiptera, Aphididae) sur cotonnier en Afrique Centrale : vers une évolution de la protection phytosanitaire [Bioecology and epidemiology of the cotton aphid *Aphis gossypii* Glover, 1877 (Hemiptera, Aphididae) on cotton plants in Central Africa: towards a crop protection strategy] by Jean-Philippe Deguine; Ecole nationale supérieure agronomique de Montpellier.

Marquage moléculaire chez la canne à sucre (*Saccharum* spp.) : décomposition d'une structure génétique complexe et application à l'amélioration variétale [Use of molecular markers for analysis of sugarcane (*Saccharum*

spp.): unravelling of a complex genome organization and applications for breeding] by Laurent Grivet; Université Paris XI, Centre d'Orsay.

Caractérisation, pathogénie et épidémiologie des *Pseudomonas fuscovaginae*, agent de la pourriture brune des gaines du riz (*Oryza sativa*) [Characterization, pathogenicity, and epidemiology of *Pseudomonas fuscovaginae*, the causal agent of sheath brown rot of rice] by Thierry Jaunet; Université Paris XI, Centre d'Orsay.

Effet de la densité de semis en sélection sur l'amélioration génétique du cotonnier : interactions, structures de corrélations, hétérosis et valeur en lignées [Plant spacing and cotton breeding: interactions, correlation structures, heterosis, and line value of a single cross hybrid] by Jacques Lançon; Université Paris XI, Centre d'Orsay.

CIRAD Trainees

Etude du comportement alimentaire de *Peregrinus maidis* (Ashmead, 1980) par électropénétrographie, en relation avec la résistance à la mosaïque du maïs [Electropenetrographic study on the feeding behaviour of *Peregrinus maidis* (Ashmead, 1980) relative to resistance to maize mosaic virus] by Cécile Buduca (France); Université Montpellier II.

Pouvoir colonisateur de *Xanthomonas albilineans* et résistance de la canne à sucre à l'échaudure des feuilles [Colonizing potential of *Xanthomonas albilineans* and resistance to leaf scald of sugarcane] by Ibrahim Saeed Mohamed (Sudan); Université Paris XI, Centre d'Orsay.

Influence de facteurs biotiques ou abiotiques sur la dynamique des populations de *Pseudomonas solanacearum* au cours de l'infection et sur le développement de la maladie [Influence of biotic and abiotic factors on the dynamics of *Pseudomonas solanacearum* populations during infection and on the development of tomato bacterial wilt] by Jean-Francis Nicole (France); Université de Nantes.

La caractérisation de la fraction volatile d'un riz aromatique : étude du déterminisme génétique du caractère aromatique [Cha-

racterization of the volatile fraction in aromatic rice: genetic determination of the aromatic character] by Marina Petrov (France); Université Paris XI.

Déterminisme génétique de la résistance du maïs (*Zea mays* L.) au maïs streak virus (MSV) [Genetic determination of maize (*Zea mays* L.) to maize streak virus (MSV)] by Anne Rodier (France); Ecole nationale supérieure agronomique de Rennes.

Influence de l'état hydrique et du comportement mécanique du sol sur l'implantation et la fructification de l'arachide [Influence of soil water patterns and soil mechanics on groundnut establishment and fruiting] by Modou Sene (Senegal); Ecole nationale supérieure agronomique de Montpellier.

Evolution de la fertilité des sols sur un front pionnier en zone nord-soudanienne (Burkina Faso) [Soil fertility patterns in newly-cleared areas of the northern Sudanian zone (Burkina Faso)] by Sibiri Jean-Baptiste Taonda (Burkina); Ecole nationale supérieure d'agronomie et des industries alimentaires de Nancy.





Tree Crops Department

The rise in commodity prices in 1994 and their stabilization at a good level in 1995 have boosted tree crop production in Africa, America, and Asia, both on estates, as found in Indonesia, or on smallholdings, for example in Côte d'Ivoire and Ghana.

Two major trends underlie this revival: the reassertion of the essential role of agricultural export subsectors in supporting overall growth and rural development in humid tropical regions, and the liberalization of the economy and government withdrawal from production and marketing operations.

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Competitiveness has become the keyword of this change and each of its component parts constitutes a number of challenges and orientations for research.

Increased output has to be backed up by technological innovation to ensure collective resource management. Crop protection, intensification, agroforestry, and farming systems are major research themes.

Improved market integration has led to a more reliable analysis of the role, interest, and behaviour of the different protagonists in the subsectors, who must organize themselves and become more professional.

Product quality has become a priority. It can be achieved by applying already proven technology, which must, however, be revalued through fairer distribution of income. It also concerns processing, diversification, and the creation of new products, whether they have a utility value, e.g. biofuels, biodegradable molecules for oil products, or a market value, e.g. homogeneity in rubber, regional specialties, and quality labels for coffee and cocoa. ■

Coffee

After the bumper year of 1994, 1995 was marked by the collapse in coffee prices (-37.5%) and by the rise of Vietnam, which became the world's eighth largest producer with 212 000 t. Vietnamese production has increased by 71% in 4 years.

Research work carried out by CIRAD has focused particularly on integrated pest management. It involved the creation of the cultivar Nemaya in partnership with Promecafé (Programa Cooperativo Regional para la Protección y Modernización de la Caficultura), and protection

of the environment and its consequences on coffee quality in association with ISABU (Institut des sciences agronomiques du Burundi) and Anacafé (Asociación Nacional del Café, Guatemala).

CREATION OF A NEMATODE-RESISTANT ROOT-STOCK CULTIVAR

Meloidogyne and *Pratylenchus* nematodes pose one of the main pest problems to coffee plants in Central America where they can lead to 15–20% production losses.

Chemical control of nematodes is costly, polluting, and often of little effect. Breeding of a root-stock cultivar was undertaken as part of a Promecafé project, with support from CIRAD, the European Union,

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Information and communication

Christine Nouaille

and the French Ministère de la coopération, for the genetic improvement of the coffee plant in Central America. The cultivar Nemaya, the result of a cross between two *Coffea canephora* plants from the CATIE (Centro Agronómico Tropical de Investigación y Enseñanza) collection, shows a high level of resistance to or tolerance of the principal nematodes of the region. Nemaya was made available by Promecafé and CIRAD for use as root-stock. Propagation and distribution methods have been defined and the rapid propagation of mother stock by somatic embryogenesis has begun. The plantlets obtained will be distributed in the countries interested and used to establish seed gardens.

Thanks to the close collaboration established between the different organizations, the creation of this variety required only 6–7 years of research, a particularly short period of time for a perennial plant.

COFFEE-LEGUME INTERCROPPING AND NITROGEN TRANSFER

Since its beginnings in the 1930s, coffee cultivation in Burundi has involved the use of grasses and harvest residues from food crops as the principal source of organic matter and nitrogen. As a substitute for this practice, CIRAD proposed intercropping nitrogen-fixing

INTERNATIONAL MEETING

Sixteenth International Scientific Colloquium on Coffee

This Colloquium on Coffee was held from 9 to 14 April 1995 in Kyoto. The event, organized by ASIC (Association scientifique internationale du café, Switzerland), brought together 400 participants from 29 different coffee-producing or importing countries.

The main papers and posters presented concerned the physiological effects, chemistry, and technology of the coffee beverage, and the agronomy of the coffee tree.

CIRAD, represented by eight researchers, presented the results of studies carried out in various fields: genetic improvement of the coffee plant, resistance of the plant to pests and methods of control, the influence of green coffee preparation procedures on the organoleptic quality of the coffee beverage, and the impact of research on the production sector.

leguminous species to reduce biomass transfer and to compensate for reduction in the area of land reserved for mulch-producing plants.

Multilocal selection of leguminous species suitable for intercropping was carried out on site. The criteria of noncompetitiveness for soil-water and protection against erosion were applied along with the capacity of the leguminous

species to form nodules with local species of *Rhizobium*.

Under local conditions, *Leucaena* is suitable since the *Rhizobium* strains specific to this legume for nitrogen fixation exist naturally in the soils. However, inputs of dolomite lime and phosphate are necessary so that the *Rhizobium* strains form nodes with the leguminous species and fix nitrogen. Coffee intercropped with leguminous species benefits from the atmospheric nitrogen fixed by the latter in amounts sufficient for its growth.

This technology is now being made available to a few coffee growers as an effective and sustainable cultivation method.

ALTITUDE, SHADING, AND QUALITY

A study carried out in Guatemala in collaboration with Anacafé has demonstrated the influence of shade and altitude (1 100 and 1 400 m) on the physical, chemical, and organoleptic characteristics of Bourbon and Catuai (*arabica*) coffees.

Altitude has no influence on the grain size of Bourbon coffee, but increases that of Catuai. The chemical composition of the two cultivars is also influenced by altitude, which increases acidity by 25%, caffeine content by 10%, and that of trigonelline slightly, and

which decreases the fat content by 12.5%.

The effect of shading has been studied only on Catuai. It leads to an improved granulometry and an increase in acidity and saccharose content, important parameters for aroma formation.

The organoleptic qualities of Bourbon were little influenced by altitude. The opposite was observed on Catuai. Shading makes the coffees less bitter and thereby improves their quality.

By delaying fruit maturity, shading and altitude can lead to improvement in quality, particularly for Catuai.



Cocoa

During the last 2 years, cocoa prices have held up a little better and are close to £1 000/t on the London market. However, the after-effects of the crisis in the cocoa market these last 10 years remain much in evidence and it is necessary to recreate a stable system that benefits everyone. This reconstruction will without doubt involve in the first place the restoration of confidence and exchange of information between partners. CIRAD made its contribution by organizing,

PRODUCTS FOR DEVELOPMENT

Launch of Fumivap

Mirids, in western Africa, are the most dangerous pests of cocoa. Their bites on young fruits lead to considerable damage, and their attacks on young shoots weaken the tree and can even cause its death.

At present, the standard equipment used for chemical control gives good results, but is difficult to use. CIRAD has launched the idea of creating smoke generators which function by burning a combustible powder containing an insecticide. The company Ruggieri has developed, in association with CIRAD, a low-temperature combustion unit that emits a thick, heavy smoke which envelops the cocoa tree. The project was supported by Rhône-Poulenc and trials were carried out in Togo and then Côte d'Ivoire, with the help of IDEFOR, on two types of Fumivap, one with lindane, the other with propoxur.

The results were at least as satisfactory as those obtained by low-volume spraying and often more uniform, provided the Fumivap was used in the total absence of wind. The technology presents many advantages: as opposed to sprayers, the Fumivap never breaks down, no toxic product is handled, and transport of water is not required. No residues are detected in the pods.

The Fumivap is a little more expensive than the standard treatment, but nothing is more costly than no treatment.

with AFCC (Association du commerce des cacaos, France) assistance, a seminar in June 1995 in Montpellier, to consider different aspects of cocoa quality.

PLANT BREEDING FOR BLACK POD DISEASE CONTROL

Black pod disease, caused by *Phytophthora* spp., is the most important disease of cocoa. Although chemical control is possible, it remains costly, problematic, and polluting. Genetic control of this disease is therefore envisaged. CIRAD, with Caobisco (Association des industries de la chocolaterie, biscuiterie et confiserie) funding,

has set up a project with the objective of identifying the genes giving resistance to the disease and preserving them during subsequent breeding stages.

This project, carried out in collaboration with IDEFOR (Institut des forêts) in Côte d'Ivoire, IRA (Institut de la recherche agronomique) in Cameroon, and CRU (Cocoa Research Unit) in Trinidad, uses molecular markers to analyse the genetic basis of resistance to this disease and to identify early selection markers. This programme is built around the genetic map of cocoa comprising 193 markers, established by CIRAD, the analysis

of population diversity of the pathogen responsible for this disease (showing the variability within species of the genus *Phytophthora*), the identification of sources of resistance (clones P 7, Sca 6 and Pa 150), and the development of an early test on leaves, which is currently being completed (analysis of correlations between tests on pods and observations in the field).

COCOA SUBSECTORS IN CÔTE D'IVOIRE AND GHANA

As part of a comparative study of the competitiveness of cocoa subsectors in Côte d'Ivoire and Ghana, CIRAD carried out in 1994 and 1995 two parallel studies on cocoa growers and cocoa agricultural systems in these two countries. Eight hundred and fifty farmers were interviewed. In Ghana, the surveys were carried out in collaboration with the University of Legon and in Côte d'Ivoire with the support of ORSTOM (Institut français de recherche scientifique pour le développement en coopération, France) and the French Ministère de la coopération.

Although numerous studies have already been made on the subject, this is the first time that parallel surveys have enabled comparison, at the same time and on large samples, of the behaviour of cocoa farmers in these two major

producing countries. They confirm that the level of technology is low and that pesticides and improved seeds are little used, but invalidate certain preconceptions: extensive cocoa cultivation is increasing; the factors responsible for the differences in yield observed between the two countries are not the average ages of the trees, but differences in the technologies used; the adoption of innovations depends little on the farmer's educational level but much more on his origin (migrant or native) and on the size of the farm. The migrants adopt innovations more easily and these are more often applied on small rather than large farms.



Oil Palm

The market in palm oil, with prices remaining close to US\$600/t, explains the enthusiasm for this crop, whether by commercial planters in Indonesia or by African smallholder farmers. In order that the best plant material is available, CIRAD is promoting it, along with African, Indonesian, and Brazilian partners, through long-term improvement programmes focused on tolerance of the principal diseases. Improved understanding of the physiology

of the oil palm will enable this tree to be better exploited, and research on diversification of the uses of palm and palm kernel oils will help maintain their prices.

EFFICIENCY IN BREEDING AND MAINTAINING GENETIC PROGRESS

Genetic improvement of a cultivar leads to the elimination of less favourable genotypes. Practised without discernment, such elimination would end up with a rapid loss of variability and would compromise the prospects for progress. This is particularly true for the oil palm, the breeding material of which derives from a handful of ancestral trees. As part of a recurrent reciprocal selection programme, it has been shown how recombination could best be used to obtain, within the improved material, an optimum expression of the variability whilst still preserving the possibilities for progress in succeeding generations. This necessitates taking account of the breeding history of the populations involved.

Furthermore, evaluation of new sources of plant material collected by the breeders has shown that, in spite of occasionally lower productivity than that of the improved material, they contain favourable characters. An appraisal of these introductions has been made in collaboration with IDEFOR in Côte d'Ivoire

which has resulted in a strategy for incorporating them in the improvement plan without adversely affecting the progress already made.

MODELLING OF ROOT SYSTEM ARCHITECTURE AND DEVELOPMENT

Analysis of the architecture of oil palm root systems and their development has revealed the existence, after brief initial growth, of eight distinct root types which can be characterized by their mode of development and the state of cell differentiation. The relative arrangement of these root types characterizes the actual functional and morphological form of the underground structure called the "root architectural unit" of the oil palm.

The processes of growing, branching, and dying of the root axes, as well as the geometric parameters, have been formulated, then reassembled in a synthetic model: the reference axis.

Three-dimensional models, created using the AMAP modelling and simulation programs, allow estimation and location of the root biomass, the absorption areas, and the volume of earth explored by the roots.

Studies of the carbon flow in the root system and the entire plant, and of the complex

phenomena of root competition, can now be undertaken.

SOIL RECEPTIVITY TO VASCULAR WILT DISEASE

The selection of planting material tolerant of vascular wilt disease, caused by *Fusarium oxysporum* f. sp. *elaeidis*, constitutes the best response to this disease, which is endemic in western and central Africa. However, numerous observations made in Côte d'Ivoire have shown that the environment plays a vital role in the oil palm's expression of tolerance potential. Links between soil receptivity in palm groves to vascular wilt and the flora antagonistic to the fungus, notably the *Fusarium* flora itself, have been studied.

The effects of mulching with palm bunches, the cultivation of *Pueraria* as a cover crop, and the topography have been studied on an IDEFOR station in Côte d'Ivoire. *Pueraria* leads to a reduction in soil receptivity correlated with an increase in the density of natural, nonpathogenic populations of *Fusarium oxysporum* and a reduction of the pathogen population. For similar *Fusarium* populations, the incidence of the disease is greater in the low-lying plots than in those of the plateaux. The seriousness of vascular wilt disease is therefore

not only a function of soil receptivity but depends also on the receptivity of the crop and on the interaction between edaphic factors and the susceptibility of the plant to the disease.

LIPOCHEMICAL PRODUCTS DERIVED FROM PALM AND PALM KERNEL OILS

Besides the large traditional production of lipochemicals, very many compounds are produced from palm and palm kernel oils in small amounts. Their applications are multiple.

It would be interesting to have available, in diversified series, branched-chain compounds derived from vegetable oils. For this reason, CIRAD has worked on long-chain ketones. A synthetic process has been developed in collaboration with the Ecole nationale supérieure de chimie de Montpellier. "Tailor-made" syntheses can be made giving access to several ranges of compounds possessing the ketone function in a given position. These ketones can already be used directly (in printing inks, cosmetics) and must be considered, additionally, as intermediates of synthesis likely to enable the production of numerous derivatives, for example biodegradable detergents.

With the aid of the French Ministère de la recherche and

the French Embassy in Malaysia, a pilot semicontinuous reactor has been constructed in order to provide samples to interested industrialists, notably in Malaysia as part of a collaboration with PORIM (Palm Oil Research Institute of Malaysia).

Increased use of ketones should open numerous outlets for vegetable oils, in particular palm and palm kernel oils, the production of which is greatly expanding.



Coconut

In 1995, the prices of copra and coconut oil remained very high, thus sustaining the interest of the actors in the subsector. This situation is all the more encouraging since it corresponds to a year of average production and not one of shortage. The multidisciplinary research efforts concerned with product diversification and quality improvement help maintain and develop this interest.

MOLECULAR MARKERS AND COCONUT DIVERSITY

Hundreds of coconut cultivars exist in the world. It is important, for germplasm conservation and

NETWORKS

CIRAD Support to the Cogent Network

CIRAD provides considerable support to the international network of coconut genetic resources, Cogent, for the training of member-country managers responsible for the cataloguing, characterization, and evaluation of genetic resources. With this aim, CIRAD experts participate actively in workshops, such as the seminars on the standardization of coconut breeding techniques, Stantech, held at IDEFOR in Abidjan, Côte d'Ivoire in 1994, then at the Balitka Center in Manado, Indonesia, at the end of 1995. CIRAD support also includes the design and use of special computer software and visits to the member countries to train national genetic resource managers in the use of the Coconut Genetic Resources Database (CGRD). Finally, CIRAD provides information and research results on subjects relating to genetic resources: biotechnology and phytosanitary control of plant material exchanges.

for breeding programmes, to clarify the structure of this diversity. In spite of striking differences in morphology or agronomic behaviour, this task is complicated by the influence of environmental conditions and the fact that the coconut has frequently accompanied man on his sea voyages. The use of molecular markers can help untangle the web.

Nine Tall and seven Dwarf cultivars, and two hybrids were studied using the restriction fragment length polymorphism (RFLP) method. In parallel to the construction of a bank of specific probes, rice heterologous probes were used, 9 of which, from 51 tested, provided 40 polymorphic markers. Examination of the data relative to the 114 individuals analysed led to two large groups being distinguished: the genotypes of the Pacific and Southeast Asia, and those of West Africa, India, and Sri Lanka. The coconut palms of the Comores have intermediate status. These findings have yet to be fully analysed, but appear to be correlated with ancient trading routes and colonization.

CHLORINE AND COCONUT PALM RESISTANCE TO DROUGHT

A coconut palm deficient in chlorine ion, a major element in its mineral nutrition, produces less and resists drought less well than a nondeficient coconut palm. New studies carried out in South Sumatra, after the dry season of 1994, showed a very clear relationship between the percentage mortality of the coconut palms and foliar chlorine levels. The study of foliar gas exchange, carried out on the same site during the dry season, revealed that the stomatic conductance, net assimilation, and

transpiration of the chlorine-deficient coconut palms were lower than those of nondeficient trees. Moreover, during the course of the day, although assimilation and transpiration remained stable for nondeficient coconut palms, they decreased in deficient plants, as did the stomatic conductance. Further measurements made in the rainy season will enable the depressive effect of chlorine deficiency on intrinsic photosynthetic activity to be evaluated.

An experiment has been set up to determine optimum chlorine fertilization. Given that part of the potassium chloride input can be replaced by cheaper sodium chloride, the best balance between these two fertilizers needs to be found, taking account of potassium-sodium antagonism, as well as the effect of inputs of sodium chloride on soil fertility.

CONTROL OF *PHYTOPHTHORA*

Phytophthora spp. cause rotting of the nut or the bud heart of the coconut palm and are responsible for annual production losses of 25–40% of nuts and the death of 40% of the trees in a few years.

Research undertaken by CIRAD, in collaboration with several partners from Europe (UK, Spain, France) and tropical countries (Philippines, Côte d'Ivoire,

Indonesia) has dealt with the taxonomy of *Phytophthora*, and the epidemiology and control of related diseases.

The species responsible are principally *P. katsurae* (Côte d'Ivoire) and *P. palmivora* (Philippines, Indonesia). The losses observed depend on the plant material and the species involved.

The injection of phosphorous acid into the stem gave effective results in Indonesia and is now recommended for the protection of coconut groves in this country.

Tolerant cultivars have been noted in existing collections and artificial inoculation of nuts in the laboratory using a zoospore suspension allows the sources of resistance to these fungi to be identified.

A performance trial with 25 hybrids obtained from crosses between 5 Dwarf x 5 Tall was set up in North Sulawesi (Indonesia) in 1993, to collect information on their resistance to *P. palmivora*.

COCONUT OIL QUALITY IMPROVEMENT

The biophysical properties of medium-chain triglycerides (MCT) are reflected at all levels of human metabolism and provide solutions to many nutritional pathologies.

These MCTs are not natural and are obtained by semisynthesis from lauric oils, such as coconut oil.

Research has been carried out with a view to replacing this synthetic route requiring several steps — hydrolyses, distillations, re-esterifications — by another method.

The typo-selectivity of the lipase of the fungus *Candida antarctica* SP 435 L for short-chain fatty acids could be used in quality improvement operations for lauric oils. The application of this method leads to an increase in MCT levels in coconut oil. However, the conversion observed is slight.

CIRAD is collaborating with the University of the Philippines at Los Baños (UPLB), with the assistance of the French Embassy, to improve the results already obtained. The multiple steps necessary to synthesize the MCTs could be replaced by a single distillation intended to eliminate methyl esters from the reaction medium.

Rubber

Natural rubber is an agro-industrial product of extreme importance in technical terms — no synthetic elastomer has really been able to replace it — and in economic and socioeconomic terms. Research efforts actively

continue and are promising. The subjects treated include: research of genetic markers for production, somatic embryogenesis, the control of *Microcyclus ulei*, responsible for a serious leaf disease, and the improvement of "jungle rubber" plantations.

MOLECULAR MECHANISMS CONTROLLING LATEX PRODUCTION

The production of latex by the lactiferous systems of *Hevea brasiliensis* is controlled by two major limiting factors: flow after tapping and the in-situ regeneration, before the following tapping, of the cellular material harvested.

Knowledge of the molecular mechanisms involved in these two processes is essential for optimizing exploitation of the tree and for providing new parameters for the breeder's use. With this aim, research using molecular biological tools has been undertaken, in collaboration with ORSTOM, the University of Mahidol in Bangkok, and the Rubber Research Institute of Thailand and with the support of the French Embassy in Thailand. It involves notably the study of heveine, an agglutinine-type protein that induces coagulation of the latex and plays an essential role in the cessation of flow.

INTERNATIONAL COOPERATION

Rubber Cultivation on the Vietnamese High Plateaux

As part of redeployment in its rubber cultivation, Vietnam plans to diversify the economy of very large areas of the high plateaux region. This zone is relatively marginal for the crop because of severe climatic conditions — drying winds and low temperatures — and its altitude.

Thanks to funding from the French Ministère des affaires étrangères, CIRAD has for several years carried out trials to define the technical norms which would enable the development of profitable rubber cultivation in this region. The purpose of the trials, carried out in collaboration with IRCV (Institut de recherches sur le caoutchouc au Vietnam), is to select local or imported clones best-suited to local conditions, specify technologies for establishing, maintaining and fertilizing the plantations, find the best tapping systems to use under these conditions, and test the intercropping of rubber with other annual or perennial crops.

In addition, CIRAD, within a Franco-Vietnamese team involving agronomists, a geographer, and a socioeconomist, participated in 1995 in an environmental study on the high plateaux, funded by the World Bank and intended to draw up a smallholders' development project in this region.

Cloning of the gene of this molecule and analysis of the promoter, which allows its specific expression in the lactiferous tissue only, are progressing well. The same applies to determination of the modifications to protein syntheses caused by the dry cut syndrome. The results obtained should allow light to be shed on the causes of this syndrome, the economic consequences of which can be serious, in order to more effectively control it.

Finally, antisenesescence genes, such as the superoxide dismutases, which allow the harmonious functioning of the lactiferous tissues, are being studied.

SOMATIC EMBRYOGENESIS

The search for an in-vitro culture method for the mass-production of plants identical to selected genotypes has enabled embryonic strains maintained in *Hevea* clones to be obtained. Around 150 plants of PR 107 and PB 260 clones, acclimatized in greenhouses in Montpellier, were transferred to the field in Bimbresso, on the IDEFOR-DPL station in Côte d'Ivoire, in June 1992 and compared with standard grafted plants. The level of uptake was 99%, growth was vigorous from the start, and the development of both roots and aerial parts "normal" — in many ways

resembling those of seedlings. After 3 years in the field, the growth of the plants obtained from somatic embryogenesis was identical to those of grafted plants for the clone PR 107, whilst for the clone PB 260 it was markedly better (+20%). These field trials will be repeated with different plant material and in different sites in order to analyse the qualities of this new material and to verify the initial hypotheses made regarding expected added value.

GENETIC IMPROVEMENT CONTROL OF *MICROCYCLUS ULEI*

Microcyclus ulei is a fungal parasite of rubber tree leaves known only in Latin America. It has serious economic effects because successive defoliations lead to a weakening of the trees and sometimes even their death.

A new strategy for genetic improvement of rubber to obtain high-yielding material resistant to the fungus has been defined, following research on host-parasite relations carried out by CIRAD in French Guyana.

An agreement made in 1993 with Michelin in Brazil has enabled CIRAD to launch this improvement programme. Basic studies on *Microcyclus* and on its relations with a whole range of *Hevea* clones are being carried out in the laboratory and in the field in Guyana, whilst new clones are

being created in a Michelin plantation in Mato Grosso State, where the first tests of agronomic quality will be made. A second Michelin plantation, situated in Bahia State and possessing a very well-equipped phytopathology laboratory, will serve as a base for testing the resistance to the fungus of plant material created in Mato Grosso.

To accelerate the process, early selection tests will be applied to identify high-yielding clones resistant to *Microcyclus*. Selection assisted by molecular markers is planned.

RUBBER IN THE AGROFORESTRY SYSTEM

In Indonesia, smallholder planters cultivate 84% of the area dedicated to rubber and are responsible for 75% of the total natural rubber production of the country. However, 70% of the rubber producers operate their plantations without using recent technology and often allow their trees to grow within forest regrowth, deriving their income from this "jungle rubber" system, which requires little investment.

As part of the Smallholder Rubber Agroforestry Project (SRAP), CIRAD, in collaboration with ICRAF (International Centre for Research in Agroforestry) and Gapkindo (Association of Indonesian natural rubber

exporters), has sought to identify both the means to increase latex production within this system, and the associated crops that would generate the highest income for the smallholders. A network of on-farm trials has been set up in the western province of Kalimantan and in Sumatra to test different *Hevea* densities associated with annual crops (rain-fed rice) and perennial crops (fruit trees, conifers, rattan), also planted at different densities. Improving the system will enable, without recourse to the major investments of commercial plantations, increases not only in yields but also in the quality of the rubber harvested, since the best clones can be used in future plantations. It will also ensure the conservation of the environment and will make diversified resources available to the farmers.



THESES COMPLETED IN 1995

CIRAD Scientists

Données sur la diversité physiologique des populations de *Phytophthora megakarya* et de *P. palmivora* responsables de la pourriture brune des cabosses du cacaoyer (*Theobroma cacao* L.) [Data on the physiological diversity of populations of *Phytophthora megakarya* and *P. palmivora* responsible for black pod disease of cocoa (*Theobroma cacao* L.)] by Georges Blaha; Institut national polytechnique de Toulouse.

Paysannerie et hévéaculture dans les plaines orientales de Sumatra : quel avenir pour un système agroforestier ? [Smallholder and plantation rubber cultivation in the eastern plains of Sumatra: what future for an agroforestry system?] by Anne Gouyon; Institut national agronomique de Paris-Grignon.

Interactions entre végétaux fixateurs d'azote et non fixateurs en culture mixte : cas des *Leucaena* spp. associées à *Coffea arabica* L. au Burundi [Interactions between nitrogen-fixing and nonfixing plants in mixed cultivation: case of *Leucaena* spp. intercropped with *Coffea arabica* L. in Burundi] by Didier Snoeck; Université Claude Bernard, Lyon I.

The effects of vesicular arbuscular mycorrhizae and nematodes on the growth and nutrition of coffee by Philippe Vaast (France); University of California (USA).

CIRAD Trainees

La fusariose du palmier à huile : influence des facteurs édaphiques et culturaux sur la gravité de la maladie [Vascular wilt disease of oil palm: influence of edaphic and cultivation factors on the impact of the disease] by Catherine Abadie (France); Université Paris XI, centre d'Orsay.

Variabilité et pathogénie des trypanosomes de plantes (*Phytomonas* sp.) [Variability and pathogenicity of plant trypanosomes (*Phytomonas* sp.)] by Emmanuelle Muller (France); Université Montpellier II.

Influence du génotype, de la fermentation et de la torréfaction sur le développement de l'arôme cacao : rôle des précurseurs d'arôme [Influence of genotype, fermentation and roasting on the development of cocoa aroma: the role of aroma precursors] by Nathalie Jeanjean (France); Université Montpellier II.

Modélisation de l'architecture et du développement du système racinaire du palmier à huile (*Elaeis guineensis* Jacq.) [Modelling root system architecture and development of oil palm (*Elaeis guineensis* Jacq.)] by Christophe Jourdan (France); Université Montpellier II.

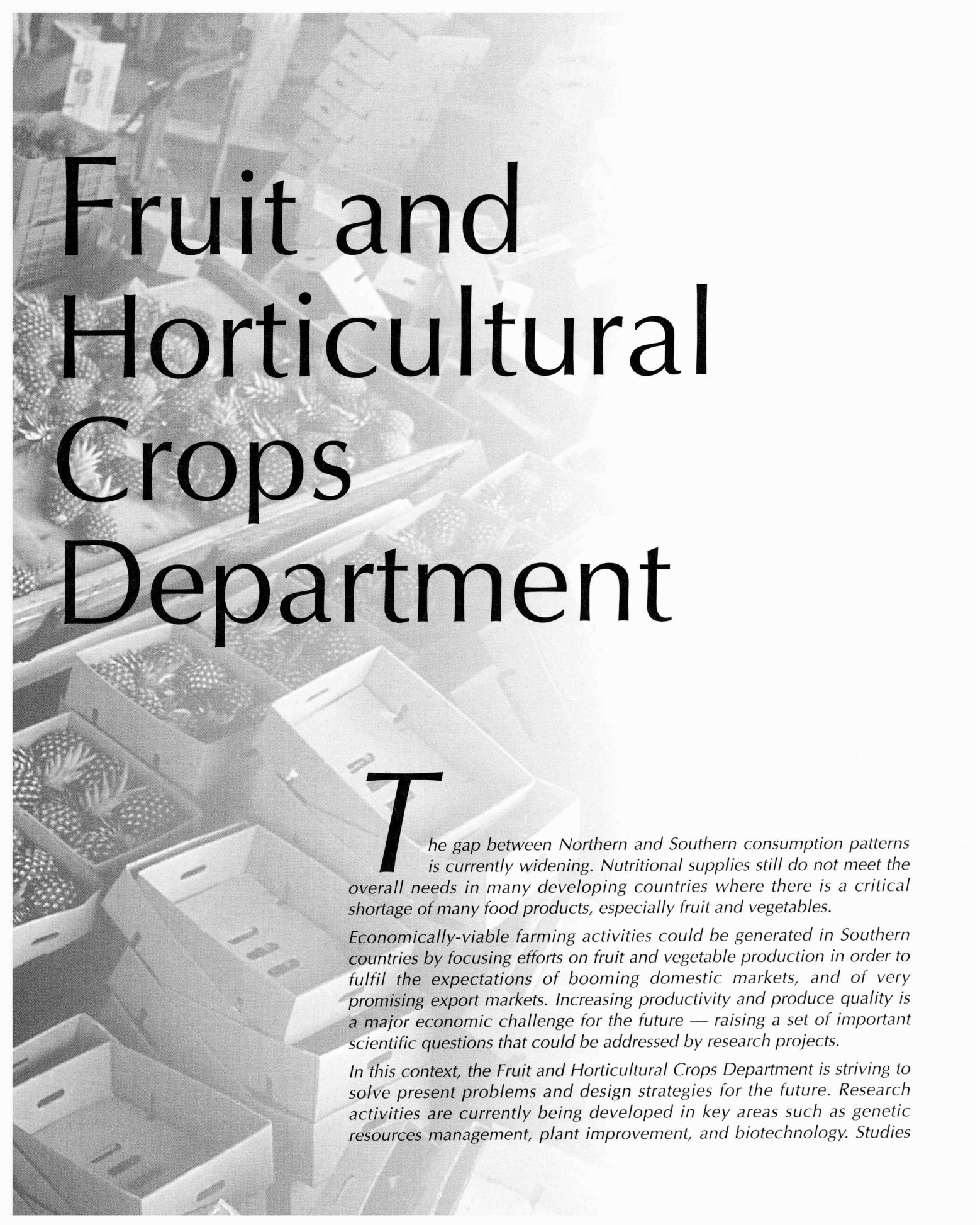
Synthèse et propriétés de cétones aliphatiques à longue chaîne et de leurs dérivés azotés [Synthesis and properties of long-chain aliphatic ketones and their nitrogen-containing derivatives] by Régis Lescure (France); Université Montpellier II.

Synthèse enzymatique d'esters d'acides gras et de saccharides [Enzymatic synthesis of fatty acid esters and saccharides] by Ines Redman (France); Institut national polytechnique de Toulouse.

Intérêt des triglycérides modèles chiraux pour l'étude des spécificités des acyltransférases [The role of chiral triglyceride molecules in the study of the specificities of acyltransferases] by Pierre Villeneuve (France); Université Montpellier II.

Organisation de la variabilité génétique chez le palmier à huile (*Elaeis guineensis* Jacq.). Conséquences pour l'amélioration et la création variétale [The structure of genetic variability in oil palm (*Elaeis guineensis* Jacq.): consequences for plant improvement and cultivar creation] by Vi Cao (France); Institut national agronomique de Paris-Grignon.





Fruit and Horticultural Crops Department


***T**he gap between Northern and Southern consumption patterns is currently widening. Nutritional supplies still do not meet the overall needs in many developing countries where there is a critical shortage of many food products, especially fruit and vegetables.*

Economically-viable farming activities could be generated in Southern countries by focusing efforts on fruit and vegetable production in order to fulfil the expectations of booming domestic markets, and of very promising export markets. Increasing productivity and produce quality is a major economic challenge for the future — raising a set of important scientific questions that could be addressed by research projects.

In this context, the Fruit and Horticultural Crops Department is striving to solve present problems and design strategies for the future. Research activities are currently being developed in key areas such as genetic resources management, plant improvement, and biotechnology. Studies

are also under way on physiological plant function mechanisms that could be responsible for produce quality. In addition, the Department is developing integrated pest and disease control programmes and agro-industrial fruit and vegetable processing techniques. There is also an increased emphasis on economic analysis to help focus research activities on the basis of market dynamics and strategies of those involved in this commodity sector.

The Department is firmly determined to collaborate with Northern and Southern partners. This cooperative approach will enhance potential sector-wide interventions through joint research programmes of regional interest. ■



Citrus and Orchard Fruit

In 1995, with respect to tropical orchard fruit, an important research programme was concluded on mango tree architecture. There was also marked progress in the control of such diseases and pests as tristeza virus and fruit flies. In addition, the promising introduction of new technology in the citrus breeding programme should soon lead to the creation of new types of citrus fruit that will be more easily marketable.

MANGO TREE ARCHITECTURE

Mango yields are generally very low in sub-Saharan Africa, i.e. around 5 t/ha/annum, due to this tree's irregular biennial fruit-production pattern. A new research study, based on tree architecture analyses,

was undertaken in Côte d'Ivoire to determine the mechanisms involved in mango tree function and growth in the presence of various endogenous and exogenous factors. Four different types of flushes were thus identified and characterized, one of which was found to be crucial for fruit production. Some of them, identified as delayed proleptic axes, bear more than 60% of the fruit, while accounting for only 30–40% of the branches on the tree. These specific axes are derived from buds that develop long before shoot elongation and are easily recognized by their frail and quite leafless appearance. For practical purposes, early identification of these axes is useful for supervised pruning management of mango trees, i.e. training, fruiting, and regeneration. This management concept is already being applied in the Sudano-Sahelian zone, especially in northern Côte d'Ivoire where mango production is being

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Research Units

Genetic resources and

plant improvement

Patrick Ollitrault

Parasite and pest biology,

disease control

Xavier Mourichon

Agronomy and farming systems

Jean-Joseph Lacoëuilhe

Economics and management

Jacky Ganry

Technology and quality control

Max Reynes

Biometrics and computer services

Xavier Perrier

Support Services

Publications, documentation

Chantal Loison

Communications

Françoise Fajac

developed to meet local and export market needs.

FRUIT FLY CONTROL

In New Caledonia, mangoes are attacked by three different species of fruit flies, *Bactrocera tryoni*, *B. psydii*, and *B. curvipennis*. In a joint project to eradicate these fruit pests, CIRAD and the New Zealand Horticultural and Food Research Institute have developed a new pulsed hot moist air treatment. Studies were conducted to accurately define the thermal thresholds and optimal treatment times. These treatments should provide satisfactory pest and disease protection for countries importing mangoes, thereby reactivating the export market for this fruit.

In Réunion, the sexual trapping techniques for monitoring *Ceratitis capitata* and *C. rosa* populations have been improved. Growers can thus now perform reliable environment-friendly spot treatments against these pests. This involves treating only a small portion of the foliage with an attractant/pesticide blend — the resulting control efficacy is as good as can be obtained with standard blanket spraying treatments. In addition, a *C. capitata* fruit fly parasite was imported from Hawaii and acclimatized; it is hoped that this will stall fruit fly outbreaks in natural vegetation. *B. zonata*, a fruit fly that was

INTERNATIONAL MEETING

Mediterranean Symposium on Mandarin

This Symposium, held in March 1995, was set up by the joint scientific research team of CIRAD and the French Institut national de la recherche agronomique (INRA) at their research station at San Giuliano (Corsica), under the aegis of the Corsican territorial government and FAO. One hundred and fifty scientists and agents involved in the mandarin subsector, from various Mediterranean countries (Spain, France, Israel, Italy, and Morocco), and Argentina, Australia, Uruguay, and USA, participated. Papers presented at the meeting reviewed recent research progress and pinpointed specific areas requiring further investigation.

recently introduced from Mauritius, was eradicated through an intensive trapping campaign conducted in the area that had been colonized by this species.

BREEDING NEW POLYPLOID CITRUS FRUIT VARIETIES

CIRAD's programme to create interspecific/intergeneric polyploid citrus hybrids aims at meeting the specific needs of Mediterranean citrus growers, through the development of: new tetraploid rootstocks that are adaptable to various soil and climatic conditions, and tolerant of pests and diseases; and triploid cultivars that produce top-quality fruit over a long production period.

Protoplast electrofusion was found to be an efficient technique for producing this type of hybrid. Five new interspecific hybrids have thus been propagated from electrofusions of willow-leaf mandarin with cv Eureka lemon, common lime, and cv Hamelin orange and, on the other hand, of cv Hamelin orange with cv Lake Lemon lemon, and common lime with cv Star Ruby pomelo. Young plantlets obtained from these hybrids are currently being monitored in the laboratory. The mandarin x lemon hybrid is at the grafted plant stage and being greenhouse-acclimatized, along with the intergeneric mandarin x cv Poncirus hybrid that was also created in this programme. It is hoped that the latter hybrid will have inherited resistance to pests and diseases (from cv Poncirus) and tolerance of saline/calcareous soils (from mandarin) — rootstock from this cross would thus be of particular interest for citrus growers in the Mediterranean basin.

Triploid hybrids will be propagated through sexual hybridization of some tetraploid somatic hybrids with diploid mandarins. They will subsequently be bred to produce new cultivars yielding tasty seedless fruit.

Triploid hybrids have also been obtained in the progeny of sexually-hybridized diploid cultivars. CIRAD is tapping this relatively rare spontaneous phenomenon through micropropagation of rescued

embryos and flow cytometry analysis of ploidy levels. In early 1995, this technique was checked with hybrids obtained in Corsica in 1994, and the results prompted the joint INRA-CIRAD team of the Agronomic Research Station of San Giuliano (Corsica) to undertake a much larger-scale hybridization programme in 1995. The parent stock derived through this programme seems promising for potential propagation of triploid cultivars with interesting traits, i.e. colour, flavour, and long duration.

Finally, clementine plants and embryogenic calli have been obtained by forced gynogenesis. In 1996, this original plant material will be used for somatic hybridizations between haploid and diploid protoplasts.

Pineapple and Fruit Diversification

In 1995, CIRAD strengthened its cooperative ties to maintain the genetic resources of pineapple and other tropical American fruits. Prior projects to support the pineapple subsector in Africa, Latin America, and French overseas departments were also continued.

PRODUCTS FOR DEVELOPMENT

Teaching Aids for Pineapple Producer Training

Pineapples sold on European markets are mainly imported from western African countries. Quality is an essential factor in this demanding market.

Training on production techniques is a basic requirement for improving fruit quality. Teaching aids (pamphlets and photographic slides) have thus been designed for programmes to train people involved in the pineapple industry at various levels.

These aids have already been tested in training sessions organized by the Comité de liaison Europe, Afrique, Caraïbes, Pacifique (COLEACP) in Ghana, Côte d'Ivoire, Benin, Togo, and Cameroon — the trainee responses to these aids were highly enthusiastic.

FRUIT GENETIC DIVERSITY IN SOUTH AMERICA

CIRAD, in close collaboration with the International Plant Genetic Resources Institute (IPGRI), is involved in promoting fruit genetic resources in Andean and Amazonian regions. This includes coordinating the Amazonian genetic resources network, Tropigen, and providing backup support for Redarfit, an equivalent network in the Andean region. One of the first research projects in the Amazon zone aims at assessing pineapple biodiversity and tapping it to create new disease-resistant varieties. This project, conducted in conjunction with the relevant

national research agencies, i.e. the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) in Brazil and the Fondo Nacional de Investigaciones Agropecuarias (FONAIAP) in Venezuela, will also foster the development of the world's largest pineapple germplasm collection which is managed by CIRAD in Martinique.

Along similar lines, another project was launched in the Andean zone, in collaboration with the Centro Internacional de Agricultura Tropical (CIAT) and several Colombian universities, to evaluate and enhance *Passiflora* genetic diversity.

SUPPORTING PINEAPPLE PRODUCERS

One of CIRAD's prime concerns is to design crop management procedures that meet with growers' specific needs. Several projects are under way worldwide to support development of the pineapple subsector. All of these activities, which mainly focus on improving the export fruit quality, include consultation with people involved in this subsector at various levels.

In Ghana, a project, supported by the Ghanaian Ministry of Agriculture and the World Bank, has been set up to support producers exporting pineapples to Europe. CIRAD is in charge of supervising a network of demonstration plots that have been set up on growers' farms, training,

and drawing up extension projects. Pineapple plantations are also being studied in collaboration with growers to determine the yield-limiting factors and to come up with practical solutions.

In Latin America, CIRAD is providing scientific backup for the Redafruthex network which organized the first seminar, in 1995, on harvesting, postharvest treatment, and processing of fruit produced in the Andean region. A support programme is under way in Bolivia, focusing on crop diversification through the development of crops with high added value in a region that is dominated by coca production. Pineapple production is thus being promoted for potential export to Argentina and Chile.

Specific smallholder support projects were initiated in the French overseas departments. In Réunion, the results of several years of experiments on cv Victoria pineapples were analysed in 1995, i.e. planting dates, sucker pruning, and fertilization. On the basis of this analysis, operational sequences adapted to very high planting densities, now a common practice in this region, have been developed; these sequences can also be adjusted to meet the requirements of various markets. Discussions with people involved in this commodity subsector highlighted research topics that could soon be in the forefront, e.g. polyethylene mulching,

INTERNATIONAL MEETING

The Second International Symposium on Pineapple

This Symposium, organized by CIRAD under the aegis of the International Society for Horticultural Science (ISHS), was held in Martinique in February 1995. One hundred and sixty people from about 40 different countries participated at this location, which is highly appropriate for discussions on pineapple. More than 80 papers were presented; they revealed the importance of pineapple cropping worldwide, reviewed ongoing research, and assessed international cooperation prospects.

fertirrigation, water/soil dynamics, and harvest planning.

In Martinique and Guadeloupe, smallholders belonging to various associations are getting regular technical assistance from CIRAD, in direct collaboration with the agricultural development services of these regions. An experimental programme was launched in 1995 to design a crop management procedure for cv Bouteille, the Caribbean green pineapple. In other islands of the West Indies, technical support activities have been undertaken jointly with the Instituto Interamericano de Cooperación para la Agricultura (IICA), Costa Rica, within the framework of a regional fruit project. These operations are mainly aimed at promoting pest and disease protection, especially through control of between-island plant

material exchanges, and rapid propagation of cultivars that are adapted to local conditions.

Banana and Plantain

Three major events highlighted CIRAD's Banana and plantain research programme in 1995. A molecular biology laboratory was created in Guadeloupe to enhance genetic diversity investigations on the *Musa* genus as part of a World Bank funded project. A large-scale study was finished on competitiveness in banana subsectors in ACP countries; the results will be used to conduct a comparative analysis of production and marketing cost differences between countries. Finally, the Programme increased close collaboration with the Vitropic subsidiary company, prompting renewed production of micropropagated banana plants for the West Indies. Collaborative links were also increased elsewhere in the world: in Latin America, research activities were developed with Colombian agencies, with the launching of a new project on *Cercospora* diseases of banana; in Africa, CIRAD's active cooperation with the Cameroonian Centre régional bananiers et

plantains (CRBP) was enforced; and in Asia, the Programme will henceforth be involved in the regional advisory committee of the International Network for the Improvement of Banana and Plantain (INIBAP).

GENETIC COMPOSITION OF THE *MUSA* GENUS

There is wide species diversity within the *Musa* genus. Because of the confusing genetic makeup of this species complex, it was necessary to clarify the genetic relations between wild seed-bearing forms and cultivated parthenocarpic forms — in the hope of improving these cultivated forms through the introduction of interesting traits derived from wild forms. A study was thus initiated, using molecular markers, to analyse genetic variability in the genus, and to pinpoint common characters between the different species. This study involved RFLP analysis: three enzyme-probe pairs were used to study the chloroplast genome, 14 for the mitochondrial genome, and 51 for the nuclear genome. Overall, almost 360 wild and cultivated genotypes were investigated.

The results revealed the presence of genome A (from *M. acuminata*) in all of the cultivars checked, and genome B (from *M. balbisiana*) in many of them. In addition, they generally confirmed the known morphological combinations

INTERNATIONAL MEETING A CIRAD-CATIE Symposium

A Symposium on Genetic Improvement and Development of Tropical Crops was jointly organized by CIRAD and CATIE in 1995. The main topics of this meeting, which marked 10 years of fruitful scientific and technical collaboration between these two centres, were genetic improvement of coffee and banana, and plant protection. It provided an opportunity to review the jointly-conducted activities — particularly, for banana, on the use of biotechnology (genome marking, haploid methods, genetic transformation, etc.), on disease resistance mechanisms, and ensuing supervised control techniques.

This Symposium also highlighted potential bases of cooperation which could, in accordance with the hopes expressed by CATIE, be extended into fields such as fruit, vegetable, and forest production, and cover other topics.

(AA, AB, AS, AAA, AAB, etc.), and the monospecific or multispecific origins were determined.

On the basis of the RFLP results, four different genetic groups were noted in the *M. acuminata* species, each comprising several subspecies. The closeness of the genetic relationships between these subspecies and diploid and triploid cultivars was measured. The seedless banana cultivars, in the two groups represented by the subspecies *banksii-errans* and *malaccensis*, showed the highest polymorphism. Moreover,

cytoplasmic and/or nuclear genomes of the subspecies *banksii* and *errans* were found in almost all of the parthenocarpic cultivars analysed. Parthenocarpy therefore seems to have first appeared in these subspecies originating from New Guinea and the Philippines, indicating that the main initial centre of banana domestication was in this region, not in Malaysia.

BANANA COMPETITIVITY IN ACP COUNTRIES

A study on competitiveness in banana subsectors was carried out, in collaboration with the Natural Resources Institute (NRI), UK, in 10 different ACP countries (Belize, Cameroon, Cape Verde, Côte d'Ivoire, Dominica, Grenada, Jamaica, Saint Lucia, Saint Vincent, and Surinam). The study was based on a technique developed by CIRAD for the analysis of entire national export subsectors. Different agroeconomic stations responsible for the international competitive status of the banana subsector were taken into consideration, in terms of the following factors: production and export techniques, product quality, marketing structures, costs, and prices. The first four factors, which are involved at all levels in the subsector, were systematically analysed; the last factor was processed separately, since national subsectors have little influence on world banana prices. The data gathering and technical and

economic analyses were based on this functional breakdown.

Production and marketing costs in each national subsector have already been determined through this analysis. Moreover, since the analytical procedure was kept constant, between-subsector comparisons could be made and the factors responsible for their competitiveness were accurately defined.

This study was financially supported by the European Union. Further analyses using the same procedure have also been conducted in Latin America as part of a CIRAD Action thématique programmé (ATP) — a project on a specific topic — and others are planned in the French overseas departments.

COLOMBIAN PLANTAINS

Colombia is the top plantain producer worldwide, with an annual production of more than 2.5 million t, all of which is consumed locally. It is generally intercropped with coffee by smallholders in highland regions.

At the beginning of the 1980s, the introduction of black leaf streak, an especially serious banana disease, represented a considerable threat to plantain production. An EU-funded research project, involving CIRAD, the Federación Nacional de Cafeteros de Colombia (Fedecafé), and the Instituto Colombiano Agropecuario (ICA),

PRODUCTS FOR DEVELOPMENT

The Katryx® Bag

The bunch bagging technique is used by all export banana growers. Bags protect banana bunches from physical damage and create a microclimate that favours fruit ripening. The Katryx® bag is a new design that was recently developed through collaboration between CIRAD, the enterprise Plastibana, and Apte, an engineering consulting agency specializing in processing methodology. This product differs from standard bags in that it is permeable to visible light, which is ideal for fruit growth, while being partially impermeable to infrared light rays, thus limiting temperature differences around the bunch. The Katryx® bag was successfully tested with cv Grande Naine in Guadeloupe, i.e. the flowering-to-harvest period was shorter and the bananas were longer than with standard bags.

was launched in 1989 with the aim of improving plantain production in coffee cropping zones. There were three parts to this project: evaluating the black leaf streak disease risk in highland regions, analysing plantain production factors, and increasing the range of plantain cultivars to be cropped. Conclusive results were obtained for the latter two parts after 4 years of study. The following factors were found to limit production: deficient mineral nutrition, poorly-adapted cropping techniques, and soil-borne parasitism. Several interesting plantain cultivars were tested in this programme — one of these, of

African origin and subsequently selected (cv Africa), has been extensively propagated and widely distributed because of its popularity with Colombian growers.

The leaf streak disease studies, on the other hand, turned out to be highly complicated. Two separate diseases were detected, black leaf streak and yellow Sigatoka; the distributions of these diseases varied spatially, according to climatic conditions, and temporally, depending on the season and banana plant development stage. A second research project was therefore set up to investigate the ecophysiology of highland-grown plantain relative to their susceptibility to *Cercospora* diseases. Funding for this project was the same as that of the first one, with one additional partner, the Catholic University of Louvain (Belgium). The studies are being carried out under very good research conditions at the Centro Nacional de Investigaciones de Café (Cenicafé).

Horticultural Products

In 1995, vegetable production in tropical countries reached 319 million t/annum — mainly

tomato, water melon, onion, cabbage, and pepper. These vegetables, since they are also cropped in temperate countries, benefit from major technological innovations. Nevertheless, the effectiveness of these techniques will have to be confirmed under tropical conditions. Floral and aromatic crops are more specific to tropical regions, and base-line studies on species and products still have to be carried out.

VIRUS DISEASES OF VEGETABLE CROPS ON TROPICAL ISLANDS

Virus diseases constantly threaten vegetable crops in the tropics, where the climatic conditions are ideal for virus vectors. Studies have been conducted to evaluate virus-free and resistant cultivars and determine the epidemiology of these diseases.

In Réunion, melon cultivars created by INRA (Montfavet, France) were found to be partially resistant to zucchini yellow mosaic virus, although the Réunion strain of this virus disease differs serologically from the Mediterranean strain.

Virus-free garlic cultivars obtained through meristem culture were found to have significantly higher mean bulb weights than infected cultivars. However, plants are quickly reinfected in cropping zones.

NETWORKS

The CORAF Vegetable Crop Network

This Network was founded in 1994 by 17 member countries of the Conférence des responsables de recherche agronomique africains (CORAF). The aim was to bring together the widely scattered organizations involved in vegetable cropping in Africa. This has led to synergetic exchanges between the national research services through various projects. The Network has advanced one step further with the holding of a workshop in Bouaké (Côte d'Ivoire) in February 1995, entitled "Training on a practical diagnosis method: study on the impact of the vegetable subsector on national economics, and provisioning large urban markets". This workshop was coordinated by CIRAD and organized with the support of Agricongo and the FAO project for the development of vegetable crops in western Africa.

In the Caribbean area, some European tomato cultivars have shown some degree of resistance to a new geminivirus that recently appeared in Guadeloupe and Martinique.

PROTECTED CROPPING: TOMGRO IN MARTINIQUE

Cultivation under plastic tunnels has proven interesting in many tropical regions. CIRAD is developing crop management procedures for tomato in

New Caledonia, Réunion, and Martinique.

In lowland humid tropical areas, plastic tunnels are efficient in maintaining a constant hot and moist environment around crops, but lighting is reduced. CIRAD, with the aim of optimizing tomato cropping conditions under protective cover, has been using a model called Tomgro that was initially designed in Florida, and subsequently adapted by INRA, to simulate tomato plant growth under temperate climates. After the modelling parameters were determined for the tropics (Martinique), the simulations revealed that growth is higher at the beginning of the cropping period, whereas the dry matter production is lower after the eighth truss, and very low in the fruit. These data will be useful for supervised management of tropical cropping systems — pruning, fertilization, irrigation, etc.

FLOWER STORAGE IN MARTINIQUE

In Martinique, farmers can diversify their crops by growing flowers — this market is very promising, and 60% of the production is exported to Europe. High-quality flowers can be obtained when the cropping techniques are fully mastered, but efficient postharvest techniques are essential to maintain this quality. CIRAD has therefore developed improved flower storage techniques for three export flower species.

PUBLICATIONS

Tropical Orchards

Some of the papers presented at the Symposium on Tropical Orchards, held in Montpellier (France) in 1993, are published in a special bilingual (French/English) issue of the journal Fruits. The papers cover economic, technical, and scientific topics that should be of interest to professional orchard fruit growers and research scientists.

Arthropod Vegetable Crop Pests in New Caledonia

The Catalogue des principaux arthropodes présents sur les cultures légumières de Nouvelle-Calédonie (Catalogue of the main arthropod pests of vegetable crops in New Caledonia) was published in collaboration with the provinces of New Caledonia. This well-illustrated manual gives a concise description of each pest, a list of host plants, control techniques, and beneficial organisms (predators and parasitoids).

Vegetable Subsectors in Brazzaville

Les filières maraîchères à Brazzaville : stratégies des acteurs et dynamique des échanges (Vegetable subsectors in Brazzaville: strategies and trading dynamics) was copublished by CIRAD, Agrisud international, and Agri-congo. It gives an overall analysis of vegetable production, marketing, and consumption patterns in the Congolese capital.

The storage-life of pink flamingo flowers can be extended to 10 days, as compared with 6 days under normal room-temperature conditions, by storing the flowers under 20 µm polyethylene film at 12–18°C. An easier way for farmers to substantially improve flower quality is by simply storing them in an air-conditioned room at 19–24°C. Red ginger flowers last longer during storage when they are opened than when they are closed or only half-opened (stages when they are usually cut). For heliconias, four of the 19 cultivars present in Martinique were found to be interesting, with a vase-life of more than 15 days; these are *Heliconia stricta* cv Dwarf Jamaican, *H. psittacorum* cv Sassi, *H. psittacorum rhizomata* and *Heliconia* sp., a natural hybrid forest species.



THESES COMPLETED IN 1995

CIRAD Scientists

Approche architecturale des mécanismes de la croissance aérienne et de la floraison du manguier [Architecture-based analysis of aerial growth and flowering in mango trees] by Thierry Goguy; Institut de botanique de Montpellier.

Le virus de la tristezza des agrumes (CTV) : variabilité de l'agent pathogène et épidémiologie de la maladie dans les conditions de l'île de la Réunion [Citrus tristeza virus (CTV): pathogen variability and epidemiology of the disease in Réunion] by Michel Grisoni; Ecole nationale supérieure agronomique de Montpellier.

CIRAD Trainees

Contribution à l'étude de la diversité intraspécifique du nématode Radopholus similis, parasite du bananier [Contribution to the analysis of intraspecific diversity in the banana pest nematode *Radopholus similis*] by Gustavo Fallas (Costa Rica); Université de Tours.

Déterminisme du nombre d'organes reproducteurs d'une inflorescence de bananier (Musa acuminata, cv Grande Naine) [Determination of the number of reproductive organs in an inflorescence of banana (*Musa acuminata*, cv *Grande Naine*)] by Magali Jannoyer (France); Institut national agronomique de Paris-Grignon.

Etablissement d'une technique d'androgénèse pour l'amélioration génétique du bananier (Musa sp.) [Development of an androgenesis technique for genetic improvement of banana (*Musa* sp.)] by Florence Kerbellec (France); Ecole nationale supérieure agronomique de Rennes.

Interrelation entre la teigne des crucifères, Plutella xylostella L., son parasitoïde, Diadegma sp., et la bactérie entomopathogène Bacillus thuringiensis Berl. [Interrelations between the diamond back moth, *Plutella xylostella* L., its parasitoid *Diadegma* sp., and the entomopathogenic bacterium *Bacillus thuringiensis* Berl.] by Rose Monnerat (France); Ecole nationale supérieure agronomique de Montpellier.

Influence des facteurs biotiques et abiotiques sur la dynamique des populations de Pseudomonas solanacearum au cours de l'infection et sur le flétrissement bactérien de la tomate [Effect of biotic and abiotic factors on *Pseudomonas solanacearum* population dynamics during infection and on bacterial wilt of tomato] by Jean-Francis Nicole (France); Université de Nantes.

Les conditions de développement d'un marché vivrier : le cas de la banane plantain en zone forestière du Cameroun [Conditions for developing a food market: a case study on plantain in a forest region of Cameroon] by Ludovic Temple (France); Université Montpellier I.





Livestock Production and Veterinary Medicine Department

***T**he work of the Livestock Production and Veterinary Medicine Department (CIRAD-EMVT) was marked by two major events in 1995. First, the Department moved to the international Baillarguet campus, Montpellier, which is shared with CIRAD's Forestry Department — creating an important agrosylvopastoral centre. Secondly, a new 5-year scientific programme was drawn up, with activities developed around this new focus.*

The research priorities include: higher sustainability of rangeland livestock production systems and mixed systems (combining livestock and crop production), enhancing farm cost-effectiveness, training research scientists and extension staff.

The Department was reorganized to provide a solid foundation for its scientific strategy. Four new research units were created (Feed Resources, Livestock Production and Herding, Aquaculture, and Tropical Livestock Diseases), along with three new programmes (Rangeland Livestock Production and the Environment, Livestock and Crop Production, and Subsectors and Diversification).

This new organization will be entrenched in 1996; the main research results of 1995 are thus presented according to the former structure. ■

Feed Resources

Fodder resources have to be carefully managed, especially in fragile ecosystems, so that the existing biodiversity will be preserved and the balance between animal populations and plant communities will not be upset. Botanical and wildlife surveys and sociological studies on livestock farmers are therefore essential elements of the feed resources programme.

Preservation of fodder species diversity is also important for maintaining the stability of traditionally transhumant or agropastoral systems.

FODDER CROP EVALUATION WITHIN THE RABAOC NETWORK

The Réseau de recherche en alimentation du bétail en Afrique occidentale et centrale (Research network on livestock feed in western and central Africa),

Rabaoc, set up by CIRAD with the International Livestock Centre for Africa (ILCA), reviewed 5 years of network activities at a meeting that was held in Lomé (Togo), April 1995. One network project, coordinated by CIRAD, is to select fodder grasses and legumes that will grow well in humid and subhumid African environments; the plant material is from a variety of origins, and much is supplied by the Centro Internacional de Agricultura Tropical (CIAT). Research centres of nine different African countries (Benin, Cameroon, the Central African Republic, Côte d'Ivoire, Ghana, Guinea, Nigeria, Senegal, and Togo) have set up tests at 19 locations using a strictly-controlled identical experimental procedure.

Fodder plant varieties have been created that are well adapted to the soil and climatic conditions, and to the biological constraints at each location. Moreover, species were identified that would be able to grow well in various subhumid zones — this highlights

LIVESTOCK PRODUCTION AND VETERINARY MEDICINE DEPARTMENT

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Sectors and diversification
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INFORM and cartography
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* In 1996.

the considerable benefits that can be reaped through network-wide research projects. The results confirmed that the grasses *Andropogon gayanus* and *Brachiaria brizantha*, and the herbaceous legumes *Stylosanthes guianensis* and *Centrosema macrocarpum*, are excellent livestock feed sources in the dry season. The shrub legumes *Cajanus cajan*, a quick-growing biennial species, and *Leucaena leucocephala* and *Cratylia argentea*, very productive perennials, are suitable for a wide range of livestock production systems.

The network will now focus its research in two different areas: new tests will be carried out with fewer species, but they will include a wider range of ecotypes that currently have key functions in livestock production systems; and varieties selected in the first test series will be used in seed production programmes.

BIODIVERSITY IN COASTAL REGIONS OF MAURITANIA

An EU-funded study of biodiversity in coastal regions of Mauritania, begun in 1993, coordinated by CIRAD and conducted in conjunction with the Mauritanian Centre national d'élevage et de recherches vétérinaires (CNERV) and the French Muséum

COOPERATION

Fodder Crop Research in the Pacific

The Northern Australian Pasture Plant Evaluation Committee (NAPPEC) is a group of Australian experts on tropical fodder plant introductions, breeding, and evaluation. It is also open to specialists from Asia and the South Sea Islands. CIRAD is carrying out studies on range-lands in New Caledonia, and has been a NAPPEC member for 4 years. The Committee also includes scientists from the Commonwealth Scientific and Industrial Research Organization (CSIRO) and the University of Queensland, as well as representatives from enterprises that market fodder seed.

Australia, with 50 years of research experience on fodder crops, and supported by an enterprising agro-industry and marketing system, has created a favourable environment for innovation in this field. CIRAD-EMVT has accepted to test, in New Caledonia, fodder plant varieties that were bred in Australia. This has given the Department access to experimental plant material, techniques, and tools developed by fellow NAPPEC members. New Caledonian livestock producers should soon benefit from this cooperative exchange.

national d'histoire naturelle, was concluded in 1995. There were three objectives: to carry out a botanical and wildlife survey and

monitor human activities along the Mauritanian coast, from the Senegal river in the south to Nouadhibou in the north; train a team of environmental specialists; and conduct a public awareness campaign to promote environmental protection in Mauritania.

In the botanical survey, a herbarium of 127 species was assembled, and the flora of the only coastal region of Mauritania was found to comprise 251 species, i.e. more than 20% of the known higher-order plants in Mauritania. Three previously unlisted species were also inventoried. Concerning wildlife, 39 mammal species and 34 reptile species were listed by the research scientists. In addition, morphological and ecological data were collected on marine mammals. A survey of invertebrates revealed an interesting variety of intermediary fauna, even though it was carried out during the dry season under quite unfavourable conditions.

Maps are being drawn up, at 1/100 000 scale, on the basis of 10 SPOT satellite remote-sensing images. The different coastal landscape types will be represented, with each unit associated with a typical plant community, as determined from 535 botanical inventory reports. The maps will be supplemented

with other 1/25 000 scale maps of eight locations along the coast that were surveyed in detail.

The sociological surveys indicated that there is very little human pressure on natural resources beyond the highly-degraded suburban regions of Nouakchott and Nouadhibou. Herders utilize the *sbar*, a thin sparsely-vegetated sand dune ridge, where camelids and small ruminants graze on the vegetation, even halophyte plants. The herds are nomadic, moving up and down the coastline with the changing seasons.

Around 15 research scientists and technicians from research institutes and national parks, and six students, have been introduced to environmental sciences and techniques. The overall aim was to create a Mauritanian team of ecological experts that could conduct support studies for the land-use planning administration.

Several public awareness activities were conducted on environmental protection: articles published in Mauritanian newspapers, photo exhibitions, and guided visits organized for state officials. At the end of the project, a conference was organized in Nouakchott with wide participation, including the scientific community, sponsors, and decision-makers, as well as young people, voluntary organizations, and nature-lovers.

Livestock Resources

A full understanding of animal populations is necessary for biodiversity preservation. Research staff have thus been surveying and characterizing livestock breeds in the tropics. These studies have also been extended to wildlife, focusing on interactions and complementarity with livestock species.

CHARACTERIZATION OF THE KOURI BREED

Kouri is a cattle breed that is limited to the Lake Chad region. It is usually identified according to three visible criteria: pale-coloured coat, no hump, and bulbous horns. However, there can be confusion since these criteria are not standardized. An FAO — and EU — funded project was thus set up in 1993, involving CIRAD, the French Institut national de la recherche agronomique (INRA), and Farcha Laboratories, to characterize the Kouri breed on the basis of visible criteria and biochemical factors.

A survey among herders revealed that half of the animals in the sample did not meet the usual Kouri identification criteria, i.e. 46% of the cattle that herders

designated as Kouri fulfilled the three characteristic criteria, while 39% fulfilled only one or two, and 15% fulfilled none. However, a comparison of blood types in the sample confirmed the herders' intuitive Kouri identifications. This indicates that the character standards for the Kouri breed have evolved according to livestock producers' needs.

Biochemical DNA analyses are under way for these cattle using 20 microsatellite markers that were previously used by INRA in studies on French cattle breeds. A novel mutation at the casein- $\alpha 1$ locus has already been detected, which could be a Kouri-specific marker. Another mutation, previously noted in the hardy French breed Tarine, was identified at the casein- χ locus. In addition, an α -lactalbumin analysis revealed a high frequency of polymorphism in zebu, but this phenomenon was very rare in cattle. Concerning the blood-group systems, there was a very high frequency (90–100%) of some erythrocyte factors that are specific to the Kouri breed; and three alleles that have never been detected in any other cattle breeds were discovered in the S system. Finally, a B-system allele, previously identified in the N'Dama breed in Burkina, was detected in Kouri.

Previous characterization criteria for Kouri, and even its breed status,

should now be reviewed in the light of these new results. The study confirmed that livestock breeds are not temporally stable — they evolve under production pressure and according to producers' objectives. Indeed, external factors (partially influenced by humans) induce the assembly, from a gene pool, of specific gene sequences that characterize a breed; these sequences can be modified or disassembled when the external factors change.

RESOURCE SHARING BETWEEN HERBIVOROUS LIVESTOCK AND WILDLIFE

What factors are responsible for structuring African herbivorous animal populations? How do they share feed resources? These are vital questions for CIRAD research scientists who are currently conducting an original livestock production experiment in Zimbabwe with mixed wildlife/livestock populations. Partial answers to these questions were already available from preliminary studies.

A comparative study of eastern and southern African ecosystems highlighted the general rules that govern their functioning.

Elevated annual rainfall levels and mineral-rich soils are responsible for high plant production rates, thus accounting for the presence of


large populations of herbivores. The animal species richness also has a positive influence on the number of animals in a population. This explains why, contrary to general opinion, animal production systems, with typically few species, cannot support more animals (in terms of herbivore biomass) than natural environments, where there are many species. Nevertheless, there are differences in the reactions of herbivorous animals to various environmental parameters, depending on whether they are browsers or grazers. An equation for evaluating rangeland-carrying capacities was formulated for each of these categories.

Species richness is influenced by primary production and by the extent of disturbance to the system, which is associated with the impact of large herbivorous animals. Interspecific competition has an important role in structuring the populations.

These rules were applied to the mixed animal population on the ranch in Zimbabwe, confirming the importance of between-species competition — but this factor is still not as critical as the structure/architecture of the forage resource. The coexistence of wild and domesticated animals on the ranch is partially possible because of the heterogeneity of the resource,

and morphological and physiological differences between species.

Intraspecific competition also affects the feeding behaviour of social herbivorous animals. A study on the importance of this factor in impalas revealed that herd size partially dictates the per-animal grass intake. This behavioural aspect should therefore be taken into account when assessing rangeland-carrying capacities.



Livestock Production Systems

Livestock farming situations are extremely varied in the tropics — and their production systems can be improved in many different ways. When CIRAD researchers dealt with projects involving the organization of a budding subsector, improving draught animal management and introducing innovations in a network of test farms, the objective was always the same: to develop simple tools that are fully adapted to farmers' needs on the basis of preliminary analyses of their livestock farming practices.

STREAMLINING PERIURBAN POULTRY FARMING IN AFRICA

In sub-Saharan Africa, feed is an essential factor for successful periurban poultry farming. Quantitative and qualitative feed supply problems, worsened by the harsh climate, often jeopardize poultry production.

In Côte d'Ivoire, CIRAD, in collaboration with the Institut des savanes (IDESSA), INRA, and the Union des fabricants d'aliments composés (UFAC), studied the ability of broiler chickens and laying hens to adapt their energy/protein intake to needs. Two types of feed distribution were compared: a standard complete feed (flour or pellet), and a free-choice feed composed of grain, a protein/mineral complement, and oyster shell (for hens only).

The performances of broiler chickens given free-choice feed or pelleted complete feed were identical, but there was a 4–7% reduction in the performance of chickens given complete feed in flour form. Hen laying performances and the characteristics of their eggs were not modified by diet. Nevertheless, hens tend to overconsume mixed feed, so it should be rationed. In these conditions, feed intake can be reduced without affecting hen laying performance, therefore

improving protein and energy efficiency.

The cost-effectiveness of the poultry farming subsector could be enhanced through the use of free-choice diets including local cereals, thus reducing transport and processing costs. However, other measures would also be possible.

Surveys of poultry farms around Dakar (Senegal), jointly conducted by CIRAD and the Institut sénégalais de recherches agricoles

(ISRA), revealed that poultry houses are often poorly ventilated, production conditions are generally unsanitary, and preventive prophylactic programmes are unsuitable or poorly applied. These conditions could be easily improved at low cost. Since poultry farms in this region are faced with a wide variety of risks, it is sometimes better to modify environmental conditions than to apply drug treatments. Poultry farmers could

PRODUCTS FOR DEVELOPMENT

A Network of Test Farms in New Caledonia

CIRAD, as part of a project to improve dairy cattle production, has set up a network of 29 sample farms in the northern province of New Caledonia. The results of a follow-up study of these farms will be used to develop technical/economic guidelines and operational animal production indicators, as requested by the Directorate of the Rural Development and Fisheries Service. This follow-up study also involves the introduction of technology innovations that are adapted to producers' needs — and the results of these in-situ experiments should also enhance the guidelines.

Preliminary results concerned the introduction of relatively simple farm management aids. Animal identification tags facilitate monitoring the lifetime performance of breeding cows, which is interesting for selection programmes, and that of other animals in the herd, useful for establishing annual slaughtering schedules. Farmers record all events in a logbook to be consulted for future scheduling and for programming livestock rotations on rangelands. An accounting book, the first step towards financial farm management, helps farmers in making strategic decisions.

Mean calving rates, which were lower than 50% in 1993, rose to about 65% in 1995 on farms with more than 200 head of livestock. On the east coast of New Caledonia, the livestock management rate increased from 5–15% in 1992 to 25–35% in 1995 — evidence that Kanak livestock farms are progressively entering production and marketing networks.

Finally, new hardy, drought-tolerant fodder grasses and legumes have been introduced. They should improve livestock feeding, which is currently a major limiting factor for production.

be provided with technical training through feed suppliers — as a means to gradually introduce simple production practices, such as abiding by standards with respect to feeding, poultry densities, and vaccinations, as well as using a thick layer of litter to reduce the need for coccidiosis control treatments.

INDICATORS FOR DRAUGHT ANIMALS IN CAMEROON

An overall understanding of draught animals, their labour potential, and stamina is a prerequisite for the development of animal traction in the tropics. CIRAD investigated this topic in northern Cameroon — monitoring farmers' practices and assessing the labour efficiency of three draught-animal species used in this region, i.e. zebus, donkeys, and horses.

Depending on needs and prevailing environmental conditions, farmers choose draught animals on the basis of three criteria: equipment cost, draught power required, and draught-animal upkeep costs. Cattle are the most common draught animals, with 37 000 teams in 1995. They provide enough power to till weedy fields for cotton and maize cropping. Culled animals can be sold. In the same year, there were 14 000 draught donkey teams. They are inexpensive

to purchase, easily manoeuvred around small plots, and generally used in foothill regions. There has been a recent sharp increase in the number of draught horse teams, with 2 000 teams operational in 1995. Horses are a good compromise, in terms of draught power and purchase cost, as compared with zebus and donkeys, but their upkeep is expensive.

The peak labour efficiency ranges for the three draught animal species are complementary. Donkeys (weighing 100–150 kg) have a draught force of less than 30 daN, at a speed of 2.6–3.2 km/h, for 3–6 h/day of labour. Horses (weighing 200–300 kg) are able to haul 45 daN at 3.3 km/h for 4.5–6.5 h/day. For the same labour time, zebus (300–450 kg live weight) have a higher draught force (up to 75 daN), but they are slower (2.4–2.9 km/h).

A biological analysis showed that muscle exercise is aerobic during labour, regardless of the hauling intensity. There is only a slight risk of hypothermia during the hot rainy season. For equine animals, measuring the heart rate 3 min after stopping work is a good way of monitoring fatigue.

Mechanical guidelines are useful for making equipment choices, providing a basis for the assessment of draught-animal/tool compatibility. Biological guidelines

are helpful for determining how long an animal should labour each day. The results of this study will lead to potential recommendations on the use of draught animals based on simple indicators.



Aquaculture and Fisheries

Southern countries respond to many challenges when promoting the development of the fish-farming industry: i.e. producing animal protein for a growing population; avoiding overuse of natural fishing environments; and encouraging the economic and social development of rural communities through lucrative activities. CIRAD's research programme has a dual role to fulfil: upstream, to develop fish-farming techniques; downstream, to organize and make the subsector functional.

REPRODUCTION OF CA-BA-SA, THE MEKONG CATFISH

Ca-ba-sa (*Pangasius bocourti*) is a catfish of considerable interest for fish farming in Vietnam. Almost 15 000 t/annum of this fish are reared in floating cages in the Mekong river delta. However,

the fry and juveniles still have to be caught in the natural environment, in the Cambodian part of the Mekong river. It is estimated that 270 million *Pangasius* fry, all species considered, are collected in Cambodia, and 200 million of them are exported to Vietnam. This highly intensive tapping of the resource, in addition to the overall degradation of the watershed environment, and the dam-building programme for the main course of the Mekong river, are threatening the ca-ba-sa fish-farming industry.

CIRAD and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM), supported by the French Ministère des affaires étrangères, launched a project to improve reproduction of this fish in captivity. The project is being carried out in collaboration with two Vietnamese universities, Can Tho and Thu Duc, and Agifish, a mixed economy aquaculture enterprise.

In 1995, ca-ba-sa fry were hatched in captivity for the first time, in the experimental fish hatchery of Can Tho. This reproductive success was obtained after treating female parents with hormones, followed by in-vitro ovule fertilization. This previously ineffective operation was successful because of the efficient parent-stock management

conditions (e.g. feed control enabled complete gonad maturation), and strict monitoring of ovocyte maturation through regular ovule sampling.

Rearing conditions were investigated with 50 000 captive hatchlings. The fry were fed a diet of crustaceans (*Artemia*), then mud worms (*Tubifex*), and finally an artificial feed containing 42% protein — which turned out to be a poor substitute, in terms of nutritional quality and conditioning. A higher quality artificial fish feed formula should now be developed.

Complete control of the ca-ba-sa rearing cycle would first require efficient reproduction of this catfish in captivity. This objective is part of a more ambitious project involving joint management of fish-farming resources of the Mekong. Three countries along the Mekong, i.e. Laos, Cambodia, and Vietnam, take around 300 000 t/annum of fish from the river. The demand for live aquatic resources is rising with the booming population growth in these countries; this demand cannot be solely met with natural resources. There will be an inevitable increase in aquaculture.

PROFESSIONALIZATION OF AQUACULTURE IN NIGER

The Association des aquaculteurs (ADA), an association of fish

farmers in Niger, was created on the basis of 10 years of experience in rearing tilapia in floating cages. ADA is now having difficulties in fulfilling its mission of organizing a self-reliant and cost-effective fish subsector. It was able to market only 35 t of fish in 1995, which is far below the 60 t that had been targeted for the year. What caused this setback, and how can the sector be restimulated?

An analysis of tilapia production revealed that the first two steps, fry production and bulking in ponds, are satisfactory, but the fish farmers are not very efficient in subsequently rearing the fish in floating cages. Indeed, half of these cages are not cost-effective because they are underexploited, survival rates are lower than 60%, and feed conversion rates are too high — indicating that feeding is unbalanced or poorly distributed. The mean prime cost of a marketed fish is currently higher than its retail price. Most of the fish farmers are therefore unable to pay back credits allotted by ADA for fry and feed purchases. This negative situation threatens the future of the Association.

ADA, despite these problems, still has a very promising future: aquaculture in Niger now has a solid infrastructure, techniques that are cost-effective when properly used, and a new market

that was developed through an efficient promotional campaign. This subsector will now have to strengthen its business strategies and give priority to dynamic fish farmers, capable of managing a risky fish production venture at high financial stakes. Recent collaborative agreements between ADA and fish producers from France and Côte d'Ivoire will undoubtedly promote this new thrust.

Infectious and Parasitic Diseases

The CIRAD-EMVT Tropical diseases laboratory (Pathotrop) was transferred to Montpellier in 1995. The new facilities have twice the former floor area, up-to-date equipment, and a P3-type quarantine chamber — conditions that will enable full analysis of microorganisms responsible for serious animal epizootic diseases, while meeting isolation requirements. Pathotrop is now able to provide efficient support for the Department's field research encompassing all areas of animal health.

PRODUCTS FOR DEVELOPMENT

Marketing of Diagnosis Kits

In 1995, CIRAD-EMVT signed a marketing agreement with Biological Diagnostic Supplies Ltd (BDSL), a Scottish enterprise, for the production of diagnosis kits developed by its Tropical Diseases Laboratory. These kits can be used for differential diagnosis of rinderpest and peste des petits ruminants. BDSL is hoping to be able to produce at least 50 of these kits annually. The reagents are manufactured by CIRAD-EMVT according to a special technique developed by the Laboratory. BDSL is responsible for packaging and marketing the product.

Since 1992, CIRAD, ORSTOM, and the Centre international de recherche-développement sur l'élevage en zone subhumide (CIRDES), in collaboration with the International Livestock Research Institute (ILRI), and the Tsetse Research Laboratory (TRL), which supply probes, have been developing molecular biology techniques to detect and characterize trypanosomes in mammal hosts, along with their vectors (tsetse flies and other biting insects).

In a recent study conducted in Côte d'Ivoire, molecular biology techniques were effective for accurate identification of these pathogens in known trypanosomosis disease foci. Ninety percent of all disease cases were found to be caused by the subgenus *Nannomonas* — this included many mixed infections with savanna- and forest-types of *T. congolense* that were detected in *Glossina longipalpis*. The two latter trypanosomes were also found in *G. tachinoides* in Burkina. Surveys carried out in other regions of western Africa highlighted parasite-vector specificity between savanna tsetse flies (of the *morsitans* group) and the savanna-type of *T. congolense*, and also between gallery forest tsetse flies (of the *palpalis* group) and the forest-type of *T. congolense*.

MOLECULAR EPIDEMIOLOGY OF TRYPANOSOMOSIS

Four trypanosomes that are pathogenic to African livestock, i.e. *Trypanosoma brucei*, *T. congolense*, *T. simiae*, and *T. vivax*, have been fully characterized through molecular biology techniques. These species are actually composed of different but morphologically-similar taxonomic groups. Species belonging to the subgenus *Nannomonas* (including *congolense* and *simiae*), for instance, are among the most virulent cattle parasites. Four different types of *T. congolense* have been characterized with molecular markers: "savanna", "forest", "kilifi", and "tsavo".

Laboratory studies, using tsetse flies reared by CIRAD-ORSTOM, confirmed some trends concerning these parasite-vector compatibilities noted in the field.

Molecular diagnosis techniques are still not fully controlled and cannot yet be used in large-scale epidemiological studies because of their prohibitive cost; nevertheless they are very useful for small-scale targeted field and laboratory investigations. In the long term, it is essential to understand how pathogenic trypanosomes circulate within disease hot-spots where several parasites and vectors are present, and to determine the most dangerous parasite-vector combinations. This information would be useful for disease protection services to accurately target control campaigns.

GENETIC DISEASE RESISTANCE

Endoparasitosis and bacterial diseases are responsible for severe livestock losses in the tropics. Efficient chemical nematode control products are available, but expensive, and the parasites quickly develop resistance mechanisms following concentrated treatments. Moreover, vaccines against infectious diseases such as dermatophilus dermatitis are difficult to develop because of the many different strains.

The genetic resistance that has been noted in some livestock against these diseases is thus an interesting new channel to explore.

CIRAD, in collaboration with ISRA and ILRI, carried out field studies on genetic resistance to stomach worms in sheep. These investigations were undertaken in two different regions in Senegal — in the north, with a Sahelian climate, and in a more humid southern region. The aim is, using standard genetic techniques, to determine resistance traits that could be focused on for breeding purposes, i.e. correlated with the extent of infestation, duplicated over time, and highly heritable.

Three resistance characters were determined in mother sheep and their lambs, but the fathers were unknown. The analysis included counts of eggs/g of faeces, hematocrit determination, and weight (of lambs).

The egg content in faeces was negatively correlated with the hematocrit level and lamb weight, but these correlations were not always significant. Other factors could have had a bearing on these results; indeed, a poor diet or a disease, such as trypanosomosis, can modify the hematocrit level.

The hematocrit regressions calculated for mother sheep and lambs were generally significant

and higher with age, i.e. as the lambs' immune systems develop.

The estimated levels of heritability for the egg content in faeces and for the hematocrit indicated a high selection potential for these characters. Studies will thus be continued under controlled conditions. Groups of highly resistant or susceptible Djallonké ewes and rams were formed and maintained at a research station. Their offspring will be evaluated to confirm and clarify the results obtained on livestock producers' farms.

In Martinique, CIRAD-EMVT research scientists have, since 1991, been studying Brahman zebus that are resistant to dermatophilosis, a bacterial disease spread by ticks. These studies, funded by the European Union, the French Ministère des DOM-TOM, and the Regional Council of Martinique, are based on molecular biology techniques.

Twelve animals considered to be disease-resistant, and 18 considered susceptible were subsequently bred on the basis of epidemiological follow-up results. Part of the DRB3 gene, encoding a key protein of the immune system, was analysed by polymerase chain reaction (PCR) and restriction fragment length polymorphism (RFLP) techniques. A unique amino acid sequence was identified in all resistant zebus; 10 of them also had

a specific allele on BoLA A8, a gene that is also involved in the immune response. Several susceptible zebus contained serine at position 30 of the antigen recognition site; this amino acid was completely absent in resistant animals.

These markers are being checked through segregation analyses in livestock herds, while assessing their genetic heritability.



THESES COMPLETED IN 1995

CIRAD Scientists

Approche dynamique du bilan fourrager appliquée à des formations pastorales du Sahel tchadien [Dynamic approach to the analysis of forage availability and consumption applied to Sahelian rangelands in Chad] by Alexandre Ickowicz; Université Paris XII.

CIRAD Trainees

Clonage et expression des gènes codant pour une HSP70/BiP et une cystéine protéase de Trypanosoma congolense : utilisation de ces antigènes dans l'étude de la trypanotolérance bovine [Cloning and expression of genes encoding an HSP70/BiP protein and a cysteine protease of Trypanosoma congolense; use of these antigens for the analysis of trypanotolerance in cattle] by Alain-François Boulangé (France); Université Bordeaux II.

Etude des systèmes mixtes d'herbivores sauvages et domestiques en savane africaine : structure des peuplements et partage de la ressource [Study of mixed livestock production systems with wild and domesticated herbivores in an African savanna region: population structures and resource sharing] by Hervé Fritz (France); Université Paris VI.







Forestry Department

In 1995, governments, international organizations, and NGOs were still looking for realistic ways of implementing the guidelines established by the 1992 United Nations Conference on Environment and Development (UNCED). One major outcome of the international negotiations was creation of the Intergovernmental Group on Forests, whose projects will be presented and discussed at the 1997 session of the United Nations Commission on Sustainable Development.

The XXth World Congress of the International Union of Forestry Research Organization (IUFRO) in Tampere (Finland) was one of the highlights of the year. It differed from previous congresses in size and scope, bringing together researchers, operators, decision-makers, and NGOs to tackle some universal problems — the influence of forests in planetary climatic change, restoration of degraded land, the criteria and methods for

sustainable forest management, and socioeconomic and institutional aspects of forest resource management — all of which roused considerable interest.

The Congress clearly highlighted the importance of forestry research in the development of tropical countries. The final resolutions called for an increase in scientific exchange and cooperation, particularly on a regional scale.

CIRAD-Forêt has developed its activities in this context, seeking to create new lines of cooperation with its Southern partners. In Côte d'Ivoire, framework agreements have been drawn up with the Institut des forêts (IDEFOR), a public research unit, and the Société pour le développement des forêts (SODEFOR), a development agency. In the Congo, CIRAD has become involved in public research and development through the Industrial Plantation Productivity Research Unit. In addition, the Department has signed several agreements with the Center for International Forestry Research (CIFOR), thereby reinforcing its presence on the international scene. ■

Natural Forests

For the past 20 years, tropical forests have been the focus of worldwide debates on the future of our planet and economic and social development of Southern countries. Tropical forest research is increasingly called on to contribute sustainable management strategies for natural forests.

These strategies presuppose a commitment on the part of researchers to forestry land use and planning, to the relationship man has with this ecosystem, and to legislation regarding its management.

MANAGEMENT OF THE DIMAKO FOREST, CAMEROON

After a 3-year study funded by the French Ministère de la coopération, a management plan for five forest units covering a 450 000 ha area in the state forest in eastern Cameroon was published in 1995. This is a first step in the Cameroonian government's integrated forestry management pilot project for Dimako.

An inventory of forest resources was conducted for each unit to determine the number of marketable tree species, distribution according to diameter classification, and unfelled and market volumes. Proposals were

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Joint CIRAD-ORSTOM Unit

Biotechnology of
tropical forest symbioses

Emile Duhoux

made to reduce damage caused by current logging techniques, i.e. drawing up a detailed logging inventory and improving access-trail layouts.

These plans set out rules for sustainable logging, such as felling cycles, potential number of trees to be logged and logging volumes, minimum felling diameter, and species and areas to be protected.

A study of villagers' use of forest and bordering forest land highlighted their many complex interactions with forests. Villagers have always cleared and burnt nearby forests for cropping purposes, but they also collect many forest products.

The hinterlands of two villages were mapped on the basis of exploitation and traditional land-use rights, since one of the project aims is to promote a mutual rights and obligations approach in order to boost inhabitants' commitment to natural resource management.

Social forestry is a fairly recent concept in Cameroon forestry legislation and leaves the way open for local management by concerned villagers. The second stage of the project, therefore, will develop village management of individual stands in the state forest, village farming areas, and village woodlots. The practical framework may be limited to a few stands for demonstration purposes.

COOPERATION

Three Agreements Signed with CIFOR

CIRAD has signed three agreements with CIFOR, the forestry research centre of the Consultative Group on International Agricultural Research (CGIAR). Natural forest management is one of CIFOR's priorities.

The first agreement defined the institutional framework which has linked CIRAD with this international centre since its creation in 1992. The second launched a regional project on tropical rain forests of Africa (FORAFRI), in collaboration with five African countries: Cameroon, the Congo, Côte d'Ivoire, Gabon, and the Central African Republic. Research has been conducted for many years in these countries to devise silviculture and planning techniques to improve ecosystem productivity and, at the same time, preserve the specific diversity of natural forests. The project, which is funded by the French Ministère de la coopération, will summarize the results for the use of those who manage the forests, i.e. governments, companies, and rural communities. It should culminate in the setting up of a regional communication scheme on forest management. The third agreement concerns a 3-year mission of a CIRAD adviser to CIFOR in Indonesia as part of a forest management programme.

MODELLING THE DYNAMICS OF A TROPICAL RAIN FOREST

CIRAD constructed a growth model, based on data obtained from 1984 to 1994 in French Guiana, which simulates forest stand dynamics in humid tropical areas. The aim is to provide a tool for sustainable forest management which can predict the effects of timber logging and tree farming on stand density and the flora, both essential for maintaining the ecosystem.

Trees were first grouped according to diameter and species use, and then 2-year simulation time intervals were established. Lastly, the mean dynamics of a unit plot of about 1 ha were studied. The resulting model makes it possible to analyse the development of the diametric structure of the stand and its flora through the relative abundance of the main ecological types present: pioneer species, canopy heliophytes, undergrowth heliophytes, and sciaphytes.

Use of this stochastic model highlighted the dynamic balance within a natural stand close to a stable state. Moreover, logging and clearing simulations show that the forest recovers its initial diametric structure 50 to 100 years after a disturbance, but that the flora is modified over 200 years, with a notable increase in the number of softwood

heliophytes. This was verified on a medium-term basis (40 years) using data from other forests. An immediate consequence, as already observed in several countries, is that short felling cycles (30 to 40 years) will alter the range of logging species.

Forest Plantations

While there has been undeniable progress in the sustainable management of natural forests, production from these stands alone will not suffice to meet the needs of Southern countries. It will most likely be necessary to rely on forest plantations for supplies of pulp and timber wood. Research to improve planting techniques, increase tree productivity and optimize the management of planted forests should help in meeting these needs.

EARLY SELECTION IN EUCALYPTUS

How can the genetic value of a tree be appraised before it reaches maturity? There are early-selection methods for some temperate species, e.g. pine and poplar, which enable breeders to recognize the best trees in the field; however, research

on tropical plantation species such as eucalyptus has made little headway.

CIRAD and their Congolese partners in the Industrial Plantation Production Research Unit have conducted trials in this field in the Congo, a country that has pioneered genetic improvement in eucalyptus and contains extensive commercial plantations. Researchers studied variability in this species during stand development and discovered that there are two phases during the first 7 years of growth, the age at which trees are usually felled in the Congo: a genetically juvenile phase, when environmental effects on tree growth prevail, and a genetically mature phase, when the tree expresses its genetic potential. There is a weak correlation between the two phases.

Field breeding can begin only after the juvenile phase. Trials have shown that this phase can be shortened by increasing stand density: the phase lasts 2 years at a density of 625 saplings/ha and only 1 year at 2 500 saplings/ha.

In other words, with a plantation density of 700 saplings/ha corresponding to maximum marketing productivity, early field selection of growth characters is efficient after the 3rd year. Increasing stand density makes earlier selection possible and reduces the costs of setting up and

monitoring selection experiments. These results will give new impetus to eucalyptus improvement programmes in the Congo, regarding both the choice of parents for cross-breeding and the selection of new efficient clones for plantations.

GENETIC MAPPING IN EUCALYPTUS

Genome mapping is particularly useful in tree improvement. This technique enables early selection of prime plants in species that normally have to undergo long breeding cycles and take a long time to express characters. A full understanding of the genome is also essential for genetic manipulations necessary to obtain higher plant productivity.

Genetic mapping studies in eucalyptus have concentrated on one F_1 family derived from a cross between a female *Eucalyptus urophylla* parent and a male *E. grandis* parent. This family of hybrids grows faster and is hardier than those of other families now being tested in the Congo. The random amplified polymorphic DNA (RAPD) technique was applied to the two parents and to 93 hybrids planted in the Congo in 1992.

The *E. urophylla* genome map contains 244 markers, that of *E. grandis* has 211, grouped in both cases into 11 linkage

groups — corresponding to the 11 chromosomes of the genus. The former covers 1 331 centimorgans (cM), the latter 1 415 cM. The genome is estimated to be 99% saturated for *E. urophylla* and 95% for *E. grandis*.

As compared with the model plant *Arabidopsis thaliana*, eucalyptus has a small genome, a high percentage of encoding DNA, and small quantities of DNA per recombinant unit, indicating that these species could be readily used for cloning genes of interest to silviculturists.

These maps have been used in research on chromosome zones responsible for variations in quantitative characters (quantitative trait loci or QTL). In *E. urophylla*, researchers have found six loci involved in tree growth and four in tree shape. In *E. grandis*, they have detected eight loci involved in growth vigour and 10 in qualitative characters. In this latter species, six markers associated with wood density, in six linkage groups, are responsible for 60% of the total variance.

The markers specific to the cross studied were tested on parents from a factorial crossing design. The initial results suggest that a certain number of the markers have a wide specificity range and could therefore be used to assess other progeny in the Congolese

Eucalyptus genetic improvement programme.

CONTROLLED MYCORRHIZATION IN FOREST SEEDLINGS

Nursery mycorrhization has resulted in better quality forest seedlings, i.e. for rapid growth, high re-establishment rate, and vigour. This technique is becoming common practice in temperate areas, but not yet in the tropics. CIRAD, the French Institut national de la recherche agronomique (INRA) and the Institut français de recherche scientifique pour le développement en coopération (ORSTOM) have thus joined forces to develop this technique in Southern forest plantations. Research scientists currently have access to a collection of more than 40 strains of ectomycorrhizal fungi, isolated from the main tropical plantation species, and 20 strains of endomycorrhizal fungi.

Molecular characterization will be useful in conducting field surveys of strains introduced in controlled inoculation tests. It is already possible to differentiate *Pisolithus* isolates of temperate origin from those of tropical origin using these methods.

The root system of seedlings that leave the nursery must have as high a mycorrhization rate as possible to remain effective after

field transplantation. At present, six eucalyptus species grown in commercial plantations are being tested for their mycorrhization potential with different fungal strains.

Agroforestry

It is evident from the study of traditional rural societies and farming systems in tropical regions that farm management and forestry can coexist. For the farmer, trees are an integral part of the farming landscape and forest inhabitants have sometimes been able to develop agroforestry techniques to manage their environment. But current social changes in the South have considerably disturbed this equilibrium. One of the main concerns of the Agroforestry programme is to analyse factors which have a bearing on agroforestry management of rural areas from agroecological, socioeconomic, and political standpoints, in order to pinpoint options that are better adapted to present realities.

WOOD MARKETS MANAGED BY RURAL COMMUNITIES

Rural communities in Niger are steadily assuming control of

their forest lands with a view to sustainable management. This is one of the main results of the Energy II project, funded by the World Bank and the Danish government, which aims at setting up a rational system for supplying fuelwood to Niamey and other cities.

Regulatory and fiscal reforms adopted in 1992 to reorganize wood marketing and transport encouraged the creation of about 60 rural markets. The new laws give villagers exclusive rights for using the wood on their lands, but this has to be organized through rural markets.

Villagers, in agreement with their neighbours and the Environment Ministry, stake out the land to be logged according to a specific management plan. It is based on fundamental forest management rules recommended by research scientists to ensure forest sustainability and natural regeneration: saplings should not be felled if their trunks are less than a specified diameter, depending on the species; plant waste is to be left on the site; and pasturing during the rainy season following a logging operation is to be avoided.

The annual wood quota, set in agreement with the administration, is sold through the autonomously-run rural market. The new tax on wood

INTERNATIONAL MEETING

Agroforestry in the Humid Lowlands of Africa

The first Regional Symposium on Agroforestry Research and Development for the Humid Lowlands of Western and Central Africa, organized by CIRAD, the International Centre for Research in Agroforestry (ICRAF), the International Institute of Tropical Agriculture (IITA) and the Cameroonian Institut de la recherche agronomique (IRA), was held in Yaoundé (Cameroon) from 4 to 7 December 1995.

Six major themes were discussed: physiology and management of multipurpose trees; status and function of trees in agroforestry systems; contribution of agroforestry to agricultural production; livestock herding and agroforestry systems; socio-economic components of agroforestry; status of agroforestry in local and regional rural development.

Eighty participants from about a dozen African and European countries reviewed existing agroforestry systems, their development and promising innovations. The conference concluded with two agreements: to establish a network to bring together researchers working on similar topics and to take part in an ecoregional programme on humid zones involving relevant research institutes.

sales is lower for rural markets, thereby encouraging trader procurement. The revenues are

shared between the state, forestry services, and rural community funds.

In 1995, 15% of the wood supplied to Niamey came from rural markets. Although still low, this percentage should increase rapidly with the increased number of markets. In the villages, wood sales earned woodmen about 90 million CFA francs, while the taxes replenished rural community funds. The result was that more than 10 million francs were invested in equipment and common ventures, e.g. well digging, vaccination campaigns, staple food purchases, creation of mini-nurseries, and credit allocation.

Decentralization, i.e. giving villagers the responsibility for forest management, is positive on two accounts: it contributes to the economical and sustainable use of wood resources, and the resulting cash revenues encourage rural development.

The success of the Niger experience has prompted neighbouring countries such as Mali, Burkina, and Guinea into setting up similar projects.

THE ROLE OF FAIDHERBIA STANDS IN SAHELIAN FARMING SYSTEMS

Faidherbia albida grows in farmland surrounding most villages and is an integral element of

the Sahelian landscape. Since it turns green again in the dry season, this tree has the double advantage of not shielding crops from the sun during their growing period and providing forage when there are shortages.

CIRAD and the French Institut de recherche en biologie et écologie tropicales (IRBET) jointly studied *Faidherbia* stands in two areas of Burkina to clarify their mechanisms, dynamics, and role in the farming system. A few of the many results obtained are discussed below.

Contrary to widespread belief, this species can grow relatively quickly, about 3–4 cm/annum in diameter at best. It can produce about 50 kg/tree/annum of dry matter, making it an indispensable forage complement for livestock herders and farmers. When well pruned, it yields a balanced supply of leaves, pods, and firewood.

A study of its moisture circulation showed that *Faidherbia* is very susceptible to soil drought. Its highly efficient root system enables mature trees to draw moisture from the water table — it therefore does not compete with cultivated crops for surface moisture.

Comparative tests revealed that moisture circulation varies considerably depending on the tree's geographical origin.

These results should help in identifying fast-growing and environmentally well adapted *Faidherbia* species.

Faidherbia populations are generally expanding in the Sudano-Sahelian zone. Agriculture plays an essential role in this phenomenon. The tree regenerates by means of stump shoots or root suckers. Man's decision to protect or destroy these shoots has direct bearing on stand renewal. However, few new stands have been observed beyond village perimeters, within which livestock manure input is conducive to permanent cultivation. It appears unlikely that *Faidherbia* could be introduced or developed outside these village areas, in spite of the tree's beneficial effects on cotton and sorghum crops.

Wood

Southern countries have a growing need for wood for building timber, fuelwood, and material for various industries. Available wood resources will have to be used more rationally if these needs are to be met on a sustainable basis. The Wood programme intends to meet

this challenge through a better understanding of tropical species, determination of their properties, and improved methods for the conservation, processing, and use of different woods.

LIGNOCELLULOSE WASTE AND ENERGY PRODUCTION IN ASIA

In countries of the Association of Southeast-Asian Nations (ASEAN), i.e. Brunei, Indonesia, Malaysia, Philippines, Singapore, and Thailand, food processing and wood industries produce 100 million t/annum of lignocellulose waste, equivalent to 25 million t of oil equivalent, which represents the current primary energy consumption of the industrial sector in this zone. Firms could be autonomous if this waste were converted into energy, and the surplus could be sold on the fast-growing domestic markets.

Northern countries have developed and tested techniques to produce electricity from biomass by thermochemical methods. CIRAD research scientists have developed a software package which should assist end users in making decisions on suitable options. This work, funded by the European Union (EU), took 6 years to complete, three of which were spent in the countries concerned.

PRODUCTS FOR DEVELOPMENT

A Tropical Wood Database

The CIRAD database on the technological properties of tropical woods is the product of thousands of tests carried out on more than 1 000 forest species. It represents a vast collection and source of information that should help in creating extension training material on tropical wood quality, e.g. technical booklets and pamphlets, atlases, and software. It will also be useful for the study of relations between wood properties and ultimate uses with a view to enhancing forest resources.

The database is set up according to types of activity: anatomy, physics, mechanics, preservation, chemistry, thermochemistry, and processing. Cross-referencing of data from different origins can be done through trial number, species name, or origin.

The currently-available package includes several types of data on seven heat/electricity production techniques — easily accessible data on, for instance, waste volumes produced, energy prices, equipment costs, along with environmental data on greenhouse gas emissions (CO , CO_2 , NO_x) and sulphur gases (SO_2).

Once these parameters have been entered, the program classifies the techniques according to two main criteria: the annual net

cost savings, indicating the investment return; and the avoided cost of emission, indicating the efficiency of the technology for reducing pollution. It can also assess the sensitivity of a given technology in relation to factors such as the dollar exchange rate, global energy prices, investment costs, and currency interest rates.

The classifications obtained with this software are in line with private investments in ASEAN countries. The macroeconomic indicators used, such as nationwide energy savings and environmental costs, should provide arguments that support the use of biomass energy in Southeast Asia. The software could be extended for the analysis of situations in other tropical countries.

NEW EQUIPMENT FOR WOOD ANALYSIS

In 1995, CIRAD spent almost 3 million francs to modernize and add to its laboratory equipment for the Wood Programme, recently transferred to Montpellier, in conjunction with other CIRAD technology laboratories already set up in the Languedoc-Roussillon region of France.

The anatomy laboratory acquired new tools for studying cuttings: fluoroscopy, microphotography, and image analysis. This laboratory

has one of the 10 largest wood collections in the world (33 000 samples: 238 families, 2 113 genera, and 8 270 species).

Computerized equipment for determining the physico-mechanical properties of tropical wood is available: an extensometer, hydraulic and electromechanical presses, and systems analysis equipment. There are several air-conditioned rooms for wood stabilization.

Wood drying studies are carried out with a sorption apparatus to obtain specific data on equilibrium moisture content of tropical species during drying, two small-scale instrumental pilot dryers for kinetic analysis, and field metrology equipment for on-site control of industrial drying cycles.

Termites and other wood-eating insects necessary for standard conservation and natural durability tests are bred in padded air-conditioned compartments. Tolerance tests of wood-consuming fungi are carried out in laboratories equipped with sterile material required to handle fungi from a collection of over 100 species.

Lastly, thermochemical treatment for improving timber properties and the use of biomass energy can now be studied with a new pressurized pyrolysis oven and torrefaction loop.



THESES COMPLETED IN 1995

CIRAD Scientists

Evolution de la variabilité avec l'âge et corrélation juvénile-adulte dans des populations d'eucalyptus [Variability changes with age and juvenile-adult correlations in eucalyptus populations] by Jean-Marc Bouvet; Institut national agronomique de Paris-Grignon.

Modèle matriciel déterministe en temps discret : application à l'étude de la dynamique d'un peuplement forestier tropical humide (Guyane française) [Deterministic matrix model in discrete time: application for dynamics analysis of a tropical rain forest stand (French Guiana)] by Vincent Favrichon; Université Lyon I.

Utilisation énergétique par voies thermo-chimiques de déchets lignocellulosiques ; outils méthodologiques d'aide à la décision : cas des pays d'Asie du Sud-Est [Energy generation from thermochemical treatment of lignocellulose waste; methodological decision-making aids: a case study in South-east Asian countries] by Philippe Girard; Université technologique de Compiègne.

CIRAD Trainees

Contribution à l'étude des interactions essences forestières à croissance rapide et sols des savanes tropicales humides : cas de la réserve forestière de Melap-Foumban au sud-ouest du Cameroun [Contribution to the study of interactions between fast-growing forest species and savanna soils of the humid tropics: a case study in the Melap-Foumban Forest Reserve in southwestern Cameroon] by Raphaël Njoukam (Cameroon); Université de Gembloux (Belgium).





Food Technology and Rural Systems Department

Many areas of the world are experiencing the difficult dichotomy of growing populations — requiring ever more food and straining renewable resources — and an ongoing exodus from farming communities towards expanding urban centres. This is why the Food Technology and Rural Systems Department is seeking ways to meet urban food needs while stabilizing the rural environment.

For cities to be fed, supplies must be able to meet demand. This implies a thorough understanding of consumer markets and the required food products, as well as an ability to develop and furnish these products. It is essential to be able to produce in sufficient quantities on a regular basis, which means consolidating farming systems, reducing risks, and processing food products to satisfy local needs. Quality is also a priority, as the products have to correspond to consumer tastes, i.e. stabilizing, preserving, and processing the products using the appropriate technology.

In addition, prices have to fully compensate the farmers, processors, and retailers while remaining within consumer reach. This means installing cost-effective processing units, providing food manufacturers with technical advice, improving production systems, and ensuring energy efficiency in production, processing, and transport sectors. Prices must also encourage local production for export.

The Food Technology and Rural Systems Department has therefore set out to devise strategies for managing farms and rural areas. The aim is also to provide backup for food industries so that they can market high-quality products, along with financial, methodological, and decision-making support for farmers. ■

Food Technology, Industries, and Markets

It is essential for developing countries to upgrade local produce through processing technology, create new jobs, and reduce their reliance on imports. The programme aims at diversifying dietary uses of local produce, thus enhancing its value and meeting consumer demand. It is also devising advisory and decision-making methods that can be used by businesses and support organizations.

ONION PROCESSING IN CAMEROON

Strong demand for onions in southern Cameroon and neighbouring countries resulted in a proliferation of private merchants

and onion production throughout the northern region, whereas this crop is traditionally grown in the extreme north only. Production for 1995 was estimated at nearly 50 000 t.

Storage of fresh onions is a major problem, as postharvest losses can be as high as 60% in traditional storage conditions. CIRAD and the Institut de recherche agronomique (IRA) of Cameroon have designed village warehouses which have limited losses to between 5% and 30% and made it possible to market the product over a 6-month period. In 1995, 10 storehouses were tested in four onion-producing zones and 50 more are planned, along with the development of storage on trays. Technical pamphlets will be printed in the local dialects to facilitate efficient use of these installations.

Dry processing of onions is another research focus. Farmer groups and merchants have thus

FOOD TECHNOLOGY AND RURAL SYSTEMS DEPARTMENT

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Food technology, industries, and markets

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Pierre-Yves Le Gal

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Socioeconomics of innovations in rural systems and food technology

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Support Services

Documentation

Marie-Dominique Lafond

Publications

Monique Pellecuer

Computer services and biometrics

Michel Passouant

Training and communication

Jean-Luc Mazot

been able to test a new product, dry onion powder. Conformity and marketing trials resulted in a product that meets consumer expectations. Onion powder is easily sold on the retail market and sells very well when fresh onions are scarce in southern markets. A small business (Tiza) in Garoua was therefore able to process and market several tonnes of onion in its first year of operation. The increase of onion production in the north to meet urban demand in the south served as a springboard for the creation of a real local agro-industry.

SUPPORT FOR SMALL FOOD PROCESSING ENTERPRISES IN BRAZIL

The food industry is an important component of Brazil's economy, accounting for 10% of the GDP. Ninety-seven percent of the industrial sector is made up of micro or small enterprises that are faced with many technology, marketing, and management problems in the course of their development. CIRAD and the Universidade Nacional do Estado de São Paulo (UNESP), Brazil, have been working together since 1993 on a Franco-Brazilian programme which runs a technological advisory network for small and medium agro-industries, bringing together research and development centres,

INTERNATIONAL MEETING

Small Food Industries

A colloquium on small food enterprises was held in Montpellier on 19 and 20 October 1995. It was organized by CIRAD in conjunction with the Université Montpellier I, the scientific interest group Altersyal, the Ecole nationale supérieure des industries agricoles et alimentaires (ENSIA) and the Université de St-Quentin-en-Yvelines. More than 120 researchers from Africa, Latin America, and Europe participated in discussions on three topics: organization and operation of small enterprises; organization and operation of small enterprise networks; promotion policies and support programmes. Working groups underlined how the use of local know-how can help promote new activities and highlighted the wide variety of strategies used by entrepreneurs in adapting to market fluctuations.

universities, and professional organizations.

Based on experience acquired in cassava processing, an initial network, the Centro de Raízes Tropicais (CERAT), Brazil, centred on the roots/tubers subsector, was created within UNESP, bringing together about 50 research scientists and developers. A technical and economic investigation of the subsector was carried out for each region and type of product to gather

information about food demand and potential market opportunities. Training sessions were organized in processing techniques, quality control, and business management. Relay centres set up in the three main crop production regions provide the network with a basic infrastructure for work that is done locally. In addition, CERAT faxes out a weekly newsletter that gives firms price updates on raw materials and processed products.

In the light of the success of this project, the programme is now ready to move into other commodity subsectors such as milk or meat, where small- and medium-scale enterprises already function well.

DEVELOPMENT OF THE CASSAVA PROCESSING INDUSTRY

The cassava improvement programme in Latin America, supported by the European Union (EU), has been endeavouring since 1992 to reduce the negative impact of processing industries on the environment and increase the profit margin on processed products — thus strengthening present markets and creating new outlets. This programme is coordinated by CIRAD-SAR, in collaboration with CIRAD's Annual Crops Department (CIRAD-CA), the Institut français de recherche scientifique pour

PUBLICATION

Cocoa Market Oscillations

The history of world cocoa production is marked by the migration of millions of people seeking land upon which to grow this brown gold — most of this land being tropical forest. Hence, the history of cocoa is also that of deforestation: the irretrievable loss of a world heritage and ecological alteration prompting economic and social upheaval. There seems to be a common pattern, despite the cultural, social, and political differences between countries. Booms et crises du cacao expounds an interpretation of these cocoa migrations and corresponding economic fluctuations, notably over the past 20 years.

le développement en coopération (ORSTOM), the Natural Resources Institute (NRI), the Centro Internacional de Agricultura Tropical (CIAT), and the universities of Buenos Aires, the State of São Paulo, and del Valle in Colombia.

Five research activities are focused on: characterization of various cassava cultivars and appraisal of conventional processing techniques; waste treatment; bioconversion of cassava flour and starch; analysis of their functional properties in view of developing new products; and market studies on traditional and new cassava-based products. There are many possible industrial applications, e.g. a pilot processing

installation was set up in Brazil for enzymatic conversion of cassava starch into maltose syrups, which breweries can use as a substitute for malt. In Ecuador, the use of cassava starch in pork processing was tested.



Farming and Rural Land Management

Population growth and the integration of local economies into world markets entail increased strain on natural resources and the environment. Technical innovations are required to modify production systems, but it is often difficult to introduce such changes — they should be fully adapted to the prevailing economic and social diversity and variability. Farmers play an important role in the development of these innovations, participating actively in improving technologies for agricultural production and for managing rural natural resources.

ADVICE ON TECHNICAL AND ECONOMIC MANAGEMENT

Giving advice on management involves a set of methods to assist farmers in making decisions on

technical choices and farm management. It is based on technical and economic parameters to quantify and qualify farm output and test potential improvements.

Management advice is included in the "Training and Visit" extension programme which has been applied in villages of Burkina. It was set up in collaboration with the Institut d'études et de recherches agricoles (INERA) and extension and development organizations and combines analysis, training, and operations with small groups of literate people who convey what they learn to other villagers. The project helps villagers choose equipment and provides them with technical advice on planting fast-growing hedges, storing forage for the dry season, etc. Work was extended to 32 villages in 1995, involving 1 300 farms and 15 000 people.

In Réunion, the search for ways of reducing sugarcane harvesting and transport costs led to the creation and monitoring of planter groups managing shared equipment. Management advice is also of interest for work agencies that do subsidized special-order work for farmers. When control discs were no longer available for agricultural machinery, these agencies were unable to monitor and therefore invoice their work. A prototype measuring device, which can be installed on

tractors to record all parameters necessary for monitoring and invoicing, was designed by CIRAD in conjunction with the Association réunionnaise pour la modernisation de l'économie sucrière (ARMES), with the support of the firm CME-Precia, a technical lycée in Réunion, and the Direction de l'agriculture et des forêts (Réunion).

FODDER SILAGE IN RÉUNION

Cattle raising in Réunion has developed apace over the past 20 years under the impetus of a highland range management programme launched by the Associations foncières pastorales (AFP). Since 1975, the 400 members of these associations have developed over half of the 12 500 ha of rangeland on the island. Grass, the main forage crop, is overabundant in the hot rainy season and scarce in the cool dry season. This fodder shortage is a major worry for cattle herders and silage provides them with an efficient way to overcome the problem and improve rangeland management.

Several silage techniques have been jointly tested by CIRAD, the AFP union, the Coopérative d'utilisation de matériel en commun des plaines (CUMA),

PUBLICATION

Agricultural Research and Innovations in Tropical Africa

Recherche agricole et innovation en Afrique tropicale discusses agricultural research contributions to development in western and central Africa. Research has played an important role in the dynamics of successive periods of agricultural growth. However, proposed research innovations are accessible only to a minority of smallholder farmers because of the many constraints they face, and because of economic policies that involve various degrees of government intervention. National and international research bodies should take special measures to make African produce competitive on national and international markets.

the dairy-based Société d'intérêts collectifs agricoles (Sica-lait) and the Etablissements départementaux d'élevage (EDE), with funding from the regional government of Réunion. Silage in wrapped round bales was analysed from economic and technical standpoints in a doctoral thesis at the French Institut national agronomique Paris-Grignon (INA-PG) as part of a French Commission de coordination de la recherche dans les départements et territoires d'outre-mer (CORDET) project.

Herders appreciate this technique. Fodder storage quadrupled in

4 years — with fodder crops harvested from an area of more than 600 ha in 1995. About 6 000 bales can be bound in a five-operation harvesting sequence. The silage technique was introduced in New Caledonia and tested there by CIRAD's Livestock Production and Veterinary Medicine Department (CIRAD-EMVT). It has been very successful and prompted the development of a number of private firms.

RANGE-WATER CONTROL IN CAMEROON

A land management programme was set up in cotton-producing regions of Cameroon at the request of the Société de développement du coton (SODECOTON), with funding from two French agencies, the Caisse française de développement (CFD) and the Fonds d'aide et de coopération (FAC). This programme, which aims at developing sustainable agriculture while maintaining soil fertility, also encourages rural communities to take more responsibility in improving land use.

A part of the programme deals with sustainable renewable resource management, especially providing year-round access to water supplies for people and livestock. At four sites where users complained of poor water

INTERNATIONAL MEETING

Environmental Sustainability and Farmer Strategies in the Humid Tropics

One hundred and twenty people attended the seminar on Fertilité du milieu et stratégies paysannes sous les tropiques humides held in Montpellier from 13 to 17 November 1995. The challenge to come up with a more systems-based approach to sustainability was addressed: sustainability was defined as the ability to meet the needs of rural communities through their systems of production and development on a sustained basis — the result of interactions between man and the environment along with a changing social structure. This approach could give new impetus to operational-based research in humid tropical regions, an idea which aroused renewed interest among the African participants.

management and/or where often costly installations were deteriorating, access routes were improved to avoid water pollution and pumping systems were installed. Discussions and negotiations resulted in a decision to create management committees to arbitrate conflicts between farmers and herders, manage water resources for both human and livestock consumption, and develop user-payment systems.

STRATEGIES OF PRODUCERS IN THE LOYALTY ISLANDS

The 1988 French Matignon agreements on New Caledonia were followed by a new generation of development contracts. They underlined the importance of studying Melanesian production systems and trade channels. The aim was to determine why small projects, based on standard imported technical models for crop intensification in a fragile ecosystem context, were only partly successful.

In 1995, CIRAD began a joint study with the economic development service of the Loyalty Islands on local social group strategies, with land-use problems as the main focal point. The research was based on an analysis of different socioeconomic strategies. Some groups upheld a strategy of remaining in agriculture, others combined different options with the ultimate objective of finding ways for their children to gradually quit farming. The study also revealed that development projects are implemented within a land-tenure strategy. The research results were presented to the agricultural development services of the province. A similar study is under way in the northern province of New Caledonia.

Institutional Support

New development agents, private firms, and rural and farmer organizations have appeared on the scene following widespread government withdrawal. Research and extension institutions have had to rethink their objectives. The Programme could help these institutions work in harmony with such new development agents. Access to credit is a farmer's key to development. The task is thus to define mechanisms required to harmonize decentralized financing systems with conventional systems.

SUPPORT FOR AGRICULTURAL RESEARCH

The Institut centrafricain de recherche agronomique (ICRA), created in 1993, aims to promote agricultural research in the Central African Republic through programmes that deal with real problems facing farmers, creation of new research teams, and rehabilitation of former research infrastructures.

In compliance with the recommendations of the Ministère de l'agriculture et de l'élevage, ICRA has adopted a systems-based approach,

TRAINING

Seminar on Research and Development Awareness

Thirty-five ICRA researchers attended an awareness and training seminar from 13 to 25 November 1995 in the Central African Republic on research and development objectives, experiments, and technical and scientific information. Participants benefited from CIRAD's experience, with discussions on research and development and the systems-based approach, including concrete examples from the Central African Republic. Experimental methods applied in farming environments were studied.

In addition, there was a presentation on accessing international scientific literature and on the circulation of articles and scientific publications. This training course led to proposals for the organization of research units in several villages to address specific farming problems. CIRAD will provide support for this operational phase.

dividing the country into sections according to major farming systems. Research programmes in the two main regions of the country have been drawn up on the basis of preliminary assessment of farmers' needs and difficulties. The programmes are monitored closely to allow for continual readjustments with respect to their components and objectives.

At present, CIRAD is providing support for the organization and management of the Institute, the choice of research programmes, group training through a seminar on a systems-based approach and individual training at its research centre in Montpellier (France). A partnership is planned which will establish agreed procedures for wider-ranging cooperation between ICRA and CIRAD.

**AGRICULTURAL CREDIT
IN BURKINA**

Production systems in Yatenga (Burkina) were in a critical situation after 25 years of successive droughts. The women, instigators of new income-generating activities, were hampered in their projects by lack of investment capital. They could offer no guarantees, lived far from banks, needed only small loans, and were therefore of no interest to formal banking institutions.

To get round these restrictions, a new type of lending system was worked out on the basis of a mutual guarantee provided by groups of five people who are successively given access to loans. Loan agents go out to meet their borrowers. Loans are very small and are repaid on a weekly basis. This project was set up by CIRAD in association with Sahel-action (a Burkina field-based NGO) and the Caisse nationale

INTERNATIONAL MEETING

Farmer Organizations React to Withdrawal of Government Support

A workshop on the impact of the withdrawal of government support on farmer organizations was held in Mèze (France) from 20 to 24 March 1995. It was organized by CIRAD and the Fondation pour le progrès de l'Homme, in collaboration with the Centre international pour l'éducation permanente et l'aménagement concerté (CIEPAC), the Institut de recherches et d'applications des méthodes de développement (IRAM), the Groupe de recherche et d'échanges technologiques (GRET), and the Réseau groupements, associations, organisations (GAO). About 40 researchers, farm managers and NGO agents from Africa, Latin America, and France took part. Farmer federations were studied from various angles and support for these organizations — a worldwide social phenomenon — was discussed.

de crédit agricole (Burkina), which provides capital through a subsidy from the Caisse française de développement (CFD).

To date, 25 000 people have been loan beneficiaries; the average loan has increased from 15 000 to 30 000 CFA francs and loan agents employed by the project have increased their productivity. The loan recovery rate is 99%.

PRODUCTS FOR DEVELOPMENT

Winstat_{IC}

Winstat_{IC} is a statistics software package for Windows that was developed jointly by CIRAD and the Institut technique des céréales et des fourrages (ITCF). This first version supplements the Stat-ITCF, Cstat, and Lisa programs and addresses the needs of users involved in graphic data scanning and hierarchical survey techniques (questionnaire design, data acquisition, and results analysis). *Winstat_{IC}* also computes important statistical parameters and enables the user to solve many sampling problems. New modules are currently being developed that will include common statistical methods (general linear model, factor analysis) to be integrated in the subsequent versions. The thousands of users of Stat-ITCF, Cstat, and Lisa will probably find this software package of considerable interest.

Other types of loan have been tested, such as the 6-month employment loan, and the financing of other activities is being considered. An attempt is being made to adjust loan terms, i.e. amounts, periods, and repayment schedules, according to the economic activity of the borrower. The project was extended to three other provinces, and the next step will be to set up a permanent agency that will be fully responsible for credit management.



THESES COMPLETED IN 1995

CIRAD Scientists

Le cadre du changement social dans la plaine de Hawd, Somalie [The framework of social change on the Hawd plain in Somalia] by Marcel Djama; Ecole des hautes études en sciences sociales, Paris.

Gestion collective des systèmes de culture en situation d'incertitude : cas de l'organisation du travail en double culture dans le delta du fleuve Sénégal [Communal management of cropping systems during difficult periods: case study on work-sharing in a two-crop farming sequence in the Senegal River delta] by Pierre-Yves Le Gal; Institut national agronomique de Paris-Grignon.

Retexturation de pulpes de fruits de la passion à l'aide d'alginate : étude de l'influence des paramètres de formulation sur les propriétés rhéologiques des gels [Texturization of passion fruit pulp with alginate: study of the influence of formulation parameters on the rheological properties of gels] by Claire Mouquet; Ecole nationale supérieure des industries agricoles et alimentaires, Massy.

Etude de l'ensilage en balles enrubannées sous climat tropical d'altitude : cas de fourrages tempérés et tropicaux récoltés à l'île de la Réunion [Study on silaging in wrapped round bales of forage material in tropical highlands: case study on temperate and tropical forage crops harvested in Réunion] by Jean-Marie Paillat; Institut national agronomique de Paris-Grignon.

L'innovation en milieu paysan ou la capacité des acteurs locaux à innover en présence d'intervenants extérieurs : nouvelles pratiques de fertilisation et mise en bogue dans le Niumakélé, Anjouan, Comores [Innovation in farming areas or the ability of local inhabitants to innovate in the presence of extension agents: new fertilizing and fallowing techniques in the Niumakélé, Anjouan, Comoros] by Nicole Sibelet; Institut national agronomique de Paris-Grignon.

Crise et perspectives de recomposition des systèmes productifs agricoles de zones difficiles confrontées aux ajustements et à la réforme de la PAC : le cas de l'Aveyron [Recession and prospects for the reconstitution of agricultural production systems in problem areas faced with adjustments and CAP reform: a case study in Aveyron] by Betty Wampfler; Ecole nationale supérieure agronomique de Montpellier.

CIRAD Trainees

Entrepreneuriat, organisation et fonctionnement en réseaux : la transformation du manioc au Congo [Entrepreneurship, organization, and network operations: cassava processing in the Congo] by Jean-Jacques Magloire Bazabana (Congo); Université Montpellier I.

Déshydratation-imprégnation par immersion en solutions ternaires : étude des transports d'eau et de solutés sur gel et produits d'origine animale [Immersion dewatering and impregnation in ternary solutions: study of water and solute transport in gels and animal-based products] by Philippe Bohuon (France); Université Montpellier II.

Les initiatives individuelles et collectives des femmes rurales : approche socio-économique des activités des femmes du département de Bignona, Sénégal [Individual and collective initiatives of rural women: socioeconomic assessment of women's activities in the department of Bignona, Senegal] by Christiane Dardé (France); Ecole nationale supérieure agronomique de Montpellier.

Dynamiques des contrats de travail en agriculture de plantation villageoise : le cas de la Côte d'Ivoire [The dynamics of employment contracts in village plantation farming: a case study in Côte d'Ivoire] by Claire de Fina (France); Ecole nationale supérieure agronomique de Montpellier.

Etude d'un réacteur continu à membrane d'ultrafiltration pour la conversion enzymatique de l'amidon de manioc en sirop de maltose [Study of a continuous reactor with an ultrafiltration membrane for enzymatic conversion of cassava starch into maltose syrup] by Ouassila Gaouar (Algeria); Université Montpellier II.



Management, Common Services and Laboratories, and Documentation Department

In 1995, CIRAD-GERDAT maintained high levels of activity within its research units and programmes and extended its collaboration. The Renewable resources and environment management unit contributed to the definition of local management of renewable resources in Madagascar. The Plant modelling unit linked up with INRA to create a forestry research

laboratory. The Biotechnology for tropical crop improvement unit concluded agreements with CIMMYT, as well as the Caobisco group, in the field of biotechnology. The Soil and plant analysis unit participated in the design of a laboratory in the Philippines.

Another departmental speciality is the creation of computer-based aids, such as the Mata agricultural policy decision-support model, developed by the Agricultural policies and outlook studies unit, or the SGR® biomodel for migratory locust population monitoring, which has recently been validated by the Operational ecology and acridology programme.

Finally, its activities have led the Department to secure contracts for the industrialization and marketing of the products of its research. For example, Rita®, a special container designed for use in plantlet production, or the Amap virtual-imaging computer programs, widely distributed in Europe and North America.

The Department has been able to enhance its achievements through industrial agreements and contracts. This represents a proof of quality for its research and is also the concrete result of a scientific policy associating research and commercial development. ■

Operational Ecology and Acridology

Prifas, the Operational ecology and acridology programme, celebrated its 20th anniversary in 1995. Since its creation, it has based its research work on an in-depth understanding of field conditions and its major concern is to disseminate widely information on locusts. Three examples of this year's activities illustrate this approach: the modelling of locust phenomena, the study of the

stakes involved in locust control, and the 10th anniversary of the SAS network newsletter.

VALIDATION OF THE SGR® BIOMODEL

The SGR® biomodel is a demographic model specific to the desert locust. It allows growth in population levels of this formidable pest to be known every 10 days anywhere in its immense distribution area. Development of the model required 10 years of effort and was supported by the FAO, the European Commission, and the French Ministère de la coopération, with

MANAGEMENT, COMMON SERVICES AND LABORATORIES, AND DOCUMENTATION DEPARTMENT

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Michel Griffon

Renewable resources and environment management

Jacques Weber

Soil and plant analysis

Paul Fallavier

Support Services

Training

Marc Roesch

Scientific and

technical information

Jean-François Giovannetti

Computer services

Joël Sor

Physical plant and maintenance

Didier Servat

the participation of Météo-France. The scientific basis of an operational prototype was tested, using statistical evaluation methods to establish correlations between the deductions of the model and the field situation. These tests confirmed the reliability of the SGR® biomodel and indicated ways to improve its performance. Operational development of this biomodel should make it possible to monitor the desert locust routinely in the 60 countries it colonizes.

PROSPECTS FOR LOCUST CONTROL IN THE SAHEL

In order to clarify the long-term prospects for the improvement of locust scouting and control south of the Sahara, Prifas has, at the request of the European Commission, carried out an in-depth study in Burkina, Chad, Mali, Mauritania, Niger, and Senegal. Several contacts were made in order to collect information from the partners concerned, and a key workshop was organized in December 1995 in Niamey, Niger, assembling around 15 representatives of the 6 national crop protection services and 4 regional organizations.

TEN YEARS OF THE SAS NETWORK

For the 10th consecutive year, Prifas coordinated the SAS

— locust and grasshopper surveillance in the Sahel — network, which links 3 000 voluntary correspondents. Again, this year, it has produced six newsletters, in French and English, intended for network correspondents. The effective educational impact of these newsletters is confirmed year by year.

Biotechnology for Tropical Crop Improvement

The Biotechnology for tropical crop improvement research unit, Biotrop, has been active in three areas: genome mapping, *Bacillus thuringiensis* toxins, and in-vitro culture, with the double objective of micropropagation and genetic transformation.

GENETIC MARKERS IN SORGHUM AND BANANA

In sorghum, molecular markers have been used to identify the genetic factors that determine productivity and grain quality, two characters that conventional breeding has never succeeded in associating in *guinea* x *caudatum* hybrids.

PRODUCTS FOR DEVELOPMENT

A Specific Promoter Tested on Rice

Promoters are sequences of DNA, situated upstream of a gene, that can modulate transcription of the gene according to the context. Thus, certain promoters authorize the expression of a gene under their control only in a particular tissue. This specificity is of major interest to genetic transformation since it allows precise targeting of the tissue within which the transferred gene will be expressed: for example, in the case of a transfer of resistance, the tissue attacked by an insect pest, and excluding other parts of the plant where useful insects reside.

By combining the skills in virology and genetic transformation within its research teams, CIRAD has been able to identify a promoter of this type — the maize streak virus promoter. Cloned, then transferred, in association with the gus reporter gene, into transgenic rice, it has been shown to be specific to vascular tissue. The stability of its activity with time and after several generations' cloning is under study. It constitutes one of the first elements in the collection of specific promoters that CIRAD is establishing.

In a first phase, a genetic map of sorghum was constructed using two segregated populations obtained from crossings between one *caudatum* line (IS 2807) and two *guinea* lines (379 and 249).

The map currently includes 199 loci, identified using 190 heterologous probes of maize and sugarcane, divided into 13 linkage groups, and covers a genetic distance of 1095 centimorgans (cM). When the map is compared with saturated gene maps produced in the USA, it can be considered as representative of 80% of the species genome.

In a second phase, this map has been used to localize the QTLs, (quantitative trait loci) — regions of the genome involved in the expression of quantitative characters associated with productivity, grain quality, and panicle mould. This localization is carried out in association with breeders in Burkina for agronomic characters and with CIRAD's cereal technology laboratory for quality. It appears that certain QTLs controlling these characters are situated in common zones of different linkage groups. Although these results do not yet allow all the mechanisms involved in gene expression in *guinea x caudatum* crosses to be understood, they open the way to early marker-assisted selection, which should enable the transfer of a small number of the QTLs in a progeny to be monitored.

For banana, microsatellites were chosen for study. These are repetitive sequences of the genome that are highly polymorphic since

PRODUCTS FOR DEVELOPMENT

A Simple Screening Method for *Bacillus thuringiensis* Toxins

An in-vitro screening technique for the toxins of Bacillus thuringiensis based on immunocytochemistry and scanning laser image cytometry was developed last year on rice stem borer. It enables detection of the presence of toxin-binding sites and quantification of their distribution on sections of insect intestine.

The method has been simplified by directly coupling the toxins to a fluorochrome. This new detection method involves only observation under fluorescence microscopy and yields results identical to those obtained by cytochemical localization.

The method has been used with success on two insect pests of cotton, Cryptophlebia leucotreta and Pectinophora gossypiella. It can now be used routinely.

they can present, for the same locus, up to 20 different alleles. Their use for the study of large numbers of samples is rapid and low-cost and requires only small amounts of DNA, of the order of 10–50 ng. On the other hand, the development of such markers is a laborious operation. The first functional microsatellites were created by CIRAD on *Musa acuminata*. There are now 25. They have enabled the species gene map to be enriched and have proved to be a very powerful tool for varietal identification.

BACILLUS THURINGIENSIS TOXINS

Bacillus thuringiensis is a bacterium capable of producing a whole range of insecticidal toxins. Some of these toxins are of major interest to agriculture since they target insect pests of crops. This is the case, among others, of Cry1 toxins, which are active against Lepidoptera. Identification of the bacterial strains synthesizing this type of toxin using the standard bioassay methods encounters a certain number of difficulties, which may be impossible to overcome. A rapid screening technique using PCR has recently been developed. It is based on the use of four specific gene primers coding for the four categories of toxin identified, each active against a different class of insects: Cry1, Cry2, Cry3, and Cry4. This preliminary sorting means that the bioassays need to be performed only on the class of insect against which the toxin is effective, thereby speeding up identification of strains of interest.

In collaboration with CIMMYT, a synthetic gene for Cry1B toxin has been constructed, i.e. modified to obtain its correct expression in the plant; it will next be integrated into the vectors usable in transgenesis. All construction processes are presently operational. A vector suitable for different toxins and target crops has been produced for dicotyledons. It has

PRODUCTS FOR DEVELOPMENT

**Rita[®], Temporary Immersion
In-Vitro Culture**

After having developed an in-vitro culture system based on the principle of temporary immersion, CIRAD has designed and produced a container specific to this application, Rita[®]. Already successfully tested on different propagation processes — e.g. somatic embryogenesis and microcuttings — and on several species — e.g. banana, coffee, rubber, and citrus — this container should answer the needs of industrial plantlet production and of research. It is already installed in the in-vitro culture laboratory set up by the tree crops department in Uganda, in collaboration with the National Agricultural Research Organization. Since its market launch in autumn 1995, it has been ordered by about 20 laboratories around the world.

already been used to transform coffee plants for resistance to *Perileucoptera coffeella*. A vector suited to monocotyledons is currently under development.

CIRAD, in association with the University of Montreal (Canada) and the Pasteur Institute, is investigating the mode of action of these toxins. Their structure includes two subunits, the "receptor domain", which recognizes the binding sites on the epithelial cell membrane of insect midgut, and the "channel domain", which makes a hole in the membrane and causes

its destruction. It was presumed that these domains were independent and that the specificity of the toxin was associated with the receptor domain. Chimeric toxins have been constructed, associating the receptor domain of the Cry1C toxin, active against *Plutella xylostella*, and the inactive channel domain of the Cry1E toxin, and vice versa. Toxicity tests on the insect gave negative results, but the same toxins have been shown to be capable of forming pores in artificial lipid membranes and cell cultures. The specificity of the toxin, therefore, does not depend uniquely on its receptor domain, but on the interaction between the different domains.

**SOMATIC EMBRYOGENESIS OF
COCOA**

Somatic embryogenesis from mother tissue is, for the cocoa tree, a particularly interesting way of propagating and distributing selected trees. It poses, however, a certain number of problems, notably concerning the maintenance of embryogenic capacity and the conversion of somatic embryos into plantlets.

The maintenance of embryogenic capacity has been improved using a culture system of temporary immersion in liquid medium. This technique has enabled friable embryogenic calluses to be obtained from staminodes (abortive

stamens) and leaves. Suspensions of embryogenic cells have been set up and maintained.

The preliminary stages of the conversion of somatic embryos into plantlets have benefited from a comparative study of the latter phases of somatic and zygotic embryogenesis. Two stages were observed for zygotic embryogenesis: the growth of embryos, then their maturing, characterized by the accumulation of reserves and dehydration. Under the conditions of culture used we did not obtain the accumulation of reserves in somatic embryos. A maturation medium promoting the synthesis of these reserves was therefore developed using high concentrations of saccharose and abscissic acid. It has enabled the maturation rate of somatic embryos to be improved. It remains to introduce a dehydration phase, which should lead to a better regeneration of the plantlets. There now exists a firm basis for the somatic embryogenesis of the cocoa tree.



Plant Modelling

The evaluation report on the Plant modelling unit, drawn up in 1995 by the external review panel,

highlights its achievements in scientific collaboration and recommends its consolidation. A network of research organizations is therefore being set up around the particular approach to modelling biological processes developed at CIRAD. A major element of this network came into existence in 1995 with the creation of a combined CIRAD-INRA laboratory. The Plant modelling unit also continues to develop and distribute its virtual-imaging computer programs, notably with the launch of a distribution network in the USA.

SIMULATION OF TREE MECHANICAL BEHAVIOUR

Foresters and wood industrialists are often confronted with technological problems when using timber: e.g. splits at felling and warps at sawing. These inconveniences stem from the mechanical behaviour of the standing tree.

In order to make best use of the light, the tree develops a generally highly-erect, aerial architecture, which gives it an unstable character. Cambial growth, which produces the rings, ensures that the main axes, particularly the trunk, are rigid. During the maturation phase, the newly-formed wood can modify its structure in response to the effect of external factors. This phenomenon generates

internal forces, which help to balance the structure, followed by modifications to tree shape due to the production of reaction wood. These mechanical and biological modifications lead to constraints on growth, the reflection of which in the rings explains the splits and warps observed.

A tool for the analysis of the mechanical behaviour of the growing tree has been developed. It functions in interaction with the plant architecture modelling computer program Amappara and uses finite element analysis procedures. It provides a better understanding of the relations between the topological evolution of the tree and the distribution of the constraints in the trunk, and thus enables the quality of the wood to be predicted.

ASSOCIATION WITH INRA IN FORESTRY

After several years of collaboration within projects funded by the European Union, closer ties between the INRA department of forestry research and the Plant modelling unit became necessary. The modelling and simulation methods developed at CIRAD correspond, in fact, to the needs of forestry research programmes: quantification of biomass, wood quality and mechanics, plant-environment interactions and simulation of tree densities.

So the Amap-Forêt laboratory was created. It will be installed on the Baillarguet campus in early 1996 and will house researchers from INRA and CIRAD departments.

DEVELOPMENT OF AMAP COMPUTER PROGRAMS

After Japan, which remains the principal market for Amap programs designed for use in landscaping, it is in the USA that the Plant modelling unit has recently set up a distribution network for its programs. Mississippi State University is responsible for user training. The results recorded in 1995 are promising: several licences have already been sold in the USA and Canada.

The range of Amap programs expands to suit national markets with increasing precision by developing partnerships with potential users as soon as new products are defined. Thus, the Plant modelling unit has started to work with professional partners, in a consortium funded by the European Union, Imago metropolis, to develop landscape simulation. This consortium includes a user, the Institut d'aménagement urbain of the Ile de France region, an Italian school of architecture, Politecnico di Milano, and a computer research institute from Portugal, INESC. This

collaboration should lead to a new generation of computer programs, intended for the European, but also international, market, better able to respond to the needs of urban planners and environment professionals.

Agricultural Policies and Outlook Studies

The Agricultural policies and outlook studies unit works according to four main research themes: outlook studies for sustainable development, agricultural policy and international economics, institutions and the role of government in agriculture, and market and household responses. In 1995, the Unit's work led to significant results in the field of food outlook studies and agricultural policies.

AN INTERNATIONAL SEMINAR ON THE DOUBLY-GREEN REVOLUTION

Since 1993, CIRAD has participated in various international forums introducing the idea that, in order to respond to world food

needs at the start of the next century, a new green revolution is necessary.

Several international organizations, notably FAO, the World Bank, and IFPRI, have worked in this field. CIRAD, for its part, has undertaken technical and economic studies on the conditions of emergence of a more productive and more environmentally-friendly agriculture.

The interest and diversity of these initiatives led CIRAD to organize in 1995, in Poitiers, an international seminar assembling the partners involved. This seminar was the occasion to debate world food outlook studies on the basis of an IFPRI model, Vision 2020. It enabled Professor Conway, as co-inventor, to develop the concept of "doubly-green revolution". The seminar provided an overview of current research on the institutional and economic conditions of the new green revolution and on the technological progress required. The necessity of basing research on an ecoregional approach and of giving centre-stage to farmers and their organizations was stressed.

MATA: A DECISION-SUPPORT MODEL

Mata (Multi-level Analysis Tool for the Agricultural sector),

an agricultural policy decision-support model, has recently been developed by CIRAD.

It enables evaluation of the impact of economic policies on agricultural production and different farming systems, and on consumers and processing industries.

The model is based on a detailed description of the behaviour of economic agents, production subsectors, and macroeconomic impacts. Its originality is that it allows a dynamic and recursive approach, an evaluation of the long-term impact on the environment, and an assessment of risk. The model is simple to use and is flexible in application.

Mata is already widely used: in Indonesia, to evaluate the effects on production and employment of the easing of restrictions on the soybean market, and to identify the policies likely to lead to self-sufficiency in soybean; in Benin and Burkina, to estimate the impact of the measures accompanying the devaluation of the CFA franc; in Thailand, to analyse the effects on farmers of the reduction of the world cassava market and to define sector policies capable of countering these effects; in Vietnam, to study the transition towards a market economy and its consequences for farmers in the Red River Delta.

AGRICULTURAL POLICIES IN ACTION IN LATIN AMERICA

For several years, CIRAD has supported, within IICA, a research programme on agricultural policies in Latin America. The studies have concerned the structural adjustment of agricultural economies in the subcontinent, then the problems of subsector competitiveness. They have resulted in an original institutional model allowing all the actors of a subsector to be brought together to work out national policy for the sector under consideration.

This model is based on the establishment of commissions assembling, in each country and for each subsector, representatives of the private sector (farmers' unions, and chambers of agro-industry, agriculture, and commerce) and the public sector (ministries of economics, commerce, rural development, etc.). The role of these commissions is to promote agreement between the different actors of a subsector in order to define a policy accepted by all concerned.

This type of commission functions as follows. It receives requests from the private subsector to work on a particular subsector. It then draws up terms of reference for a study of the subsector based on previous research on the competitiveness of the subsector.

The study is assigned to a local economist. In parallel, a "national programme" for the subsector is set up and placed under the supervision of a "manager". The study and the first proposals it contains are presented to the actors of the subsector at national seminars, which generate prognoses on the possibilities of improving the functioning of the subsector. The national programme manager then looks for agreement between the different partners on the measures to be taken, both by the private sector and by government.

These commissions are a novel institutional entity. The government does not play a central role of organizer and initiator of development, but a functional role, in line with other actors. Private enterprise is represented and takes its place opposite the administration. Information from the subsector study is available to all the actors, who thus hold complete data on the markets and the behaviour of the other agents. Finally, the commission introduces a "flexibility" to the functioning of the markets.

This institutional model appears to be particularly well-suited to a context where structural adjustment and the easing of restrictions have limited the initiating and organizing role of government.

Renewable Resources and Environment Management

Two years after its creation, the Renewable resources and environment management unit, Green, is developing its activities in several fields: water and runoff-erosion, forests, wildlife, nomadic grazing, and biodiversity. In each of these fields, it has carried out methodological research and fieldwork, and has established relations with universities and research teams in Cameroon, Senegal, Madagascar, and Brazil. It has also strengthened its training programme with the supervision of theses and the organizing of seminars in association with universities and grandes écoles. Its aim is to participate in resolving specific development problems whilst at the same time carrying out theoretical and modelling studies.

LOCAL MANAGEMENT OF RENEWABLE RESOURCES IN MADAGASCAR

In Madagascar, the Unit has played an important role, in collaboration with Madagascan teams, in drafting a national policy on the local

TRAINING

Management of Renewable Resources

Green organized, as every year, a training course in the management of natural resources, which brought together 25 trainees, development managers, and African and French researchers. It ran courses in Madagascar as well as in France (EHESS, ENGREF, Ecole des mines, INA, Université d'Orléans, Université de Créteil). It instituted a seminar on ecosystems and sustainable development with the postgraduate school of the Université Paris IX-Dauphine concerned with the mathematics of decision-making.

management of renewable resources and of areas under State ownership — which constitute the key part of the island's natural heritage. It has, among other things, organized several national workshops, which have revealed the necessity for a contractual arrangement between the government and local communities, on a voluntary basis. To promote this new policy, a reform programme will be initiated in which local communities will be entrusted with managing renewable resources and access to them. Implementing this programme will be the particular responsibility of specially-trained mediators for the environment. They will help communities to draw up

management plans and design local management structures, as a basis for contracts between the government and communities. The programme also includes a system for levying a tax on the collecting and gathering of resources from the natural environment, which will give an intrinsic value to the resources and will provide the revenue required to manage the system. This taxation, variable according to location, will allow resource collecting and gathering to be directed towards little-exploited areas and will promote, in particular, the production of firewood in periurban areas.

Local management of renewable resources has become a key component of the environmental plan in Madagascar, which includes the objective of drawing up at least 200 contracts between 1997 and 2002. This is a large-scale programme of reform, concerning potentially 12 000 communities. The Unit has participated in evaluating this second environmental plan.

ECOSYSTEM MODELLING

The study of ecological and social dynamics is particularly complex. In order to tackle this complexity, the Unit has developed methodological tools based on multiple-agent modelling. This modelling clarifies the processes of decision-making

and decision-implementation as complex problems: it means understanding the rules of interactions between actors with different representations and influence. Through simulating the behaviour of these different agents in a given ecosystem, the Green team attempts to understand its overall functioning. Several simulators have thus been conceived, corresponding to two different approaches.

In the first approach, research on the management of common property is based on simple, synthetic models, such as those based on games theory or ecological models of competition and predation. Two simulators incorporating a spatial dimension have been developed to make the models more complex: one reconstructs the interactions between several players, and the other models the interactions between different predators and preys. Through the rules of local interactions between agents, it is thus possible to simulate more complex behaviour than that of synthetic models. This leads to solutions more true to life in social and biological terms.

In the second approach, studies in the field aim to understand the functioning of ecosystems by reference to multidisciplinary knowledge. Modelling, by creating

a virtual world to represent the observed world, participates in this by constructing an overview of the interactions between the different dynamics. It involves identification of the correspondence between the spatial and temporal scales and the levels of organization. This approach led to the construction of a simulator that enabled different water management methods in the irrigated areas along the Senegal river to be compared. The simulation obtained shows that, when the agents can exchange information and services, it is the structure of the social fabric that influences the functioning of the area. Comparing these results with reality in the field enables the models developed to be refined. By alternating between modelling and fieldwork, a better perception of the complexity of the questions treated and development of the systems observed can be obtained.

Whether they involve making the models more complex or deciphering reality, the different simulators constructed allow, in association with field research, definition of the relevant levels for dealing with questions arising in the use of renewable resources.

One of the firm results expected from this modelling is the reduction in the repeated trial and error initiatives in development projects,

the "learning by doing" for which the local inhabitants all too often pay the price.

Soil and Plant Analysis

The Soil and plant analysis unit carries out its activities in the departments newly-installed at Baillarguet and in research organizations established in the region. Thanks to the expertise acquired, it is also called on to design and supervise the installation of laboratories. Finally, it carries out considerable research work on soil chemistry. In 1995, its activities became better known through various publications.

LABORATORY ANALYSES

The Unit is expanding its analyses to cattle feeds, to respond to requests from the Livestock Production and Veterinary Medicine Department (CIRAD-EMVT), and performs additional analyses for external organizations, notably CNRS and ORSTOM. It has also entered into a close collaboration with the latter in research on the physico-chemistry of acid soils. And it now

INTERNATIONAL COOPERATION

A Laboratory in the Philippines

The Unit has been assigned the task of designing the new analytical laboratory of the Philippine Coconut Authority, funded by the World Bank. This project, spread over 2 years, includes the overall design of the laboratory, the definition of the analytical methods, the selection and installation of equipment, and the training of the managers. The laboratory will become operational during the second half of 1996.

participates in the analytical control network coordinated by the Bureau interprofessionnel d'études analytiques (BIPEA), in order to obtain certification from the Ministère de l'agriculture in recognition of the quality of its soil analyses.

TOLERANCE OF MAIZE TO ALUMINIUM TOXICITY

The first phase of the research project on the tolerance of maize cultivars to aluminium toxicity in tropical acid soils has come to an end and initial results have been obtained. It was observed that, in tolerant cultivars, absorption of aluminium by the root apices increased in the presence of dinitrophenol, a reagent that blocks cellular respiration. This suggests that aluminium tolerance involves energetic mechanisms that actively exclude aluminium in the root apices. In addition, a screening test of cultivars in nutritive solutions

was validated using the results obtained in the field in Cameroon and Brazil. The second phase of this programme, also funded by the European Commission, will be focused on modelling the physico-chemical phenomena of tolerance at the soil-root interface.

ALKALINIZATION OF IRRIGATED SOILS

A study of the geochemical and physico-chemical mechanisms involved in the alkalization of irrigated soils is being carried out with the Water management research unit of the Annual Crops Department (CIRAD-CA). It covers two aspects: cation exchange on the soil mineral colloids and the speciation of ions in the soil solution, including the phenomena of precipitation and dissolving of minerals. The aim is to develop a rapid and precise method of predicting the evolution of these soils.

Training

One of CIRAD's missions is to enable young French scientists and those from other countries to do research and learn research techniques. In 1995, CIRAD was responsible for the training of

808 external researchers, 411 of whom were from Southern countries. It also arranged 430 professional training courses for its own personnel, which represents an increase of 50% over the previous year.

In addition, it is developing its expertise with the organization of specific training courses in partnership with others. The following examples illustrate the diversity of its activities. A training course for university professors and development staff was organized, in collaboration with CNEARC, at the University of Southern Mindanao in the Philippines. It covered rural development and included a field study of pioneer settlements in the Arakah valley. Two specialized training courses were run in association with several research institutions, including INRA and ORSTOM. One of these, concerning on-farm research, was arranged for visiting researchers. The other, on research and development in the light of economic and environmental challenges, was aimed at expatriate staff from the French Ministère de la coopération.

Finally, CIRAD assists in planning training programmes spanning several years. It collaborated with ICRA in the Central African Republic, and participated with IRAG in Guinea in a study on human resources development and research plans.

Scientific and Technical Information

In 1995, the central Scientific and technical information unit reorganized the Philippe Ariès library, which now houses the entire collection of previous and current documents of the Montpellier centre.

New reading areas have been created to facilitate access to recent documents; more than 1 000 periodical titles, 10 000 monographs and around 20 international databases are now available there.

In addition, the Unit participated in creating the national database of scientific expertise, Fines, for which it has already provided descriptions of the skills of over 100 personnel. The aim of this database, set up on the initiative of the Ministère de la recherche, is to "make available to commerce and industry a tool for improving the management of the industry-research interface".

This work led to investigating how the skills of the personnel listed might be merged with CIRAD's internal information system, Atlantis. Computer scientists favour the use of software able to perform

on-line searches for skills available within an organization in a specific field, and to generate different CV formats automatically.

Computer Services

In 1995, CIRAD modernized its internal management aids in order to provide itself with the hardware and software required to set up an operational management information system that is more accessible to the decision-makers than before and therefore of wider usefulness. New-generation management software packages make this possible. They are built around relational databases that facilitate data access. Used in a client/server format, these access facilities allow the installation of powerful data-retrieval aids.

CIRAD has committed itself to several developments in this direction, exploring two approaches.

On the one hand, there are ready-to-use, specialized applications, answering a precise need and therefore easily learned by users, but which are of inflexible format and data-retrieval mode. On the other hand, there are "information-centre" environments

which are much more flexible, supplied with menus for most requirements, and allowing experienced users to program their own queries. Though at an early stage of development, these approaches are in line with the management software of the future.

In addition, CIRAD still aims to move from data management to communication. The central computer service therefore intends to promote and put into operation communication protocols and software used by the international scientific community on Internet. This approach has been extended, on an "intranet" basis, by ensuring its internal communication, retrieval, and presentation software conforms to Internet formats.



THESES COMPLETED IN 1995*

CIRAD Scientists

Analyse du comportement mécanique d'une plante en croissance par la méthode des éléments finis [Analysis of the mechanical behaviour of a growing plant using the method of finite element analysis] by Thierry Fourcaud; Université Bordeaux I.

CIRAD Trainees

Régénération par embryogenèse somatique en milieu liquide et transformation génétique par biolistique de bananiers di et triploïdes [Regeneration by somatic embryogenesis in liquid medium and genetic transformation by biolistics of diploid and triploid banana

plants] by Agnès Grapin (France); Ecole nationale supérieure agronomique de Montpellier.

Etude des sites récepteurs et de la toxicité des delta-endotoxines de *Bacillus thuringiensis* Berliner chez les larves de la pyrale du riz, *Chilo suppressalis* Walker [Study of receptor sites and toxicity of the delta-endotoxins of *Bacillus thuringiensis* Berliner in larvae of the rice stem borer, *Chilo suppressalis* Walker] by Lidia Mariana Fiuza (Brazil); Ecole nationale supérieure agronomique de Montpellier.

Embryogenèse somatique du cacaoyer, *Theobroma cacao* L. : contraintes, progrès et perspectives [Somatic embryogenesis of cocoa, *Theobroma cacao* L.: constraints, progress and prospects] by Laurence Alemanno (France); Université Montpellier II.

Etude expérimentale et simulation des transferts hydriques dans les plantes individuelles : application au caféier, *Coffea arabica* L. [Experimental study and simulation of moisture transfer in individual plants: application to coffee, *Coffea arabica* L.] by Bruno Rapidel (France); Université Montpellier II.

Effets de la toxicité aluminique sur les plantules de maïs cultivées en solution nutritive de faible force ionique : approches de quelques mécanismes explicatifs de la tolérance à l'aluminium [Effects of aluminium toxicity on plantlets of maize cultivated in low-ion nutritive solution: approaches to some mechanisms explaining the tolerance of aluminium] by José Carlo Pintro (Brazil); Université de Rennes.

Intensification de la caféiculture chez les petits producteurs du Guatemala : rapports entre la structure, le fonctionnement et les performances des exploitations [Intensification of coffee growing among smallholders in Guatemala: relations between the layout, cultivation and yield of the farms] by Juan Carlos Mendez (Guatemala); Ecole nationale supérieure agronomique de Montpellier.

* Research staff of the Department have additionally supervised thesis studies listed elsewhere.

CIRAD at a Glance

Organization chart

Committees

Research coordination

Regional representatives

CIRAD worldwide

Budget

Personnel

CIRAD training

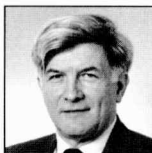
Organization Chart



Board of Trustees

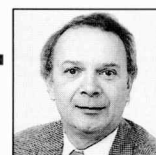
Chairman

Guy Paillotin



Director General

Michel de Nucé de Lamothe



Scientific Advisory Committee

Chairman

Alain Pavé

(proposed for appointment)



Secretary General

Jean-Marie Sifferlen



Director, Montpellier Research Centre

Gérard Matheron



Director, Research

Didier Picard



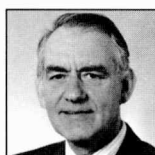
Director, External Relations

François Vicariot



Development Coordinator

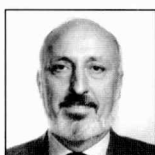
Christian Brunin



CIRAD-CA

Director

Jacques Lefort



CIRAD-CP

Director

Jean-Luc Renard



CIRAD-FLHOR

Director

Jean-Pierre Gaillard



CIRAD-EMVT

Director

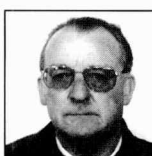
Pierre-Charles Lefèvre



CIRAD-Forêt

Director

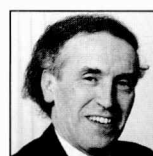
Jean-Marc Dubois



CIRAD-SAR

Director

Marc Le Moigne



CIRAD-GERDAT

Director

Jean-Marie Sifferlen

of CIRAD in 1996

General Secretariat

Special Advisor
Robert Jouanique

Accounts and finance
Marc Gélis

Personnel
Danielle Bonneau

Legal affairs
Hervé de Font-Réaulx

Computer services
Joël Sor

Physical plant and maintenance
Didier Servat

French Overseas Departments and Territories

Regional Manager
François Pointereau

Centre representatives
(see page 104)

Scientific and Technical Information

Head
Jean-François Giovannetti

Publications
Martine Séguier-Guis

Library
Marie-Gabrielle Bodart

Automatic information systems
Jean-François Foucher

External Relations

Africa, Indian Ocean
Maurice Izard

Latin America, Caribbean
Jean Laboucheix

Asia, South Pacific
Patrick Safran

International organizations,
North Africa,
Middle East
Pierre-Luc Puglièse

Communication:
Publicity
Anne Hébert

Communication:
Press relations
Benoît Catrisse

Overseas representatives
and correspondents
(see page 104)

Development

European unit,
applications
Alain Guyot

Project monitoring
Claude Malvos

Research Administration

Deputy Director
Michel Eddi

Research Coordination

Crop and environment
management
Hubert Manichon

Plant improvement
Dominique Nicolas

Plant protection
Jean-Loup Notteghem

Animal production
Gérard Matheron

Technology
François Challot

Economics and sociology
Michel Griffon

Biometrics
Xavier Perrier

Services

Training
Marc Roesch

Internal Auditor

Internal auditor
Antoine Bourgeois

CIRAD Committees (1996)

BOARD OF TRUSTEES	
<i>President</i>	Guy Paillotin
<i>Government representatives</i>	Albert Prévos , representing the Minister for Research François Gauthier , representing the Minister for Cooperation Jean-Baptiste Pinton , representing the Deputy Minister for the Budget Hervé Bichat , representing the Minister for Agriculture, Fisheries and Food Francis Lefèvre , representing the Deputy Minister for Overseas Affairs
<i>President, Institut national de la recherche agronomique</i>	Guy Paillotin
<i>External members</i>	Jacques Alliot , Deputy Director General, CFD, retired Michel Fichet , Chairman, CFDT Hubert Fournier , Chairman, ORSTOM Alain Godard , Director General, Rhône-Poulenc Agrochimie Henry Jouve , Chairman, AFDI Christiane Mercier , Research Director, groupe Danone
<i>Staff representatives</i>	Alain Bertrand, Henri Calba, Eric Jallas, Jacques Monnier, Jean Pichot, Ange-Marie Risterucci
SCIENTIFIC ADVISORY COMMITTEE	
	<i>Appointments pending</i>

Research Coordination (1996)

CROP AND ENVIRONMENT MANAGEMENT

Coordinator **Hubert Manichon**

Deputy coordinators **Jean-Joseph Lacoeyllhe**
Jean Pichot

Scientific committee

Chairperson

External members

Jean-Claude Rémy, ENSA Montpellier
Bruno Delvaux, Université catholique de Louvain-la-Neuve
Alain Capillon, INA-PG
Jean-Marc Meynard, INRA, INA-PG
Pierre Milleville, ORSTOM
Bernard Saugier, Université Paris XI
Bernard Seguin, INRA
Franck Warembourg, CNRS
Departmental representatives

CIRAD members

PLANT IMPROVEMENT

Coordinator **Dominique Nicolas**

Deputy coordinator **Hélène Joly**

Scientific committee

Chairperson

External members

Yves Hervé, ENSA Rennes
André Charrier, ORSTOM, ENSA Montpellier
Yves Chupeau, INRA
Yvette Dattée, GEVES
Alain Deshayes, Nestlé
Serge Hamon, ORSTOM
Departmental representatives

CIRAD members

PLANT PROTECTION

Coordinator **Jean-Loup Notteghem**

Deputy coordinator **Maurice Vaissayre**

Scientific committee

Chairperson

Michel Dron, Université Paris XI

<i>External members</i>	Jean Dunez , INRA Pierre Ferron , INRA Yves Gillon , ORSTOM Hervé Lecoq , INRA Jacques Luisetti , INRA Nicole Pasteur , CNRS Guy Riba , INRA
<i>CIRAD members</i>	Departmental representatives
ANIMAL PRODUCTION	
<i>Coordinator</i>	Gérard Matheron
<i>Deputy coordinator</i>	Philippe Lhoste
<i>Scientific committee</i>	
<i>Chairperson</i>	Julien Coléou , INA-PG
<i>External members</i>	Roland Billard , Muséum national d'histoire naturelle Alain Bourbouze , IAM Jacques Renoux , Université Paris XII Michel Theriez , INRA Jacques Thimonier , ENSA Montpellier
<i>CIRAD members</i>	Departmental representatives
TECHNOLOGY	
<i>Coordinator</i>	François Challot
<i>Scientific committee</i>	
<i>Chairperson</i>	Antoine Gaset , ENSC Toulouse
<i>External members</i>	Jean-Claude Brosse , University of Maine Yves Darricau , ONUDI Pierre Germain , ENSAIA Christiane Mercier , groupe Danone René Urien , CEMAGREF Jean-Anne Ville , ANVAR
<i>CIRAD members</i>	Departmental representatives
ECONOMICS AND SOCIOLOGY	
<i>Coordinator</i>	Michel Griffon
<i>Scientific committee</i>	
<i>Chairperson</i>	Philippe Lacombe , ENSA Montpellier

External members	Jean-Pierre Bertrand, INRA Catherine Bonjean, CERDI Pierre Campagne, IAM Jean Chataignier, INRA Johnny Egg, INRA Jean-Marc Gastellu, ORSTOM Jean-Charles Hourcade, CNRS Michel Labonne, INRA Yves Léon, INRA Jean-Pierre Prod'homme, INA-PG Michel Vernières, Université Paris I Departmental representatives
CIRAD members	
BIOMETRICS	
Coordinator	Xavier Perrier
Scientific committee	
Chairperson	Yves Escoufier, Université Montpellier II
External members	Bruno Goffinet, INRA Richard Tomassone, INA-PG
CIRAD members	Departmental representatives

Regional Representatives

FRENCH OVERSEAS DEPARTMENTS AND TERRITORIES

Guadeloupe
French Guiana
Martinique
Mayotte
New Caledonia
French Polynesia
Réunion

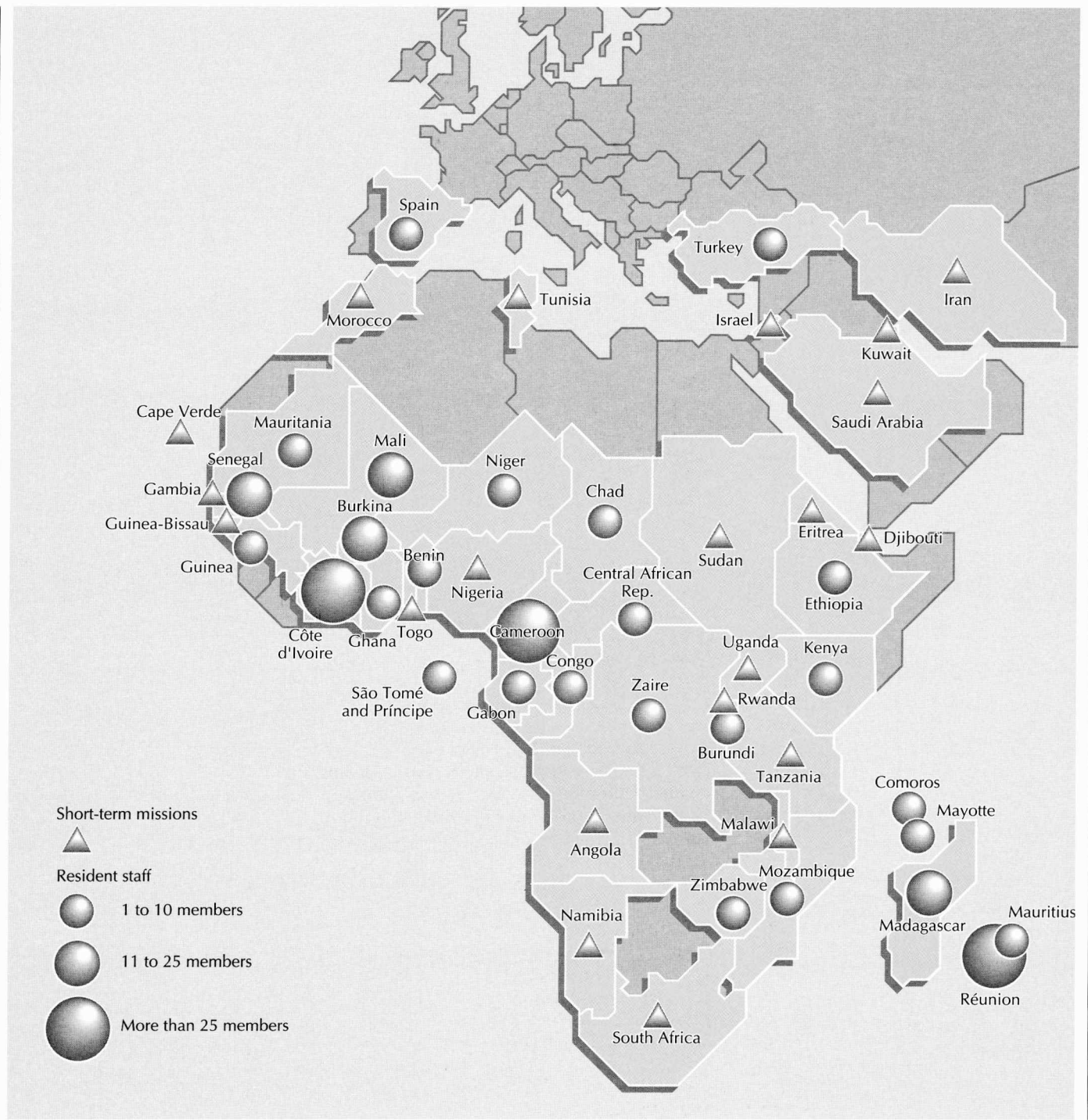
Emmanuel Camus, Representative
Johann Huguenin, Representative
Philippe Melin, Representative
Bernard Leduc, Correspondent
Claude Calvez, Centre Director
Jean-Jacques Baraer, Representative
Paul Gener, Representative

OTHER COUNTRIES

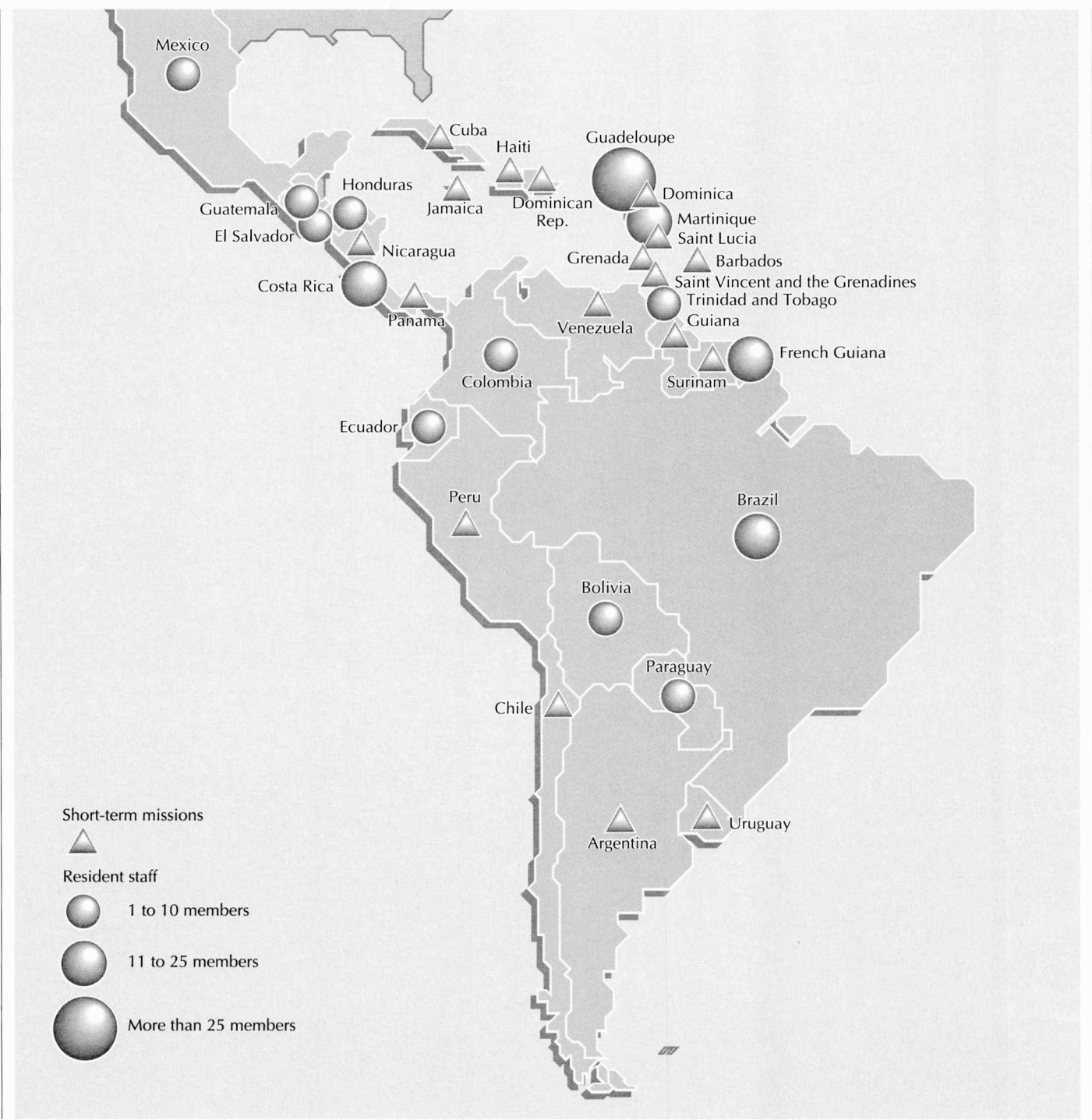
Benin
Brazil
Burkina
Burundi
Cameroon
Chad
Comoros
Congo
Costa Rica
Côte d'Ivoire
Fiji
Gabon
Guatemala
Guinea
Honduras
Indonesia
Madagascar
Malaysia
Mali
Mauritius
Nicaragua
Niger
Panama
Philippines
Republic of South Africa
Senegal
Singapore
Thailand
United States
Vanuatu
Vietnam
Zaire
Zimbabwe

Pierre Silvie, Correspondent
François Bertin, Representative
Jacques Dubernard, Representative
Gérard Fourny, Correspondent
Patrice de Vernou, Representative
Didier Bouchel, Correspondent
Paul Gener, Representative (based in Réunion)
Jean-Marc Bouvet, Correspondent
Jean Laboucheix, Representative for Latin America and the Caribbean
Jacques Teissier, Representative
Olivier Trocmé, Correspondent
Franck Enjalric, Correspondent
Jean Laboucheix, Representative (based in Costa Rica)
Jean Servant, Correspondent
Jean Laboucheix, Representative (based in Costa Rica)
Gabriel de Taffin, Representative
Jean-Louis Reboul, Representative
Patrick Durand, Representative (based in Singapore)
Jacques Dubernard, Representative (based in Burkina)
Paul Gener, Representative (based in Réunion)
Jean Laboucheix, Representative (based in Costa Rica)
Jacques Dubernard, Representative (based in Burkina)
Jean Laboucheix, Representative (based in Costa Rica)
Jean-François Julia, Correspondent
Jean-Paul Loyer, Correspondent
Jean-Louis Messenger, Representative
Patrick Durand, Representative
Jean-Claude Vincent, Representative
Jill Barr, Correspondent
Guy Mossu, Representative
Philippe Godon, Correspondent
Jacques Monnier, Correspondent
François Monicat, Correspondent

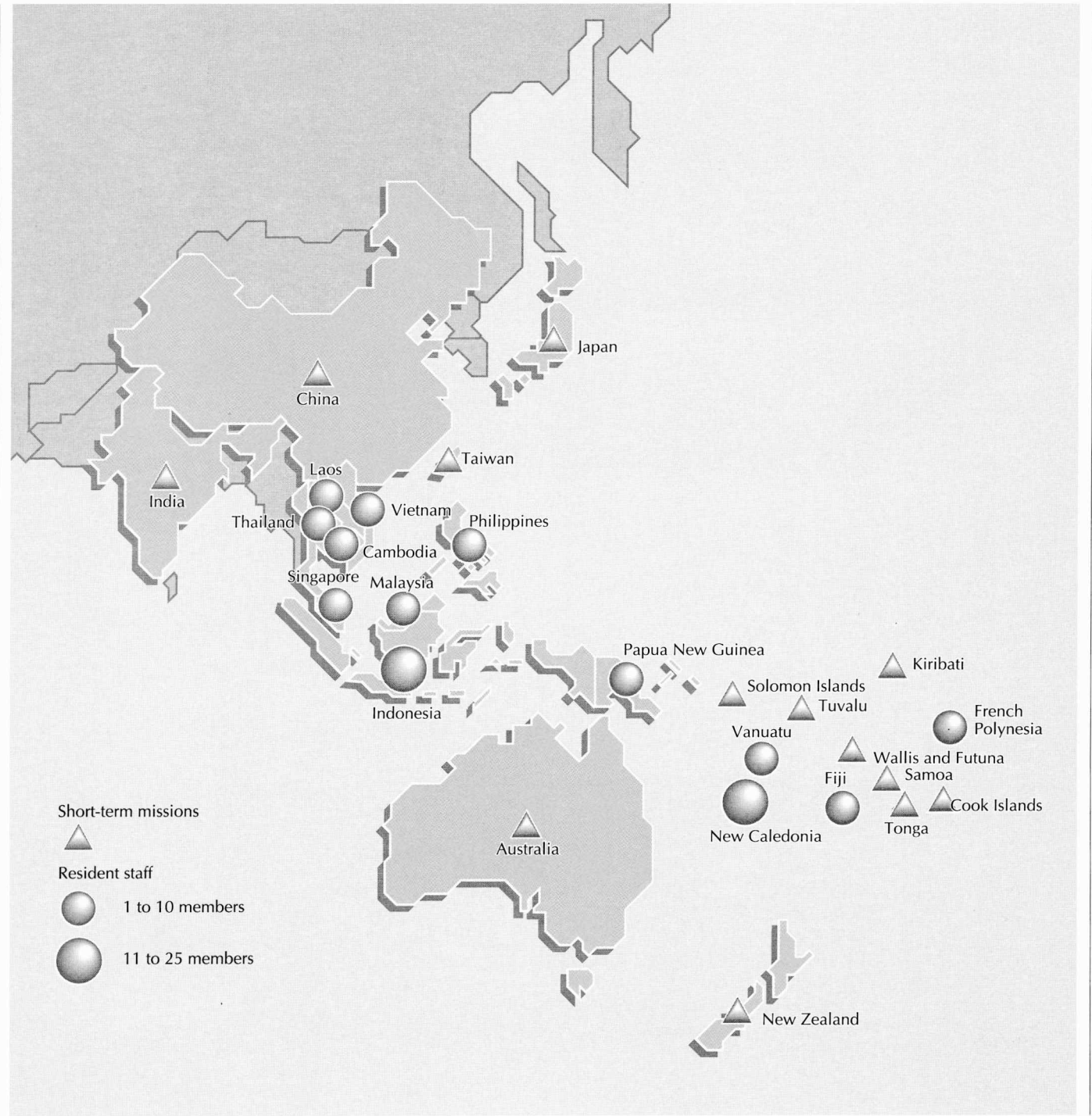
CIRAD Worldwide: CIRAD in Africa and the Indian Ocean



CIRAD in Latin America and the Caribbean

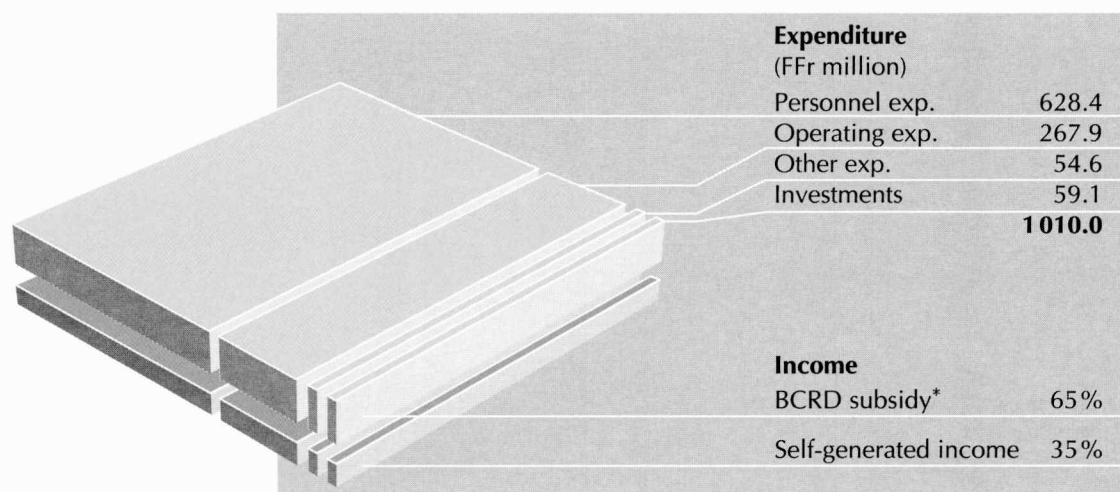


CIRAD in Asia and the South Pacific

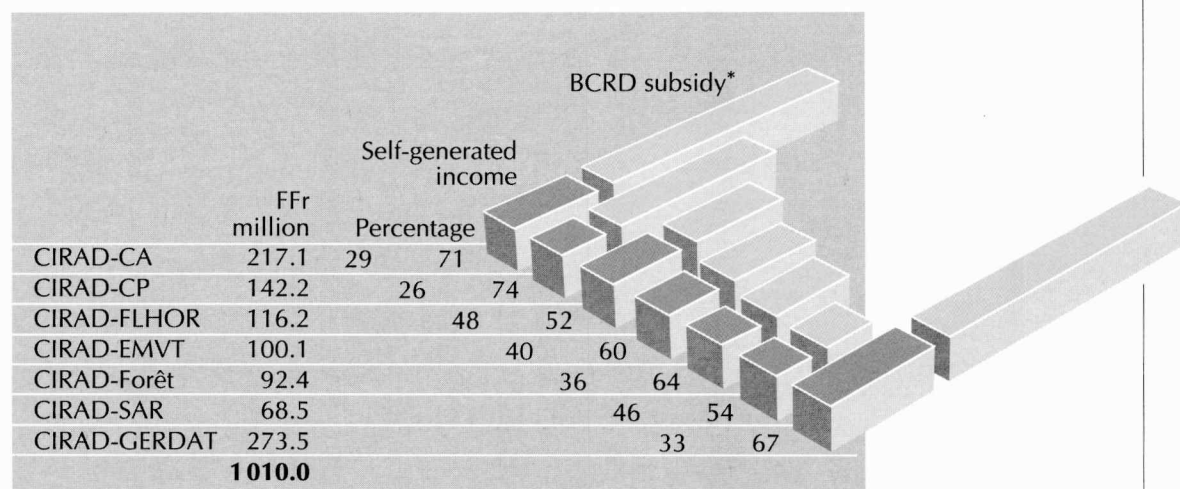


1995 Budget: FFr 1 010 million

INCOME AND EXPENDITURE



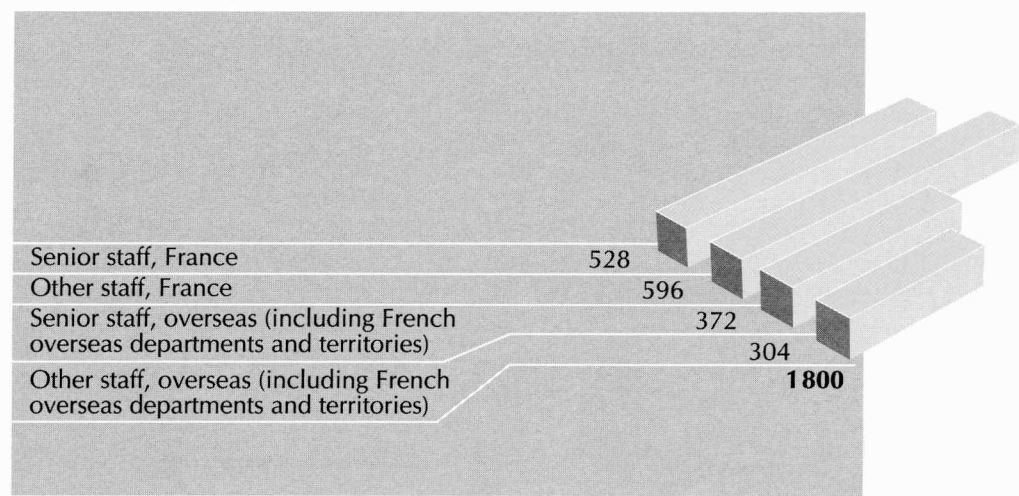
DISTRIBUTION AND SOURCE OF FUNDS BY DEPARTMENT



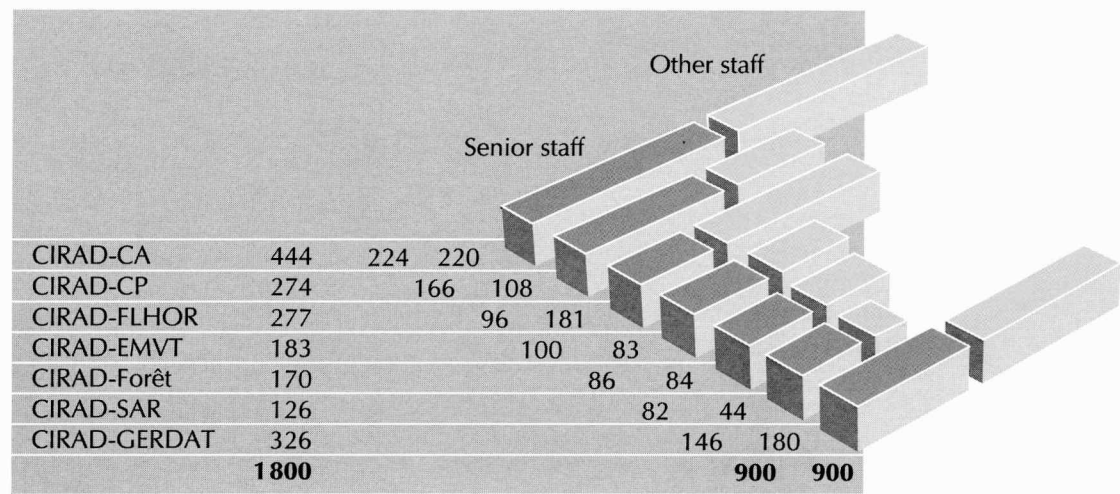
* Civil research and development budget.

1995 Personnel: 1 800 staff members*

DISTRIBUTION BY STAFF CATEGORY AND LOCATION



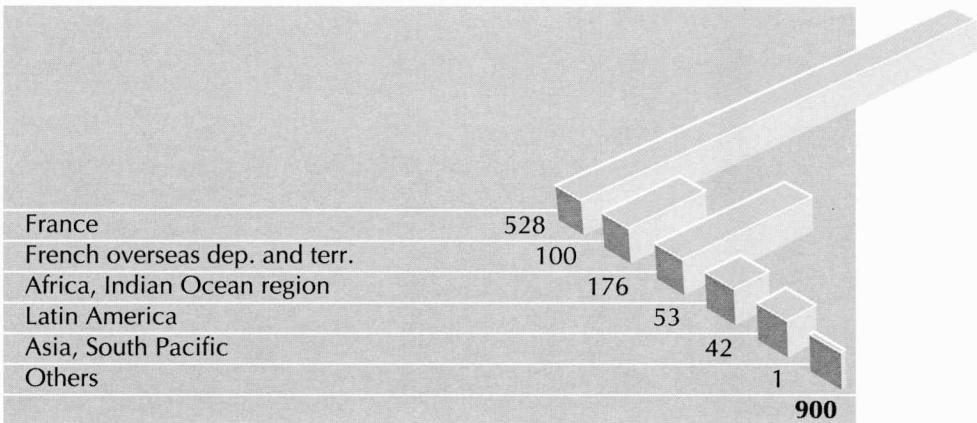
DISTRIBUTION BY DEPARTMENT



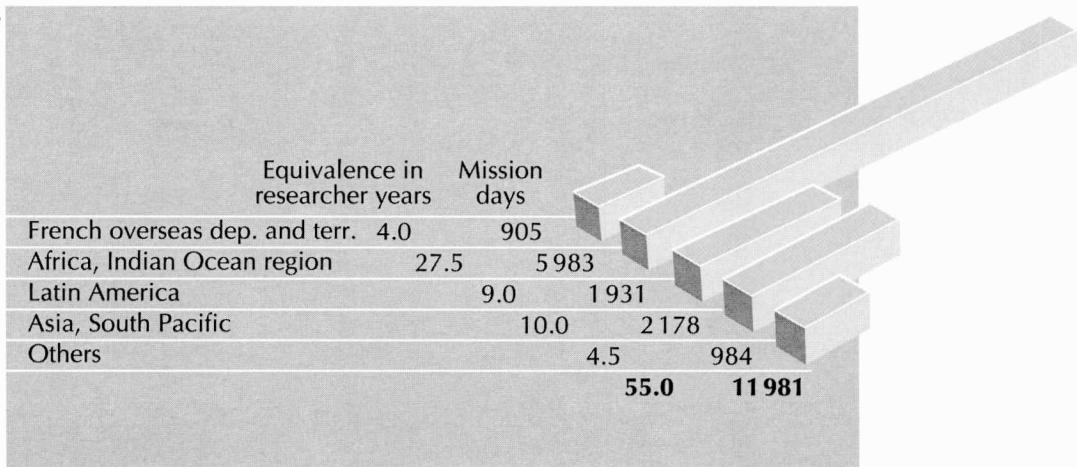
* Excluding staff seconded to CIRAD, trainees, and daily wage workers.

Senior staff: 900 members

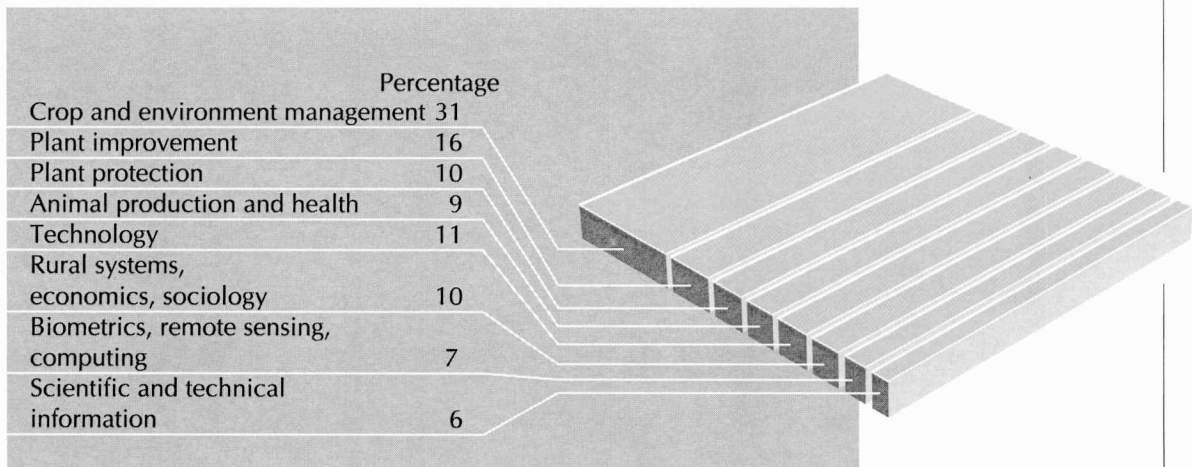
GEOGRAPHIC
DISTRIBUTION



MISSIONS OVERSEAS
INCLUDING
FRENCH OVERSEAS
DEPARTMENTS
AND TERRITORIES

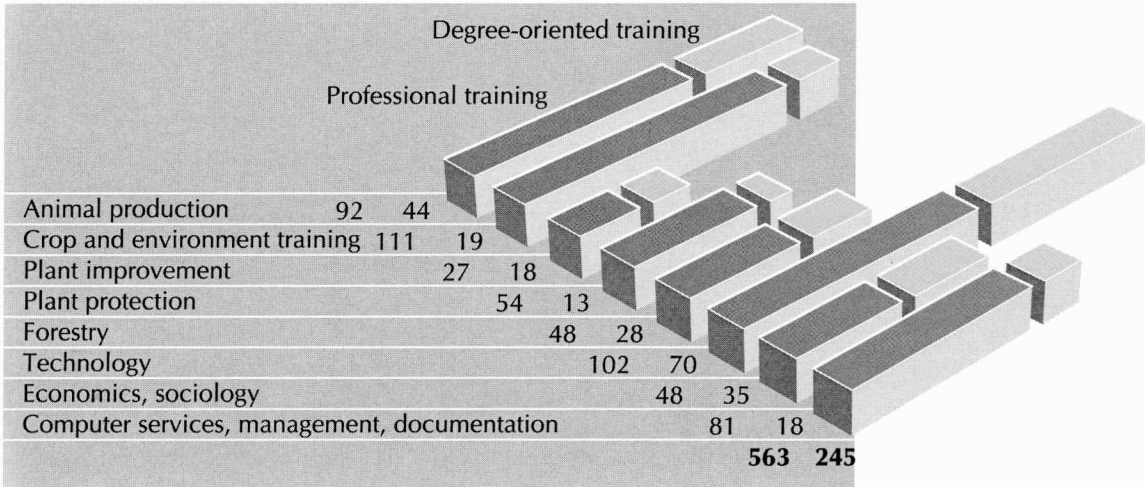


DISTRIBUTION
OF SCIENTISTS
BY DISCIPLINE
(%)

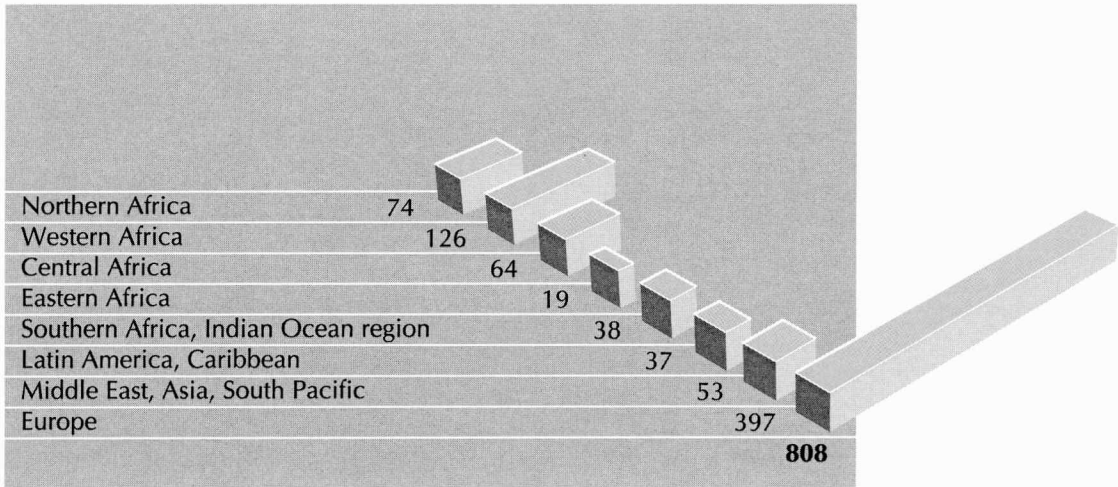


CIRAD Training in 1995

DISTRIBUTION BY DISCIPLINE AND TYPE OF TRAINING



DISTRIBUTION OF SCIENTISTS BY GEOGRAPHIC ORIGIN



Annexes

Interorganization thematic research projects

CIRAD addresses

List of acronyms

Interorganization Thematic Research Projects financed in 1995

Work area	Theme	Partners
CROP MANAGEMENT, ENVIRONMENT	<i>Study of soil-machine interactions in mechanized tillage</i>	INRA, CEMAGREF, CNRS CIRAD-SAR, CIRAD-CA, CIRAD-FLHOR
	<i>Reproductive organ formation and maintenance mechanisms in tropical plants as a basis for crop yield improvement: trophic factors in banana, cotton, groundnut, and cowpea</i>	ISRA (Senegal), INRA, ENSA Montpellier CIRAD-FLHOR, CIRAD-CA, CIRAD-EMVT
	<i>Biomass flow and fertility management on smallholdings</i>	IRZV, IRA, Ministère de l'élevage, des pêches et des industries animales (Cameroon), IRCT (Chad), ORSTOM CIRAD-SAR
	<i>Role of research in the diffusion of technological innovations and in local development</i>	APR, CAHEB, SUAD, Chambre d'agriculture, ONF (Réunion) CIRAD-CA, CIRAD-SAR, CIRAD-Forêt
PLANT IMPROVEMENT	<i>Strategies for tree crop improvement</i>	INRA CIRAD-Forêt, CIRAD-CP
	<i>Development and improvement of haploid and doubled haploid plant production techniques</i>	Université de Zurich (Switzerland), ENSA Rennes, CNRS, Université de Toulouse CIRAD-FLHOR, CIRAD-CA, CIRAD-GERDAT
	<i>Development of gene transfer methods in tropical plants</i>	INRA, Université Paris VI, ORSTOM CIRAD-GERDAT, CIRAD-CA, CIRAD-CP, CIRAD-FLHOR, CIRAD-Forêt
	<i>Management of genetic resources: how to best preserve genes of agronomic interest</i>	IDEFOR (Côte d'Ivoire), CRBP (Cameroon), CRU (Trinidad-and-Tobago), CDC (United Kingdom), ORSTOM, CNRS, INRA CIRAD-CA
	<i>Comparative genome mapping studies in Gramineae species: uses for physiological analysis</i>	INERA (Burkina), IRRI (Philippines), University of Milan (Italy), INRA, ENSA Montpellier CIRAD-GERDAT, CIRAD-CA

Work area	Theme	Partners
PLANT PROTECTION	<i>Use of sensitive plant pathogen detection techniques in modelling bacterial and virus diseases that hinder the development of fruit and vegetable crops in Réunion. Defining control strategies</i>	INRA CIRAD-FLHOR, CIRAD-CA
	<i>Analysis of the susceptibility of pest insects from different origins to <i>Bacillus thuringiensis</i> and the effects of toxic compounds on the insect populations</i>	ISRA (Senegal), CIMMYT (Mexico), NRI (United Kingdom), USDA (United States) CIRAD-GERDAT, CIRAD-CP, CIRAD-CA, CIRAD-FLHOR
	<i>Colletotrichum spp. in tropical zones: host-pest interactions and epidemiology</i>	ORSTOM, Université Paris XI, INRA CIRAD-CP, CIRAD-FLHOR
ANIMAL PRODUCTION AND HEALTH	<i>Animal traction study: improving the efficiency of harness/tool assemblies</i>	IRA, IRZV (Cameroon), INRA, ENV Toulouse CIRAD-EMVT, CIRAD-CA, CIRAD-Forêt, CIRAD-SAR
	<i>Gastro-intestinal strongyloidiasis of small ruminants in tropical regions: genetic resistance and infestation environment</i>	ISRA (Senegal), CIRDES (Burkina), ITC (Gambia), ILRI (Kenya), INRA CIRAD-EMVT
	<i>Milk and traditional dairy product supplies for African urban centres</i>	LRVZ (Chad), CIRDES (Burkina), ILRI (Kenya), INRA CIRAD-EMVT, CIRAD-SAR, CIRAD-FLHOR
TECHNOLOGY	<i>Controlling product quality: biochemical, technological, and breeding approach</i>	INERA (Burkina), IDESSA, IDEFOR (Côte d'Ivoire), ORSTOM, ENSIA, Mars CIRAD-CP, CIRAD-CA, CIRAD-GERDAT

Work area	Theme	Partners
RURAL SYSTEMS, SOCIOECONOMICS	<i>Packaging and environment in developing countries: biodegradable packaging</i>	Université de Brazzaville (Congo), ORSTOM, ENGREF, INRA, Université Montpellier II, CIRAD-SAR, CIRAD-CA, CIRAD-CP, CIRAD-Forêt
	<i>Modelling and optimization of frying processes</i>	SICOR (Côte d'Ivoire), CRBP (Cameroon), Univalle (Colombia), CNRIT (Madagascar), University of Jerusalem, Technicon (Israel), CNRS, ENSIA, CIRAD-SAR
	<i>Assessment of subsector competitiveness</i>	SODEPALM (Côte d'Ivoire), ORSTOM, Université Paris X, CFD, Ministère de la coopération, CIRAD-GERDAT, CIRAD-CP, CIRAD-SAR, CIRAD-CA
	<i>Model used to assist decision-making in agricultural policies; application to diversification in Indonesia</i>	University of Berkeley (United States), INRA, CERDI, CIRAD-GERDAT
	<i>The doubly-green revolution: aims, methods, and models</i>	University of Brighton, IDS (United Kingdom), JIRCAS (Japan), IFPRI (United States), CNASEA, Club du Sahel, CIRAD-GERDAT, CIRAD-CA, CIRAD-CP
	<i>Food supplies for African urban centres: intermediary organizations</i>	Boston University (United States), INRA, IRAM, Université Paris X, Université de Versailles-Saint-Quentin-en-Yvelines, ORSTOM, CIRAD-FLHOR, CIRAD-SAR, CIRAD-CA, CIRAD-GERDAT, CIRAD-EMVT
	<i>Improving the quality of tropical products for international markets</i>	ICAC (United States), ICCO, IRSG (United Kingdom), ACNA (Côte d'Ivoire), INRA, CIRAD-CP, CIRAD-CA

CIRAD Addresses

HEADQUARTERS

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75116 Paris
France
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Telex: 648729 F

MONTPELLIER RESEARCH CENTRE

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CIRAD DEPARTMENTS

CIRAD-CA

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fruitières et horticoles
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Fax: (1) 40 53 04 26

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Département d'élevage
et de médecine vétérinaire
Campus international de Baillarguet
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Fax: 67 61 12 23
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Fax: (1) 47 27 58 13
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CIRAD IN THE FRENCH OVERSEAS DEPARTMENTS AND TERRITORIES

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Fax: (594) 32 42 27
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Punaauia-Tamanu
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Fax: (590) 25 24 92

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Fax: (596) 60 09 24

Mayotte

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97600 Mamoudzou
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Fax: (269) 61 21 19

New Caledonia

M. le directeur
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Païta
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Fax: (687) 35 32 23

Réunion

M. le délégué
Station de La Bretagne
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Telephone: (262) 52 80 00
Fax: (262) 52 80 01
Telex: 916033 RE

OTHER COUNTRIES**Benin**

M. le correspondant
 DRCF, BP 715
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 Telephone: (229) 31 34 46
 Fax: (229) 31 26 46

Brazil

M. le délégué
 SHIS – QI 11
 Conjunto 6, casa 7
 71 625-260 Brasilia DF
 Telephone: (55) 61 248 41 26
 Fax: (55) 61 248 23 81

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M. le délégué
 01 BP 596
 Ouagadougou
 Telephone: (226) 30 70 70
 Fax: (226) 30 76 17

Burundi

M. le correspondant
 c/o ISABU
 BP 795
 Bujumbura
 Telephone: (257) 22 33 90
 Fax: (257) 22 87 29

Cameroon

M. le délégué
 BP 2572
 Yaoundé
 Telephone: (237) 21 25 41
 Fax: (237) 20 29 69
 Telex: 8202 ou 8531 KN

Chad

M. le correspondant
 Laboratoire de Farcha
 BP 433
 N'Djamena
 Telephone: (235) 52 30 07
 Fax: (235) 52 83 02

Comoros

M. le délégué
 (resident in Réunion)

Congo

M. le correspondant
 BP 1291
 Pointe-Noire
 Telephone: (242) 94 31 84
 Fax: (242) 94 40 54
 Telex: 8303 KG (att. CIRAD)

Costa Rica

M. le délégué pour l'Amérique latine
 et la Caraïbe
 Apartado 1127
 2050 San Pedro
 San José
 Telephone: (506) 225 59 72
 Fax: (506) 225 09 40

Côte d'Ivoire

M. le délégué
 01 BP 6483
 Abidjan 01
 Telephone: (225) 22 18 69
 Fax: (225) 21 43 68
 Telex: 23220 CI

Fiji

M. le correspondant
 GPO Box 16213
 Suva
 Telephone: (679) 387 554
 Fax: (679) 387 855

Gabon

M. le correspondant
 CATH
 BP 643
 Libreville
 Telephone: (241) 75 83 72
 Fax: (241) 73 65 76
 Telex: 5900 GO

Guatemala

M. le délégué
 (resident in Costa Rica)

Guinea

M. le correspondant
 c/o MCAC
 Ambassade de France
 BP 570
 Conakry
 Telephone: (224) 41 10 59
 Fax: (224) 41 10 59
 Telex: 22400 GE (att. CIRAD)

Honduras

M. le délégué
 (resident in Costa Rica)

Indonesia

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List of Acronyms

ACNA, Association professionnelle du caoutchouc naturel en Afrique, Côte d'Ivoire

ADA, Association des aquaculteurs, Niger

AFCC, Association française du commerce des cacaos, France

ANACAFE, Asociación Nacional del Café, Guatemala

ANVAR, Agence nationale de valorisation de la recherche, France

APR, Association pour la promotion en milieu rural, France

APTE, Application des techniques d'entreprises, France

ARMES, Association réunionnaise pour la modernisation de l'économie sucrière, France

ASEAN, Association of Southeast Asian Nations

ASIC, Association scientifique internationale du café, France

AVRDC, Asian Vegetable Research and Development Center, Taiwan

BIPEA, Bureau interprofessionnel d'études analytiques, France

CAHEB, Coopérative agricole des huiles essentielles de Bourbon, France

CAOBISCO, Association des industries de la chocolaterie, de la biscuiterie et de la confiserie, Belgium

CATIE, Centro Agronómico Tropical de Investigación y Enseñanza, Costa Rica

CDC, Commonwealth Development Corporation, UK

CEMAGREF, Centre national du machinisme agricole, du génie rural, des eaux et des forêts, France

CENICAFE, Centro Nacional de Investigaciones de Café, Colombia

CERAAS, Centre d'étude régional pour l'amélioration de l'adaptation à la sécheresse, Senegal

CERAT, Centro de Raízes Tropicais, Brazil

CERDI, Centre d'études et de recherches sur le développement international, France

CFD, Caisse française de développement, France

CFDT, Compagnie française pour le développement des fibres textiles, France

CGIAR, Consultative Group on International Agricultural Research

CGPRT, Regional Coordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific, Indonesia

CIAT, Centro Internacional de Agricultura Tropical, Colombia

CIEPAC, Centre international pour l'éducation permanente et l'aménagement concerté, France

CIFOR, Center for International Forestry Research, Indonesia

CIMMYT, Centro Internacional de Mejoramiento de Maíz y Trigo, Mexico

CIRDES, Centre international de recherche-développement sur l'élevage en zone subhumide, Burkina

CNASEA, Centre national pour l'aménagement des structures des exploitations agricoles, France

CNEARC, Centre national d'études agronomiques des régions chaudes, France

CNERV, Centre national d'élevage et de recherches vétérinaires, Mauritania

CNIA, Comité national interprofessionnel de l'arachide, Senegal

CNRADA, Centre national de recherche agronomique et de développement agricole, Mauritania

CNRIT, Centre national de la recherche industrielle et technologique, Madagascar

CNRS, Centre national de la recherche scientifique, France

CNRST, Centre national de la recherche scientifique et technologique, Burkina

COLEACP, Comité de liaison Europe, Afrique, Caraïbes, Pacifique

CORAF, Conférence des responsables de recherche agronomique africains

CORDET, Commission de coordination de la recherche dans les départements et territoires d'outre-mer, France

CRBP, Centre régional bananiers et plantains, Cameroon

CRU, Cocoa Research Unit, Trinidad and Tobago

CSIRO, Commonwealth Scientific and Industrial Research Organization, Australia

CUMA, Coopérative d'utilisation de matériel en commun

DRRT, Délégation régionale à la recherche et à la technologie, France

DRTA, Direction de la recherche technologique agricole, Chad

EAGGF, European Agricultural Guidance and Guarantee Fund

EDE, Etablissements départementaux d'élevage, France

EHESS, Ecole des hautes études en sciences sociales, France

EMATER-GO, Empresa de Assistência Técnica e Extensão Rural do Estado de Goiás, Brazil

EMBRAPA, Empresa Brasileira de Pesquisa Agropecuária, Brazil

EMPAER, Empresa Matogrossense de Pesquisa, Assistência e Extensão Rural, Brazil

ENGREF, Ecole nationale du génie rural, des eaux et des forêts, France

ENSA, Ecole nationale supérieure agronomique, France

- ENSAIA, Ecole nationale supérieure d'agronomie et des industries alimentaires, France
- ENSC, Ecole nationale supérieure de chimie, France
- ENSIA, Ecole nationale supérieure des industries agricoles et alimentaires, France
- ENV, Ecole nationale vétérinaire, France
- FAC, Fonds d'aide et de coopération, France
- FAO, Food and Agriculture Organization of the United Nations, Italy
- FEDECAFE, Federación Nacional de Cafeteros de Colombia, Colombia
- FONAIAP, Fondo Nacional de Investigaciones Agropecuarias, Venezuela
- GAO, Réseau groupements, associations, organisations, France
- GAPKINDO, Association des producteurs exportateurs du caoutchouc naturel indonésien, Indonesia
- GEVES, Groupement d'étude et de contrôle des variétés et des semences, France
- GRET, Groupe de recherche et d'échanges technologiques, France
- IAM, Institut agronomique méditerranéen, France
- ICA, Instituto Colombiano Agropecuario, Colombia
- ICAC, International Cotton Advisory Committee, USA
- ICCO, International Cocoa Organization, UK
- ICRA, Institut centrafricain de recherche agronomique, Central African Republic
- ICRAF, International Centre for Research in Agroforestry, Kenya
- ICRISAT, International Crops Research Institute for the Semi-Arid Tropics, India
- IDEFOR, Institut des forêts, Côte d'Ivoire
- IDESSA, Institut des savanes, Côte d'Ivoire
- IDS, Institute of Development Studies, UK
- IER, Institut d'économie rurale, Mali
- IFPRI, International Food Policy Research Institute, USA
- IICA, Instituto Interamericano de Cooperación para la Agricultura, Costa Rica
- IITA, International Institute of Tropical Agriculture, Nigeria
- ILCA, International Livestock Centre for Africa, Ethiopia
- ILRI, International Livestock Research Institute, Kenya
- INA-PG, Institut national agronomique Paris-Grignon, France
- INERA, Institut d'études et de recherches agricoles, Burkina
- INESC, Instituto de Engenharia de Sistemas e Computadores, Portugal
- INIBAP, International Network for the Improvement of Banana and Plantain, France
- INRA, Institut national de la recherche agronomique, France
- INRAN, Institut national de recherches agronomiques du Niger, Niger
- IPGRI, International Plant Genetic Resources Institute, Italy
- IRA, Institut de la recherche agronomique, Cameroon
- IRAG, Institut agronomique de Guinée, Guinée
- IRAM, Institut de recherches et d'applications des méthodes de développement, France
- IRBET, Institut de recherches en biologie et écologie tropicale, Burkina
- IRCT, Institut de recherches du coton et des textiles exotiques, Chad
- IRCV, Institut de recherches sur le caoutchouc au Vietnam, Vietnam
- IREAH, Initiative pour la recherche écorégionale en Asie humide
- IRRI, International Rice Research Institute, Philippines
- IRSG, International Rubber Study Group, UK
- IRZV, Institut de recherches zootechniques et vétérinaires, Cameroon
- ISABU, Institut des sciences agronomiques du Burundi, Burundi
- ISHS, International Society for Horticultural Science, Netherlands
- ISRA, Institut sénégalais de recherches agricoles, Senegal
- ITC, International Trypanosomiasis Center, Gambia
- ITCF, Institut technique des céréales et des fourrages, France
- IUFRO, International Union of Forestry Research Organization, Germany
- JIRCAS, Japan International Research Center for Agricultural Sciences, Japan
- LRVZ, Laboratoire de recherches vétérinaires et zootechniques, Chad
- NAPPEC, Northern Australian Pasture Plant Evaluation Committee, Australia
- NARO, National Agricultural Research Organization, Uganda
- NRI, Natural Resources Institute, UK
- ONAHA, Office national des aménagements hydroagricoles, Niger
- ONE, Office national des forêts, France
- ORSTOM, Institut français de recherche scientifique pour le développement en coopération, France
- PORIM, Palm Oil Research Institute of Malaysia, Malaysia
- PRASAC, Pôle régional de recherche appliquée au développement des savanes d'Afrique centrale

PRASAO, Pôle régional de recherche appliquée au développement des savanes d'Afrique de l'Ouest

PROMECAFE, Programa Cooperativo Regional para la Protección y Modernización de la Caficultura, Costa Rica

PSI, Pôle régional de recherche sur les systèmes irrigués soudano-sahéliens

SAED, Société nationale d'aménagement et d'exploitation des terres du delta du fleuve Sénégal et de la Falémé, Senegal

SAFER, Société d'aménagement foncier et d'établissement rural, France

SAPHIR, Société d'aménagement des périmètres hydroagricoles de la Réunion, France

SARI, Savanna Agricultural Research Institute, Ghana

SICA, Société d'intérêts collectifs agricoles

SICOR, Société ivoirienne de coco râpé, Côte d'Ivoire

SODECOTON, Société de développement du coton, Cameroon

SODEFOR, Société pour le développement des plantations forestières, Côte d'Ivoire

SODEPALM, Société pour le développement et l'exploitation du palmier à huile, Côte d'Ivoire

SUAD, Service d'utilité agricole pour le développement, France

TRL, Tsetse Research Laboratories, UK

UFAC, Union de fabricants d'aliments composés, Côte d'Ivoire

UNESP, Universidade Nacional do Estado de São Paulo, Brazil

UNIDO, United Nations Industrial Development Organization, France

UPLB, University of the Philippines at Los Baños, Philippines

UPPI, Unité de recherche sur la productivité des plantations industrielles, Congo

USDA, United States Department of Agriculture, USA

WARDA, West Africa Rice Development Association, Côte d'Ivoire

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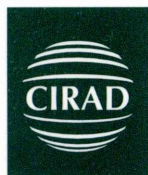
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