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Zaïre Applied Agricultural Research and Outreach Project II

The Legacy of USAID Support to Agricultural Research in Zaïre

South-East Consortium for International Development
and
Southern University

in cooperation with

Service National de Recherche
Agronomique Appliquée et Vulgarization (SENARAV)
Government of Zaïre

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The Legacy of USAID Support to Agricultural Research in Zaïre

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MAP OF ZAÏRE

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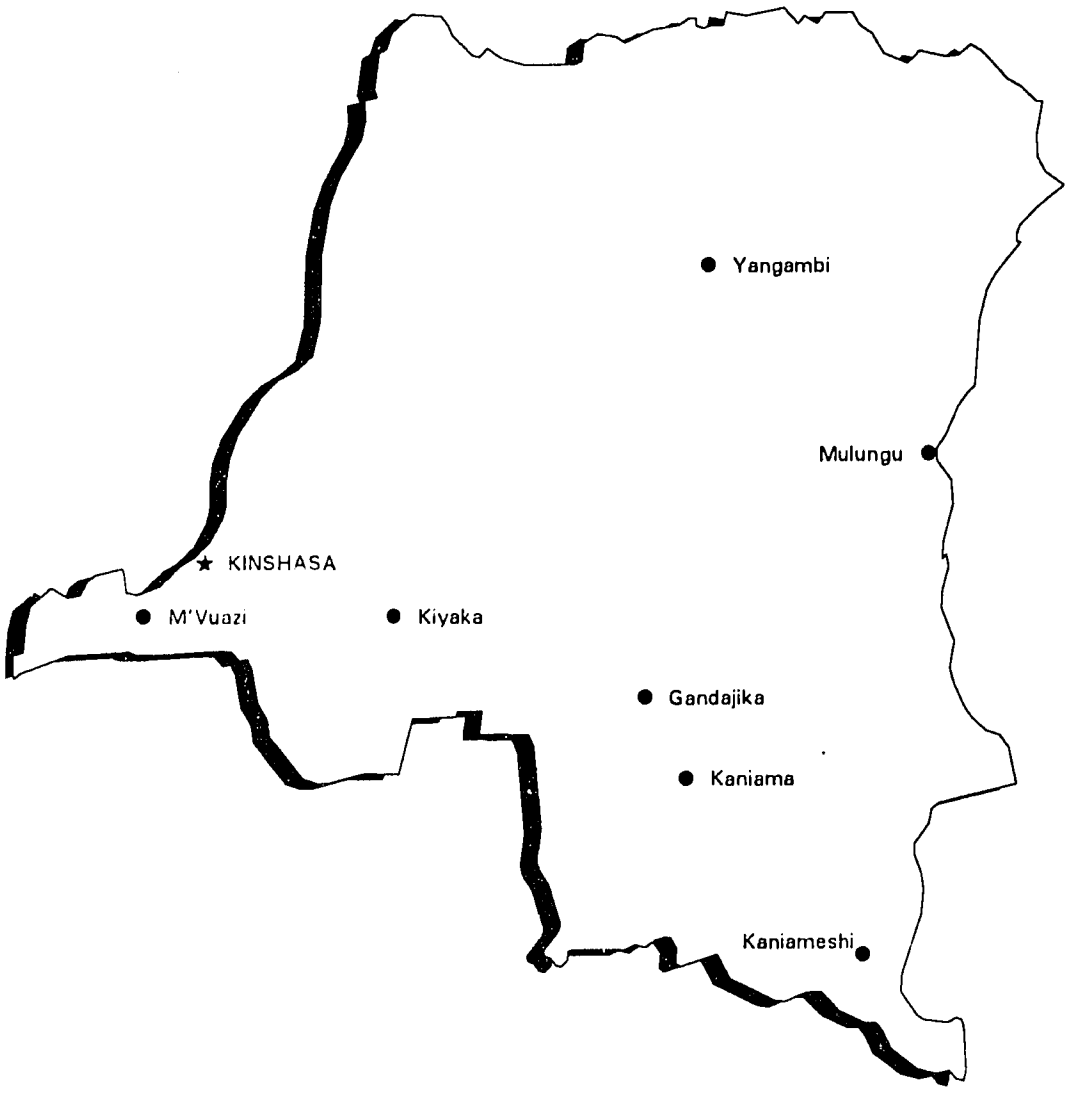

ACRONYMS

ACOOPANOKI	Association Coopérative des Agriculteurs du Nord Kivu/Cooperation Canadienne
AEPRP	African Economic Policy Reform Program
AIDIN	Agence Indigène pour le Développement du N'Gandajika
AVRDC	Asian Vegetable Research and Development Center
BCP	Biological Control Program of IITA/Ibadan, Nigeria
BUNASEM	Bureau National des Semences
CAD	Cassava Anthracnose Disease
CBB	Cassava Bacterial Blight
CEPGL	Communauté Economique des Pays des Grands Lacs (Rwanda, Burundi, and Zaïre)
CGIAR	Consultative Group for International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture)
CIAT/Rwanda	CIAT-established Regional Program for Bean Improvement in the Great Lakes Region of Central Africa, sponsored by Canada and Switzerland and headquartered in Rubona, Rwanda
CIMMYT	Centro Internacional para el Mejoramiento de Maiza y Trigo (International Maize and Wheat Improvement Center)
CIP	Commodity Import Program
CMD	Cassava Mosaic Disease
DAI	Development Alternatives, Inc.
DHS	Distribution, Homogénéité, Stabilité
DMPCC	Directorate of Markets, Prices and Campaign Credit
DOA	Department of Agriculture (GOZ)
DORD	Department of Rural Development (GOZ)
FAO	Food and Agricultural Organization of the United Nations
FSR	Farming Systems Research
FSR/E	Farming Systems Research and Extension
GOZ	Government of Zaïre
GTZ	Kabare Project in South Kivu
IARC	International Agricultural Research Center of CGIAR
IBPGR	International Board for Plant Germplasm Resources
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFA	Faculty Institute of Agriculture
IITA	International Institute of Tropical Agriculture
INEAC	Institut National pour l'Etude Agronomique du Congo Belge
INERA	Institut National pour l'Etude et la Recherche Agronomique
INTSOY	International Soybean Organization, United States
IPM	Integrated Pest Management
IRAZ	Institut Régional d'Agronomie et Zootechnologie
ISDR	Higher Institutes for Rural Development
ISEA	Institut Supérieur d'Enseignement Agricole
ISNAR	International Service for National Agricultural Research

MASI	Multinational Agribusiness Systems, Inc.
MSTAT	Experimental Statistics Package Trade Name
NARS	National Agricultural Research Systems
NGO	Non-Governmental Organization
ONACER	Office National des Céréales
PACD	Project Agreement Completion Date
PIP	Priority Investment Program
PMKO	Projet Maïs Kasai Oriental
PNL	Programme National des Légumineuses
PNM	Programme National du Maïs
PNS	North Shaba Rural Development Project
PRAAL	Plan d'Action pour la Promotion Vivrière et l'Autosuffisance Alimentaire
PRELAAC-3	Pepinière Régional d'Evaluation des Lignes Avancées en Afrique Centrale No. 3
PRESU	Projet de l'Enseignement Supérieur et Universitaire
PROCAR	Projet de Développement de la Production et Commercialization Agricoles Régionales
PRODALU	Projet de Développement de la Lulua
PRODEK	Projet de Développement d'Est-Kasai
PRONAM	Programme National du Manioc
PSSP	Private Sector Support Program
PVO	Private Voluntary Organization
RAV I	Zaïre Applied Agricultural Research and Outreach Project I
RAV II	Zaïre Applied Agricultural Research and Outreach Project II
SECID	South-East Consortium for International Development
SENAFIC	National Fertilizer Program
SENARAV	Service National de Recherche Agronomique Appliquée et Vulgarisation
SENASEM	Service National des Semences
SEP	Studies and Planning Service
SNV	National Extension Service
TA	Technical Assistance or Technical Assistant
USAID	United States Agency for International Development
USAID/Kinshasa	United States Agency for International Development in Kinshasa, Zaïre
USAID/REDSO/ESA	USAID Regional Economic Development Services Office for East and Southern Africa
VAT	Valeur Agronomique et Technologique

PREFACE

Background

From the 1970s through late 1991, millions of U.S. dollars, along with similar contributions from the Government of Zaïre, were invested in Zaïrian food crops research and outreach projects. This assistance made valuable contributions toward rebuilding Zaïre's food self-sufficiency status, which the country had enjoyed in the late 1950s but had lost during political struggles shortly after independence in 1960. U.S. assistance, however, was terminated abruptly as a result of civil disturbances in Zaïre on September 23, 1991. All non-essential U.S. personnel, including all who were participating in the management of assistance projects, were evaculated from Zaïre, halting several active USAID agricultural development projects.

One of these projects was a comprehensive, eight-year, $45.9 million effort designed to consolidate and culminate prior U.S. investments in Zaïrian food crops research and outreach programs. The Zaïre Applied Research and Outreach Project II (660-0124), or Projet de Recherche Agronomique Appliqué et Vulgarisation (RAV II), was only in the first year of implementation when the ordered evacuation occurred. Upon the departure of the USAID contractor's eleven-person technical assistance team, project activity was suspended. All U.S. development assistance to Zaïre was later suspended, and all projects were terminated in early 1992.

The sixteen-year U.S. investment in food crops research and outreach programs was at risk of being lost, since all USAID and contractor project personnel left Zaïre before national staffs were ready to assume these development responsibilities. The departure of the U S. technical assistance team and the subsequent cessation of USAID funding left the Zaïrian counterpart agency, SENARAV, without the technical and financial resources to carry out planned activities. Newly developed genetic materials were at risk of not being properly maintained, and raw research data, recently analyzed data, and other, unpublished data were in jeopardy. Furthermore, recent gains made during RAV II project implementation had not been documented.

Rationale and Purpose

The South-East Consortium for International Development (SECID), with six member and collaborating institutions led by Southern University (Baton Rouge, Louisiana), proposed to preserve some of the U.S. Government's investments in agricultural research and extension in Zaïre by documenting the considerable work that had taken place over the years. This offer was premised on the assumption that U.S. assistance to Zaïre would resume at some future date. If prior accomplishments were not documented, such future efforts would not benefit from the lessons already learned.

This compendium is the product of that documentation effort by the SECID/Southern University team. It presents within one cover a comprehensive

description and status report of U.S.-supported food crops research in Zaïre. This volume is intended for use by individuals with program planning responsibility and by technical assistance personnel concerned with food crops in Zaïre.

Methodology

This document was prepared primarily during the first three weeks of April 1992, with publication in early September 1992. Prior to actual manuscript preparation, numerous documents had to be located, since the project team had left behind in Zaïre all relevant documents and data. Many documents were located at IITA headquarters, in Ibadan, Nigeria. Others were loaned by SENARAV staff to SECID RAV II team members at a meeting in Kigali, Rwanda, in late March 1992; copies of these documents were made, and the originals returned to SENARAV. Still other materials were obtained from USAID archives in Washington, D.C. Finally, some documents could not be traced. The difficulty of reconstructing documentary evidence for the long-term research effort demonstrates the considerable value of a single, comprehensive document such as this compendium.

Content

Chapter 1 presents a brief overview of food crops research activities and institutions in Zaïre over the past sixteen years, focusing on programs and projects supported by the U.S. government. This chapter sets the stage and places individual programs and projects in a historical perspective.

Chapter 2 offers a discussion of the economics associated with food crops research and outreach development programs in Zaïre.

Germplasm development and conservation for the major crops--cassava, maize, and the grain legumes (beans, peanuts, cowpeas, and soybeans)--are covered in Chapter 3. The chapter treats the germplasm development research planning processes, including selection of breeding objectives, breeding and selection methods and the germplasm materials used, and variety multiplication methods and cooperators in variety diffusion. It includes a presentation of results, descriptions of varieties released and other important germplasm, an assessment of the methods used, and the outlook for further progress.

Chapter 4 reviews plant protection program strategies and research in Zaïre, including crop-specific research, cropping systems, and integrated pest management research. The chapter discusses the relationship of plant protection research and plant breeding programs, and documents the development and release of pest-resistant and pest-tolerant plant materials.

Research in soils, agroforestry, and alley cropping is described in Chapter 5. Research objectives and the criteria used for selecting appropriate tree species and

cropping systems for each agroecological zone are detailed. SENARAV's participation in international agroforestry and alley-cropping networks is also reviewed.

A summary of suggested priorities for any continuation of effort is contained in Chapter 6. These suggestions are intended to serve as guidelines for any future U.S. involvement in agricultural programs in Zaïre. Included in this final chapter are lessons learned, programs and activities showing the most promise for future impact, and recommendations for retention or modification of particular activities.

It is the hope of SECID and Southern University that this compendium will permit any future USAID-supported food crops research and outreach projects in Zaïre to begin with minimal delay and optimal design.

SECID/Southern University
September 1992

CHAPTER 1

OVERVIEW OF U.S.-SUPPORTED FOOD CROPS RESEARCH IN ZAIRE

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I. Introduction

This chapter presents an overview of U.S.-supported research on food crops in Zaïre. Important information on numerous outreach efforts is also included because USAID's approach to agricultural development closely integrated applied research and outreach activities.

A brief historical presentation of contributions prior to USAID's involvement in Zaïre precedes the discussion of U.S.-supported efforts. Significant research efforts were contributed by the Colonial Belgium Government beginning in the 1910s and by Zaïrian nationals after independence, with and without assistance from external sources. These early contributions formed the basis for project designs and thus served as an important foundation for subsequent U.S.-supported research.

Tables 1.1 and 1.2 provide summaries of significant data, including the dates of project planning and implementation events, budgeting information, and other information summaries.

II. Food Crops Research Prior to Zaïre's Independence

The Colonial Belgium Government had long been concerned with agricultural research in Zaïre (earlier known as the Congo Free State and as the Belgian Congo). The Government's main effort was directed toward increasing the production of particular crops. In 1933, Prince Leopold of Belgium established a very active agricultural research system in Zaïre, which received significant resources. By 1960, this system, the Institut National pour l'Etude Agronomique du Congo Belge (INEAC), was recognized as the finest tropical agricultural research facility in Africa. Supporting INEAC's research activities were over 950 Belgium scientists and extension workers in regions throughout Zaïre; more than 4,000 Zaïrians were also employed as laboratory and field technicians. Although INEAC focused on income-producing export crops such as coffee, cocoa, cotton, palm oil, and rubber, it included a division for food crops. The food crops division worked on improvement and protection of traditional crops (cowpeas, field beans, cassava, maize, peanuts, rice, soybeans, sweet potatoes, and sugar cane) and adaptation of exotic species and cultural practices.

Outputs from INEAC programs for improvement of food and export crops were transferred to indigenous farmers through the system of paysannata. This program was a scheme to resettle subsistence farmers on seven-hectare plots in areas with good access to marketing transport systems, thereby providing for effective colonial

administration of cultural practices and more efficient extraction of marketable surpluses. However, farmers were often physically coerced to participate in this production scheme.

INEAC's research contributed to production improvements of all food and export crops produced by the commercial or plantation sector and the indigenous subsistence farming sector. Coupled with restrictions on migration of Zaïrians to urban areas, the system provided Zaïre with food surpluses in certain impact areas during the late 1950s.

III. Food Crops Research Immediately Following Independence

Following independence in 1960, Zaïre was soon torn by political turbulence, which had far-reaching negative impacts on most aspects of the country. INEAC activities in Zaïre were interrupted periodically during these conflicts. Security problems and other factors led to the withdrawal of Belgian personnel from Zaïre in 1969. Zaïrians assumed operation of the INEAC facilities, though only seven Zairians had academic training in research. This manpower vacuum led to the collapse of the institution's ability to maintain its physical and organizational infrastructure. In 1970, the Government of Zaïre (GOZ) reorganized INEAC as the Institut National pour l'Etude et la Recherche Agronomique (INERA) within the Office of the President. Seven Zaïrians, who had been able to keep one station (Gandajika) operating throughout the turmoil of the 1960s, were given the job of developing programs within the new organization.

The thrust of the newly created INERA was to support family-tended farming units with both cash and subsistence crops. In actuality, research was still directed mainly toward export crops, although the plantation system had declined along with support for INERA. INERA was placed in the Office of the Director General of Agriculture in 1975, under the leadership of the former director of INERA. INERA underwent many organizational changes, including integration with the Faculty of Agricultural Sciences at the University in Yangambi. This integration, however, was not fully implemented for many reasons, including a severe economic crisis that began with rising fuel costs and declining copper prices. In the mid-1970s, the budget, in real terms, was only three percent of the pre-independence budget that INEAC had enjoyed. The lack of personnel with the necessary skills to manage the large, technically oriented organization, along with the dearth of academically trained personnel and severe shortages of funding, left INERA ineffective. Maintenance of the large complex at Yangambi consumed one-third of the meager budget, and salaries consumed most of the remaining two-thirds, leaving little or no money for research supplies and equipment.

IV. Beginning of U.S. Support

During the turbulence of the 1960s, agricultural production, like research capability, also declined. The paysannata system was abandoned; security was a problem; the infrastructure needed to support food crop production and marketing was not maintained; and food shortages and malnutrition became serious problems. During 1967 and 1968, the Government of Zaïre initiated several high-priority programs to address these problems; INERA, however, was unable to respond. The GOZ thus sought support from external sources. Prior to the call for U.S. assistance, the GOZ was financing its own development efforts, such as academic training of Zaïrian personnel and procurement of external technical assistance.

USAID support to Zaïrian food crops research began indirectly during the early 1970s through support to International Agricultural Research Centers (IARCs), namely the International Institute of Tropical Agriculture (IITA) and the Centro Internacional para el Mejoramiento de Maiza y Trigo (CIMMYT), before evolving into direct project support.

A. Programme National du Maïs (PNM)

In order to alleviate food grain shortages through the improvement of maize production, the GOZ in 1991 entered into a ten-year agreement with CIMMYT for assistance in building its maize research capabilities. The Programme National du Maïs (PNM), founded under this agreement, was intended to be superior by international standards and to be capable of establishing a useful pattern for other research projects, thereby serving as a nucleus for a re-oriented and strengthened national agricultural research service essentially linked to farm production, extension, and education.

A team of three expatriate scientists from CIMMYT, which worked with the new program in Zaïre, launched studies on maize selection, breeding, and cultural practices. Zaïrians received on-the-job training at CIMMYT and were enrolled in Master's and Ph.D. degree programs at U.S. universities. (Contributions of this program are discussed in Chapters 3 and 4.)

PNM was initiated as a separate program attached to the National Cereals Office to ensure it the autonomous management necessary to be able to more efficiently reach its specific goals. However, PNM officially became a part of INERA on July 1, 1977, in a move to regroup several externally supported activities within the INERA structure.

B. North Shaba Rural Development Project (660-0059)

Although the United States did not initially provide direct funding to PNM, the research/extension component of the North Shaba Rural Development Project (660-0059) was designed to make a major contribution to both maize research and applied food crops research in general. The purpose of this project was "to identify an effective rural development process for improving small farmer production and income that [was] replicable in other parts of Zaïre." It was expected that crop production and marketing, particularly for maize, would increase as a result of this effort.

While the North Shaba Rural Development Project was not totally a food crops research project, applied research/extension was one of the six subsystems or components. Other subsystems dealt with development of cooperatives, marketing and credit, infrastructure development, and monitoring and evaluation. The applied research/extension component, which was implemented within the Ministry of Agriculture, collaborating with the Office of Roads (infrastructure development) and the Bank of Kinshasa (farmer credit administration), was to be closely geared with outreach and to have maximum farmer participation.

Technical assistance was provided by an American agronomist working with three PNM scientists. Although there was no participant training, a center was established at Mbulula for training extension workers and others involved in outreach.

This six-year project (September 1976 to August 1982) had a total budget of over $19.07 million. The budget consisted of a loan of $3.5 million, a $6.29 million USAID grant, and $9.27 million from the GOZ. The level of support for the research/extension component was $1.454 million. Development Alternatives Incorporated (DAI) was contracted to provide technical assistance and project leadership for USAID.

The life of the North Shaba Rural Development Project was extended by one year, to September 1983, with $3.6 million in additional funding. The objectives remained very similar to those originally proposed.

C. Programme National du Manioc (PRONAM)

Coupled with the grain shortage, a serious cassava blight disease appeared in Bandundu during the 1968-69 season and quickly spread to Bas-Zaïre and the Kasais. In March 1973, the GOZ and USAID/Zaïre made an urgent request to IITA to assist in identifying the disease. This successful relationship with IITA led to a cooperative agreement between the GOZ and IITA in 1974 to establish a national cassava research and training program, the Programme National du Manioc (PRONAM). Like the maize program, PRONAM was funded almost entirely by the GOZ. IITA provided some scholarships for Zaïrian personnel and training at IITA; and INERA provided PRONAM with facilities and a national staff, which was trained under the program.

D. Cassava Outreach Project (660-0077)

In 1977, the Government of Zaïre, facing serious economic problems, sought funding and support for PRONAM from USAID. Project support was forthcoming through the Cassava Outreach Project (660-0077). Prior to granting this support, USAID had supported the Department of Agriculture's successful request to the Department of Plan to obtain counterpart funds for PRONAM.

The project paper was approved in June 1978 for providing $4.5 million in foreign exchange cost for continuing the program through 1982. The GOZ contribution was set at nearly $19 million. The U.S. government contributed 30 person-years of technical assistance (agronomy, plant breeding, entomology, extension agronomy, training, and physical plant services) through a contract with IITA. Eight expatriat positions were provided by IITA. Implementation did not actually begin until May 1980. IITA continued to provide technical assistance to the program. The project completion date was in July 1985.

The project paper made clear that USAID project support was for applied substation research, logistics support services, and training Zaïrian researchers and extension agents. The purpose of this project was "to develop the institutional capability of PRONAM (1) to conduct adaptive and applied research on cassava, and (2) to make new cassava technology available for distribution to subsistence farmers in Zaïre."

The project provided academic training for 22 individuals to advanced degree levels and paraprofessional training for 32 technicians. Research equipment, vehicles, maintenance tools, communication equipment, and other equipment were procured for the M'Vuazi station and five substations including Kiyaka and Gandajika. A training center was established at M'Vuazi, and electricity was brought to the station by this project. This project was implemented in cooperation with the Department of Agriculture. (The technical accomplishments of this project and of PRONAM in general are discussed in Chapters 3 and 4.)

V. The Advance of U.S. Support to Zaïrian Food Crops Research

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As mentioned earlier, USAID support to Zaïrian food crops research began indirectly through CIMMYT and IITA. U.S. support advanced more directly with the Cassava Outreach Project, the emphasis of which was outreach. Applied food crops research was similarly supported through one component of the North Shaba Rural Development Project.

The projects reviewed in this section are those that were designed for the primary purpose of directly addressing food crops research and outreach concerns.

A. INERA Support Project (660-0064)

PNM (initiated in 1972) and PRONAM (initiated in 1974), discussed earlier, had been initiated without U.S. assistance and were implemented essentially outside the INERA structure. The INERA Support Project's purpose was to assist the GOZ in mounting an effective program of field-oriented research in soil science and food legumes. The overall goal was to make Zaïre self-sufficient in the production of major agricultural crops by 1985. A major concern during this period was to augment the protein level of the Zaïrian diet. Thus, grain legumes were considered important crops for improvement.

Capabilities were to be developed directly within INERA to develop production packages for food legumes through applied adaptive research. INERA was to provide soil services to the country in general and to concentrate its resources in priority areas of agricultural research. The project was designed to be a four-year, $6.159 million effort, with USAID providing $3.35 million in grant funds and the remainder from GOZ resources. Over 26 person-years of long- and short-term technical assistance were to be provided to the project by Multinational Agribusiness Systems Incorporated (MASI).

On-the-job training was to be provided along with short-term formal training and long-term advanced degree-level education for 11 participants in food legumes (emphasizing soybeans) and soils. The soils laboratory at Mulungu was to be remodeled and enlarged, along with the installation of new equipment. Another component was to assess the agricultural research subsector and INERA.

The INERA Support Project began in November 1979; the project completion date was December 31, 1984.

B. RAV I (660-0091)

Unlike the previous research efforts by CIMMYT and IITA, which developed single-crop research through PNM and PRONAM (on maize and cassava, respectively), the Projet de Recherche Agronomique Appliquée et Vulgarisation (660-0091), or RAV I, took into consideration the common food crops that farmers grew in intercropped systems. Along with maize and cassava, these crops included edible beans, cowpeas, peanuts, and soybeans.

A key feature of RAV I was the integration of three commodity research programs into a single administrative unit within the Department of Agriculture. In addition to PNM and PRONAM, a third program, for legumes, had been formed: the Programme National des Légumineuses (PNL).

RAV I reflected other USAID approaches to development, namely, th strengthening of existing appropriate technologies and the integration of research ano outreach through the farming systems approach. Thus, RAV I was not an entirely

new project. Rather, it was an effort to consolidate and integrate former gains in food crops research for the practical purpose of packaging relevant technologies for introduction to farmers. Its purpose was "to improve and expand the ability of the Department of Agriculture to undertake applied research and to transfer agricultural technology needed to increase village cultivators' production of food crops; and to increase institutional capacities to conduct agricultural research supporting outreach programs."

RAV I was authorized on September 7, 1983, with a life-of-project funding of $10 million in USAID grant funds. The project agreed completion date was originally September 30, 1989, but completion was later extended to September 30, 1990, with $5 million in extra funding. In addition, counterpart funds in the amount of $13.654 million were provided for local currency costs. Although the project agreement was signed September 13, 1983, the project did not actually begin until 1985 upon the arrival of the IITA contractor technical assistance team. Fifteen technical assistants served on the project initially; near the end-of-project date, the number of long-term technical assistants had decreased to twelve.

Nineteen ninety-five also saw the formation of the Service National de Recherche Agronomique Appliquée et Vulgarisation (SENARAV). This unit was established to formalize within the Department of Agriculture a unit for the implementation of RAV I.

RAV I was successful in developing several high-yielding lines of cassava, maize, peanuts, beans, cowpeas, and soybeans. The project provided long-term training for 35 Zairian M.S. and Ph.D. candidates. Seventy SENARAV employees participated in short-term technical training programs. The project established an organizational structure for SENARAV and built up the infrastructure for the three national programs. Foundation seed were distributed to at least 30,000 farmers through 139 private voluntary organizations (PVOs) and governmental and private-sector outreach entities. This project had many successes; its weaknesses were addressed by the follow-on project, RAV II.

C. RAV II (660-0124)

RAV II (660-0124) sought to strengthen and expand the ongoing research on cassava, maize, and grain legumes; provide increased support to farming systems and outreach activities; and improve research management. Additionally, RAV II sought to improve long-term financial, program, and environmental sustainability; to strengthen monitoring and evaluation systems; and to focus on key areas in human resources development.

The purpose of RAV II was "to strengthen and improve the capacity of the Department of Agriculture and collaborating institution to develop and transfer agricultural technologies for selected food crops, on a sustainable basis, to farmers." This carefully prepared statement in the project paper allowed for inclusion of INERA

as a partner with the Department of Agriculture in the generation and transfer of technologies. It also provided for non-governmental organizations, private voluntary organizations, and others to participate in outreach. The sustainability requirement was also given in this purpose statement.

RAV II was designed and implemented with the South-East Consortium for International Development (SECID) as USAID's technical assistance contractor. Southern University, in Baton Rouge, Louisiana, was lead institution for the effort, which involved five other SECID member and collaborating institutions.

RAV II was initially designed as a $40.9 million, eight-year project, consisting of a $20 million USAID grant, with the rest provided by GOZ resources. The project paper was amended soon after project implementation began to include a natural resources management emphasis and to adjust for GOZ budgetary shortfalls. This modification added $5.0 million in USAID grant funds to the project; the end-of-project date remained September 30, 1998.

Eleven long-term technical assistants were employed from among SECID's member and collaborating institutions along with short-term personnel to provide over 48 person-years of technical assistance. The project paper specified that 11 Ph.D. and 22 M.S. degree candidates would be supported. Three women were to be among the M.S. degree candidates, and one woman was to continue through Ph.D. candidacy. Participant training was budgeted at more than $4.3 million. Investment in equipment and facility improvement were to cost over $2.7 million in U.S. grants and over $3.1 million in counterpart funds.

The implementation contract was signed late in September 1990, and implementation began soon thereafter. Essentially all implementation team members were posted in Zaïre in January 1991.

RAV II ended abruptly and prematurely when civil disturbances broke out and the U.S. ambassador ordered all official Americans evacuated from Zaïre in late September 1991. These disturbances included looting of businesses throughout Kinshasa and other areas of Zaïre. Houses of selected government officials were also looted by the indigenous population, led by mutinous soldiers who had not received pay raises as promised, nor any salary for several months. Political events also precipitated these disturbances, particularly the alleged government-instigated interferences with a people-supported National Conference to chart the course to a true multiparty democracy. The conference opening had been stalled since March 1991; the conference finally opened in July 1991, only to spend the next three months checking the credentials of delegates and amending convention rules.

Following the evacuation, USAID suspended development support to Zaïre and terminated all project activities. SECID was allowed to continue some project efforts in the United States. One of these efforts was the preparation of this compendium by six of the original RAV II team members.

The major accomplishments of RAV II included the establishment of new policies within SENARAV, the rehabilitation of facilities, the establishment of formal outreach units and national coordination for these units, and the establishment of a tissue culture laboratory. Considerable work in the areas of training package preparation and research planning and preparation was pending at the time of the evacuation of the U.S. team from Zaïre. Ten new candidates for M.S. and Ph.D. degrees were being admitted to U.S. universities at that time.

RAV II also supported 27 participants who had begun candidacy for advanced degrees during RAV I. Five of these participants completed their programs and returned to Zaïre during RAV II. At the time of this writing, Southern University was to continue coordinating the participant training program through at least December 1992, after which all but three participants were to have completed their programs.

VI. Other Relevant U.S. Efforts

In addition to the projects discussed above, it is likely that there were other U.S.-funded efforts that contributed to Zaïrian food crops research. Some of these may have been included as components within rural development projects in general, such as the North Shaba Rural Development Project. The Central Shaba Agricultural Development Project (660-0105) conducted on-station and on-farm trials, particularly with maize. These investments may be included as applied research if they consisted of more than simply seed multiplication. The Area Food and Market Development Project (660-0102) also carried out on-farm trials and may have contributed substantially to the applied food crops research investment pool.

Table 1.1. Planning and Implementation Dates of USAID-Supported Food Crops Research and Related Projects in Zaïre

Project Number	Short Title	Project Paper Approval Date	Implementation Start Date	Completion or Termination Date[1]
660-0059	North Shaba Rural Development	September 9, 1976	NA	September 1983
660-0064	INERA Support	June 5, 1977	November 1979	December 31, 1984
660-0077	Cassava Outreach	June 8, 1978	May 1980	July 1985
660-0091	RAV I	September 7, 1983	July 29, 1985	September 30, 1990
660-0124	RAV II	June 6, 1990	October 1, 1990	May 10, 1992

[1]Participant training continued beyond completion/termination date for some projects.

Table 1.2. Budgeting of USAID-Supported Food Crops Research and Related Projects in Zaïre

Project Number	Short Title	USAID Grant ($US millions)	Government of Zaïre Resources ($US millions)	Other (loans, etc.)
660-0059	North Shaba Rural Development	1.454	[1]	[1]
660-0064	INERA Support	3.350	2.809	
660-0077	Cassava Outreach	4.500	19.000	
660-0091	RAV I	15.000	13.654	
660-0124	RAV II	25.000[2]	20.900	

[1]Total budget was over $22 million. Amount shown is the estimated amount for food crops research component.

[2]Only about $13 million was obligated for the first 21 months. Unknown amount was de-obligated upon premature project termination.

References

Baffes, J., T. M. Lukusa, and G. C. W. Ames. 1987. "Optimal Crop Combinations under Risk: The Case of Maize Production in the Kasai Region of Zaïre." In How Systems Work: Proceedings of Farming Systems Research Symposium, 1987. Washington, D.C.: University of Arkansas, Winrock International Institute for Agricultural Development.

International Institute of Tropical Agriculture. 1985. Final Report: Cassava Outreach Project. USAID Project No. 660-0077. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Linsenmeyer, Dean. 1974. An Economic Analysis of Maize Production in the Kasai Oriental Region of Zaïre: A Research Proposal. East Lansing, Mich.: Department of Agricultural Economics, Michigan State University.

Programme National du Maïs (PNM). 1973. Annual Report 1972-1973. Kinshasa: National Maize Program, Department of Agriculture, Republic of Zaïre.

South-East Consortium for International Development. 1992. Contractor Final Status Report: Zaïre Applied Agricultural Research and Outreach Project II. USAID Project No. 660-0124. Washington, D.C.: SECID.

U.S. Agency for International Development. 1976. Project Paper: North Shaba Rural Development (Project 660-0059). Washington, D.C.: USAID.

------. 1977. Project Paper: INERA Support (Project 660-0064). Washington, D.C.: USAID.

------. 1978. Project Paper: Cassava Outreach (Project 660-0077). Washington, D.C.: USAID.

------. 1980. Project Paper: Amendment for North Shaba Rural Development (Project 660-0059). Washington, D.C.: USAID.

------. 1982. Midterm Evaluation: INERA Support (Project 660-0064). Washington, D.C.: USAID.

------. 1983. Project Evaluation Summary: Cassava Outreach (Project 660-0077). Washington, D.C.: USAID.

------. 1984. Country Development Strategy Statement, FY 1986: Zaïre. Washington, D.C.: USAID.

------. 1988a. Threshold Decision Evaluation: Zaïre Applied Agricultural Research and Outreach Project (660-0091).

------. 1988b. Final Project Evaluation: Zaïre Applied Agricultural Research and Outreach Project (660-0091). Washington, D.C.: USAID.

------. 1989. Midterm Evaluation: International Potato Center (CIP)/Regional Potato Culture Improvement Program (PRAPAC) Potato Network Research Project (698-0435.04). Washington, D.C.: USAID.

------. 1990. Project Paper: Zaïre Applied Agricultural Research and Outreach Project II (660-0124). Washington, D.C.: USAID.

CHAPTER 2

AGRICULTURE'S IMPORTANCE SEEN THROUGH THE GENERAL ECONOMY, PUBLIC INVESTMENTS, USAID'S PROGRAM, AND RESEARCH AND EXTENSION

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I. Economic Setting

A. The Zaïrian Economy

The Zaïrian economy grew slowly during much of the period since independence. Growth in gross domestic product (GDP) averaged less than 1.5 percent in 1965-1985. This slow economic growth has been attributed to (1) deterioration in transportation infrastructure, (2) sharply reduced investment following nationalization in 1973, (3) cumbersome governmental regulations on economic activity, (4) bureaucratic inertia, and (5) decline in international prices of mineral exports (USAID, 1990).

After independence, rising copper prices helped finance a program of large public projects such as the Inga hydroelectric dam, the Inga-Shaba high-voltage power line, and the Maluku steel complex. External factors--the oil crisis of the 1970s, falling copper prices, and the inability to ship ore through Angola--and internal policies, including the nationalization of major industries, combined to decrease the availability of foreign exchange for technical equipment and of managerial expertise needed to keep the mining industries operating effectively (Tollens and Shapiro, 1992).

Deterioration of the balance of payments and GDP led the International Monetary Fund to impose a stabilization program that involved control of the Bank of Zaïre in 1982. Concurrently, Zaïre implemented macroeconomic policy changes designed to stimulate economic growth through the elimination of price and marketing controls and a move toward flexible exchange rates. The World Bank worked closely with the Government of Zaïre (GOZ) toward macroeconomic policy reforms.

Price liberalization did stimulate the economy later in the 1980s. However, foreign exchange shortages and falling private investment mitigated the potential benefits of macroeconomic policy reforms. The rapidly deteriorating infrastructure, especially roads and railway, is a crucial remaining constraint to growth that will continue to restrain the impact of improvements in economic policies.

B. Agricultural Policy

> *From independence until the early 1980s, Zaïre (like many other African countries) pursued macroeconomic policies that on balance had adverse effects on the agriculture sector. These policies included, among others, maintenance of an overvalued exchange rate, low official producer prices for food crops, high export duties and cumbersome bureaucratic procedures for agricultural commodities, many internal local taxes on production and marketing of agricultural goods, and substantial public borrowing leading to a very heavy debt service burden which severely limited foreign exchange availability* (Tollens and Shapiro, 1992:36).

The goal of the macroeconomic policy changes of the early 1980s was to create conditions favorable to agricultural growth and investment through foreign exchange availability, investment incentives, low inflation, export facilitation, and decreased bureaucratic impediments. It was hoped that higher prices to producers would encourage production; however, the deteriorating infrastructure has tended to lead to an ever-increasing percentage of the final consumer price going to transportation. Combined with the exploding rate of inflation, farmers have not been encouraged to market an increasing agricultural surplus for urban populations; instead, farmers have opted for barter and home consumption.

C. Importance of Agriculture in the National Economy

Seventy percent of Zaïre's labor force is involved in agriculture, about 30 percent of GDP comes from agriculture, and about 60 percent of agricultural production comes from the traditional sector (Tollens and Shapiro, 1992). The most important crops are cassava, maize, groundnut, beans, bananas, and rice. The diverse ecological zones of the country result in tremendous variation in the crops grown, with the important exception of cassava. According to a 1985 survey in the southern band, 97 percent of households produced cassava. Maize and groundnut were the second and third crops, accounting for 92 percent and 44 percent, respectively, of households covered by the survey.

Per capita food production has not increased since independence. While production growth has exceeded that of many other African countries, population growth has more than equaled the growth in agricultural production. After declines in agricultural output in the 1965-1973 period, agricultural production has experienced annual growth ranging from 0.9 to 3.6 percent (World Bank, 1988). These rates compare favorably with an average growth rate of sub-Saharan countries of 0.4 percent (World Bank, 1988).

Population growth has been concentrated in urban areas. Population growth has been only 1.2 percent in rural areas, contrasted with 7 percent in urban areas, resulting in a national population increase averaging about 3.1 percent (Shapiro, 1990). To meet this shortage, food imports have increased to 20 percent of all imports (Tollens and Shapiro, 1992).

Agricultural research and extension has made an important contribution to the growth in agricultural production. Before independence, Zaïre's agricultural research system, INEAC (Institut National pour l'Etude Agronomique du Congo Belge), was a well-respected and well-supported institution. However, INEAC had the unfortunate policy of not training Zaïrians for scientific positions, a policy that has had significant negative implications for decades and led to the dismantling of the system after independence. Nationai commodity research programs for cassava (PRONAM), maize (PNM), and legumes (PNL) were placed in a new institution (RAV I in 1983 and SENARAV in 1989).

Table 2.1 illustrates the contribution of agriculture to the national economy. Agriculture recently has become the leading sector, averaging over 30 percent as compared with mining's 24 percent. It is important to note, however, that agriculture has used about 70 percent of the population to generate only 30 percent of GDP.

Table 2.1. Sectoral Contributions to GDP, 1982-1987 (percentage of value added by sector)

Sector	Year					
	1982	1983	1984	1985	1986	1987
Agriculture						
commercialized	13	13	14	11	13	13
subsistence	22	21	18	16	16	18
Mining (extraction)	12	19	25	31	33	24
Manufacturing	2	1	2	2	2	1
Other goods	4	4	3	3	3	4
Commerce (trade)	21	20	19	17	16	18
Other services	20	17	16	15	14	17
Misc. other[1]	5	4	4	4	4	5
Total	100%	100%	100%	100%	100%	100%

Source: Bank of Zaïre, Rapport Annuel 1988, Table 4, p. 69.

[1]Includes import duties and noncommercialized construction.

During the 1980s, commercial agriculture grew in importance relative to subsistence agriculture (Table 2.2). The latter continues to be the larger component (60 percent compared with 40 percent), but its relative share has been decreasing. Production of food crops contributes the greatest share to GDP. In commercial agriculture, 60 to 70 percent of value added comes from marketed food production, and 70 percent of this production is crop output. Livestock and fish make up most of the remainder. Exports account for about 25 to 30 percent of value added from the commercial agricultural sector, as compared with 10 to 15 percent for agro-industrial production for domestic purposes (Tollens and Shapiro, 1992).

Table 2.2. Components of Agriculture's Contribution to GDP, 1982-1987 (percentage of value added by subsector)

Subsector	Year					
	1982	1983	1984	1985	1986	1987
Subsistence agriculture	63	61	57	59	55	57
Commercial agriculture	37	39	43	41	45	43
Commercial agriculture						
Agriculture for export	5	5	12	11	17	12
Agro-industrial production[1]	5	8	7	5	4	5
Marketed food production	27	26	24	25	23	26
Marketed food production						
Food crops	19	18	17	18	17	19
Livestock	4	4	4	4	3	4
Fish	4	4	3	4	3	3
Total	100%	100%	100%	100%	100%	100%

Source: Bank of Zaïre, Rapport Annuel 1988, Table 4, p. 69; Table 6, p. 71.

[1]For domestic use.

Agriculture can serve as a leading sector in the economic growth of Zaïre. Because of the dominant role of agriculture in employment, improvements in the sector have a wide-ranging impact throughout classes and regions of society. The importance of making product available for urban centers, in addition, puts improvements in the marketing of agricultural products as an equally important strategy along with production advances for stimulating economic growth. Activities that have been suggested to achieve this agriculturally led economic growth strategy include:

- increase sustainable crop production and productivity for the domestic and export markets;
- provide market-oriented policy and institutional incentives for rural agricultural enterprises; and

- improve rural financial services for production, storage, processing and marketing activities by small and medium-sized farm firms and entrepreneurs (Tollens and Shapiro, 1992:128).

D. Development Plan for Agriculture

The five-year development plans for 1986-1990 and 1991-1995 have the following agricultural objectives: food self-sufficiency, raw materials for domestic agro-industrial enterprises, and increased rural incomes. Self-sufficiency has been generally achieved for rural areas, but it remains an important concern in urban areas. Imports have largely increased in response to this deficit for urban populations. Policy-makers appear to believe that self-sufficiency has been achieved for cassava and nearly for maize, whereas supplies of rice, wheat, sugar, livestock, and fish are inadequate (Tollens and Shapiro, 1992). Food self-sufficiency is more of a political goal than an economic need or reality.

According to a World Bank agricultural policy statement for Zaïre (World Bank, 1989), nine policy areas should be the focus of agricultural development initiatives:

- geographic concentration of development activities;
- increased size of operations;
- productivity improvements;
- price liberalization;
- private-sector services for production inputs and extension;
- improved institutional framework;
- increased financial resources;
- improved marketing policy; and
- equitable land tenure policy.

Only private-sector agricultural services and land tenure were added from the 1986-1990 plan. Transportation, input supply, and extension continue to be the focus of efforts toward self-sufficiency.

The need to target development efforts geographically is dictated by the size of the country, the often-poor soils, and the generally diffuse population. The successful development of infrastructure and services for production and marketing requires a critical mass of people and activities.

The size of farming enterprises is largely determined by the availability of mechanization. Focus must be placed on increasing the area that can be farmed per family in areas where field labor, largely women, is severely constrained during critical stages in the growing season. In most agricultural areas in Zaïre, labor is more constraining than land.

Increased productivity can assist in several ways. First, a greater surplus is generated after home consumption needs have been met. Where there has been a deficit in meeting home nutritional requirements, the increased productivity will result in a healthier and more productive labor force. Second, greater productivity will result in larger quantities for processing and marketing, thus providing more income and labor opportunities for this sector. Higher rural incomes should be achieved not only by farmers but also by farm laborers and by individuals involved in processing, transportation, and marketing. It might be further hoped that the increased agricultural surplus resulting from higher productivity will put downward pressure on consumer prices.

The GOZ has not tended to get directly involved in agricultural production or marketing through commonly used programs such as agricultural cooperatives and price control boards. Its involvement has been limited to maintenance of infrastructure, extension, research, and credit.

Price liberalization has been combined with trade protection to increase profitability for producers. Based on estimates contained in a ZTE/COGEPAR study (1987), import taxes have been set at 50 percent for livestock, 40 percent for sugar, 30 percent for flour for bread, and 10 percent (the minimum allowable) for fertilizer (Tollens and Shapiro, 1992).

Specific incentives that will result in greater private-sector involvement in input services for agriculture have not be explicitly formulated. Target areas would include extension assistance in recommendations for production practices and crop yield loss diagnostics; fertilizer transportation and marketing; and production and marketing of improved seed varieties.

Coffee, cocoa, tea, rubber, and quinine are the most important export crops. The GOZ strategy toward these foreign exchange earners involves "the elimination of institutional constraints (foreign exchange allocation, export constraints, official price listings) and technical constraints (research, extension, transport, improved planting material, etc.), and an association of public and private interests; the encouragement of replanting of plantation crops; and the creation of smallholder plantations where this option is possible" (Tollens and Shapiro, 1992:41).

Cotton, palm oil, sugar, and tobacco are the most important agro-industrial crops. The GOZ strategy toward these crops is "...the elimination of technical constraints (inadequate extension, lack of new cotton varieties, poor state of feeder

roads) and institutional constraints (insufficient marketing credit, monitoring and management, multiplicity of taxes)" (Tollens and Shapiro, 1992:38).

The Five-Year Plan, due to public finance constraints, depends largely on facilitating efforts in the private sector. Emphasis is placed especially on marketing. Improved information and marketing infrastructure to transport, store, and package agricultural products is used as an important means of dealing with the crucial shortage of agricultural products available to the large urban concentrations. The creation of wholesale markets is also suggested. These market-oriented improvements will be combined with more effective property rights for traditional farmers.

II. Public Investment in the Agricultural Sector

Policy-makers in the Zaïrian government have frequently asserted the importance of the agricultural sector; however, public spending in agriculture has been far less than its contribution to GDP. In 1985, the agricultural sector's share of public spending was only about 1 percent, while its contribution to GDP was approximately 30 percent (World Bank, 1988). From 1986 to 1989, the Priority Investment Program (PIP) represented between 8 and 11 percent of public investment in agriculture (IMF, 1989). Thirty percent of the 65 PIP projects, generally under the Ministries of Agriculture and Rural Development, were targeted to food crop production.

Plan d'Action pour la Promotion Vivrière et l'Autosuffisance Alimentaire (PRAAL) was put in place to assist in achieving the goal of agricultural self-sufficiency as part of the Five-Year Plan (1986-1990). PRAAL focused its efforts on providing agricultural support services and materials to areas not served by existing projects of the Departments of Agriculture (DOA) and Rural Development (DORD).

INERA, in the Ministry of Higher Education and Scientific Research, and SENARAV, in the DOA, are the two major research agencies. INERA employs 59 researchers. Four of the researchers hold Ph.D degrees, 10 hold M.S.-equivalent degrees, and 45 hold AO degrees (approximately equivalent to B.S. degrees). SENARAV, financed partially by USAID from 1983 until the suspension of support in 1992, employs 55 researchers, including five trained at the Ph.D. level and 21 at the M.S. level (including those currently in advanced degree training) (USAID, 1990).

The International Service for National Agricultural Research (ISNAR) has developed, in conjunction with GOZ planners, a National Agricultural Research Program for 1990-2000. The plan designates main research stations (Yangambi, Nioka, Mulungu, Gandajika, and M'Vuazi) and secondary research stations (Kiyaka, Bambesa, Luki, Kaniameshi, and Kipopo (or Kaniama)).

The National Extension Service (SNV), consisting of 5,000 agents, has had a poor history of collaborative effort with research, and its supplies, especially vehicles, have been greatly lacking. In addition to the public efforts in extension, there is a diverse array of organizations in the private and non-governmental sectors.

A. Agricultural Policy

The Studies and Planning Service (SEP) and the Directorate of Markets, Prices and Campaign Credit (DMPCC) are the agencies designed to provide agricultural policy analysis, planning, and statistics. SEP (originally, Bureau d'Etudes) was created to provide agricultural economics analyses, and a department of agricultural economics was initiated at Yangambe.

USAID made an important investment in SEP by providing graduate-level training in the United States for 70 professionals. This training was supplemented with on-the-job training. The SEP's data-collecting capability, on which its policy analysis depends, remains a major stumbling block (Tollens and Shapiro, 1992).

The collection of market data for policy analysis is the responsibility of DMPCC. Primary activities have been collection of market information (prices and quantities) and supervision of marketing credit. Several surveys of the marketing system have been conducted, especially on the transportation and marketing channels for the key subsistence food crops moving from rural areas into the major urban area of Kinshasa.

B. Research

Agricultural research is carried out by a diverse array of public and private organizations. SENARAV is the primary contributor to food crop research and perennial crops are the focus of INERA and private corporations. The following research institutes or agencies are involved in agricultural research:

(1) Department of Higher Education and Scientific Research
- *(a) INERA*
- *(b) Centre Regional d'Etudes Nucléaires de Kinshasa (CRENK)*
- *(c) Centre de Recherche en Sciences Naturelles (CRSN)*
- *(d) Institut de Recherche en Sciences de la Santé (IRSS)*
- *(e) Centre de Recherche Agro-Alimentaire de Lubumbashi CRAAL)*
- *(f) Centre d'Etudes des Substances Naturelles d'Origine Végétale (CESNOV)*
- *(g) Faculté de Medecine Vétérinaire de l'Université de Lubumbashi*
- *(h) Institut Facultaire des Sciences Agronomiques de Yangambi (IFA)*
- *(i) Institut de Recherche Agronomique et Zootechnique (IRAZ-CEPGL)*

(2) *Department of Agriculture*
   (a) *SENARAV*
   (b) *Programme National du Maïs (PNM)*
   (c) *Programme National du Manioc (PRONAM)*
   (d) *Programme National des Légumineuses (PNL)*
   (e) *Programme National du Riz (PNR)*
   (f) *Programme National de l'Engrais (PNE)*
   (g) *Bureau National Semencier (BUNASEM)*
   (h) *Bureau de Projet ITURI (BPI)*
   (i) *Projet Maraichage et Pisciculture (PMP)*
   (j) *Projet Maïs Kasai Oriental (PMKO)*
   (k) *Projet de Développement Rural Intégré de Kabare (Kivu-Sud)*

(3) *Department of Land, Environment and Nature Conservation*
   (a) *Programme "Man and Biosphere" (MAB)*

(4) *Presidency*
   (a) *Programme d'Etude des Ressources Terrestres par Satellite (ERTS)*

(5) *Gecamines Développement*
   (a) *Centre de Recherche sur le Maïs*

(6) *Private sector*
   (a) *Centre de Binga (SCZ-PLZ) for oil palm*
   (b) *Pharmakina et Kinaplant for cinchona* (Tollens and Shapiro, 1992:61)

USAID and ISNAR assisted the President's Office in developing a strategy to improve agricultural research institutional organization. In 1985, ISNAR published a report that summarized the institutional changes that were needed. In the report, USAID identified three principal constraints to improving INERA's performance:

- *national pride in the institution that had acquired an international reputation for excellence has inhibited consideration of more modest approaches which could be realistically considered;*

- *nostalgia on the part of the Belgian Cooperation has led to proposals that seek to reestablish the institution as it once was; and*

- *INERA's reputation among donors as a bottomless pit capable of absorbing unlimited resources and as having a limited outlook for eventual establishment of the institution as a sound productive entity* (Tollens and Shapiro, 1992:63).

The report noted several obstacles that were preventing INERA from making a significant contribution to agricultural research in Zaïre:

- *lack of financial resources;*
- *infrastructure and equipment which has been allowed to run down;*
- *isolated research stations, without modern facilities, with large overhead costs and unable to attract good staff;*
- *inadequate, unrealistic and overambitious administration and research program;*
- *lack of an overall framework to coordinate research in Zaïre; and*
- *lack of commitment from the GOZ to agricultural research and to agriculture* (Tollens and Shapiro, 1992:63).

The main recommendations of the ISNAR report were:

- *on the administrative level, to transfer INERA's headquarters from Yangambi to Kinshasa and to organize management practices;*
- *reduce INERA's research stations from 20 to 9 and evaluate the research potential of these 9;*
- *limit Yangambi to agricultural research, trim its infrastructure to fit research needs, and balance future needs with costs;*
- *establish a research program committee within INERA's Direction Générale, also with responsibility for hiring staff; and*
- *improve links with other relevant departments* (Tollens and Shapiro, 1992:64).

The World Bank is focusing on the rehabilitation of research facilities. Additional areas include transport infrastructure, agricultural credit, extension, agricultural input services through NGOs, and GOZ institutional reform. The Food and Agricultural Organization (FAO) is providing technical assistance in statistics, price analysis, and seed certification and support for the National Fertilizer Program (SENAFIC) and the national seed agency (Service National de Semence, SENASEM). Some of Belgium's over 50 projects are collaborative efforts with the World Bank. Canada has focused its program in the Kivu region, particularly livestock and forestry. Bas-Zaïre and western Bandundu receive most of the rural development and reforestation programs of the EC. The budget calls for $50 million over five years.

C. Education

Four levels of education can be pursued at institutions for agricultural training in Zaïre. Technical secondary schools offer A2 and A3 level education. An A1 degree is offered at the Institut Supérieur d'Enseignement Agricole (ISEA), which has facilities at Bengamisa, Haut-Zaïre, and at Mondongo, Equateur. Higher Institutes for Rural Development (ISDR) at Bukavu, Mbeo, Tshibashi, and Mbandaka offer a "graduate" degree in rural development. A0, or agricultural engineers, are trained at the Faculty Institute of Agriculture (IFA) at Yangambe. The degrees awarded at these institutions from 1980 to 1986 are shown in Table 2.3.

Table 2.3. Agricultural Diplomas Awarded by Level and Year, 1980-1986

	Year						
Degree	1980	1981	1982	1983	1984	1985	1986
A0 and A1							
A0 Yangambi	34	6	--	82	16	50	--
A1 Bengamisa	98	28	45	50	62	35	--
A1 Mondongo	31	20	23	19	33	26	--
A2 and A3							
Agriculture	--	--	879	810	1,150	1,660	1,550
Horticulture	--	--	6	17	10	9	11
Veterinary Science	--	--	121	83	48	113	193
Food Industry	--	--	7	14	8	8	10
Nutritional Science	--	--	--	--	--	5	7
Total	N/A	N/A	1,081	1,075	1,327	1,906	N/A

Source: Commission Permanente des Etudes, Kinshasa, October 1986.

The facilities at Yangambe are well built, but transportation and communications are considerably limited. Many think the Yangambe campus is not viable over the long term and that IFA should be moved near a major urban area so medical, transportation, and communication amenities would be available to the staff.

The World Bank initiated an effort, Projet de l'Enseignement Supérieur et Universitaire (PRESU), in 1990 to improve Zaïrian higher education institutions. The project will address constraints at IFA, at ISEA at both Bengamisa and Mondongo, and at eight non-agricultural higher education institutions.

D. Extension

The effectiveness of Zaïre's extension programs is constrained by a broad range of limitations:

- *low pay, lack of motivation, and low status of the extension service, and distrust of the farmers;*

- *multiple tasks: extension, tax collection, crop imposition, agricultural statistics, party duties;*

- *lack of logistical support: means of transport, office supplies, extension materials;*

- *lack of overall coordination and organization, duplication of effort and conflicting messages (e.g., cotton versus food crops); and*

- *lack of a backlog of farmer-proven, tested varieties and recommended cultural practices, resulting in an absence of clear themes and messages for extension* (Tollens and Shapiro, 1992:68).

According to a 1988 survey by DORD, there were over 5,000 extension agents in Zaïre, of which 15 percent were A2 or higher and 40 percent were from 31 to 40 years of age. Traditional farmers perceive extension as paternalistic or as a remnant of colonialism. In colonial times, extension agents often imposed harsh measures and dictated the method of cultivation. Some of this attitude may persist today, resulting in an extension agent who perceives the farmer-peasant as irrational and a farmer who looks on the extension agent as an arm of the government controlling his activities (Tollens and Shapiro, 1992).

Most donors have not been comfortable relying exclusively on the government extension program. Instead, they either have tended to develop some extension capability in their projects or have developed relationships with NGOs and PVOs.

A new emphasis on the training and visitation (T&V) methods of technology transfer, as developed by Benor and Harrison, has been receiving increasing attention through World Bank extension programs in over 30 African countries. Operation of agricultural services is a centerpiece of this program. A pilot extension program was initiated in Ubangi, Bumba, Kwango-Kwilu, and Kabinda. Some have expressed doubt as to whether this approach will be successful:

- *Unless there is on-the-shelf, farmer-proven improved technology available, T&V will fail. There is doubt that such a backlog exists.*

- *T&V has proved its effectiveness in Asia, particularly for irrigated rice in monocropping. As most farming systems in Africa include*

intercropping and have a high degree of complexity, it is not clear that T&V is adapted to this reality.

- *The basic tenet of Benor's philosophy is that farmers need to increase production to cover their own home consumption. However, in most countries (including Zaïre) the challenge is to feed the rapidly growing urban population, which requires attention to rural infrastructure, in particular roads, marketing development and price policy.*

- *Other constraints which weigh heavily on the agricultural sector are not addressed by T&V, such as the disproportionate share of women's work, the lack of rural infrastructure and effective input delivery systems, labor scarcities, credit constraints, inadequate government policies, etc.* (Tollens and Shapiro, 1992:70).

E. Human Resources

Table 2.4 presents the educational level of the staff at the departments of Agriculture and Rural Development. Clearly, there was a considerable decrease in the numbers of young staff recruited into these programs in the 1980s; many of the staff are older and less educated.

Austerity programs have led to a dramatic reduction in the attractiveness of a public service career. Public servants have not done well in recent years in Zaïre, particularly in view of the very high inflation rates, which make salaries almost insignificant. Incentives for good performance are rare. Projects financed by USAID or the World Bank have usually been able to supplement government salary levels. These supplements have caused rivalries between groups within DOA and DORD based on the existence of the added funding. Along with the salary supplements often comes greater access to operating funds for travel and to educational funds.

F. Agricultural Budget

The budget for the Department of Agriculture has two main components: one for operating funds (BO) and one for investment funds (BI). The salaries of career personnel are paid by the Départment de la Fonction Publique; the salaries of temporary, usually project-specific, activities come from a separate DOA budget.

Table 2.5 presents the operating and investment funds for the DOA for 1982-1988. These data clearly demonstrate that agriculture has not received the support that its importance in the national economy should dictate. The introduction of Priority Investment Program (PIP) funding (Table 2.5) has begun to increase agriculture's relative share. The priority areas in the agriculture projects in PIP, in descending order, are food crop production, livestock, and cash crops. Marketing, extension, research, and seed production have not received substantial attention.

Table 2.4. Level of Training by Age and Length of Service of the Departments of Agriculture and Rural Development, 1987

Level of Training	Age (Years)						
	21-30	31-40	41-49	50-55	55+	Total	No. of Staff
D6 and above	6%	59%	30%	4%	1%	100%	784
Less than D6	5%	37%	35%	17%	6%	100%	4,312
Total	5%	40%	34%	15%	5%	100%	5,096

Level of Training	Length of Service (Years)					
	>27	26-19	18-13	12-0	Total	No. of Staff
D6 and above	3%	19%	18%	60%	100%	787
Less than D6	15%	25%	25%	34%	100%	4,323
Total	13%	24%	24%	38%	100%	5,110

Source: Adapted from Tollens and Shapiro, 1992, p. 73.

Note: Rows do not always add to 100 percent, due to rounding.

Table 2.5. Recurrent and Investment Budgets for Agriculture, 1982-1988

Budget	Year						
	1982	1983	1984	1985	1986	1987	1988
	(thousands of $US)						
Recurrent budget (BO)							
Agriculture	217	202	186	265	308	610	699
Total	7,391	12,215	19,413	33,941	65,484	106,015	152,777
Agriculture's share of total BO (%)	2.9	1.7	1.0	0.8	0.5	0.6	0.5
Investment budget (BI)							
Agriculture	19	32	58	67	64	1,556	1,941
Total	1,190	727	1,400	2,600	3,424	13,253	7,805
Agriculture's share of total BI (%)	1.6	4.4	4.2	2.6	1.9	11.7	24.9
BO + BI							
Agriculture	236	234	244	332	372	2166	2640
Total	8,581	12,942	20,813	36,541	68,908	119,268	160,582
Agriculture's share of total BO + BI (%)	2.7	1.8	1.2	0.9	0.5	1.9	1.6

Source: Bank of Zaïre and Budget de l'Etat, 1988.

Note: Agriculture is used here to refer to the Department of Agriculture and the Department of Rural Development.

III. USAID Agricultural Program

The objective of USAID's agricultural program in Zaïre is to increase agricultural production, productivity, and rural household incomes. The premise of the program is that market-oriented policies are the key to increasing production and improving distribution of food crops in Zaïre. The appropriate role envisioned for government in agricultural development is to provide and maintain infrastructure, to carry out applied agricultural research to facilitate the flow of information and credit to producers and marketing agents, and to set and enforce minimum quality standards (e.g., through seed certification) (USAID, 1990).

USAID/Zaïre has placed primary focus on increasing production and rural incomes. The geographical emphasis of USAID/Zaïre has been the Bandundu and the Shaba regions (until political events at the university in Lubumbashi resulted in curtailment of USAID activities in the Shaba region). Rural income and food for local and urban consumption have been key indicators of USAID/Zaïre's agricultural programs.

At the time of evacuation of USAID/Zaïre, there were four main agricultural projects: Applied Agricultural Research and Outreach (RAV II); Area Food and Marketing Development (PROCAR); Central Shaba Agricultural Development; and Agricultural Policy and Planning.

Applied agricultural research and outreach was supported by USAID through a project initiated in 1983 that was intended to improve the Department of Agriculture's capability to pursue research directed toward improving agricultural production and productivity. The objective of RAV I and RAV II (Projet de Recherche Agronomique Appli-quée et Vulgarisation) was to improve DOA's research capability and its ability to disseminate new food crop technologies to rural farmers. The principal strategy to implement these goals was to improve the seed development activities of three national crop improvement programs (cassava, legumes, and maize).

On-station research was given an important stimulus through the efforts under RAV I (USAID, 1989; Ariza-Nino, 1988). RAV II was specifically designed to correct some of the shortcomings of RAV I in terms of outreach accomplishments (USAID, 1990). (See Table 2.6 for details on RAV II project budget.) Development strategy under RAV II was based on the farming systems research (FSR) approach of more emphasis on on-farm trials and greater reliance on understanding how a new technology might complement or compete with existing activities. RAV II gave priority to communicating farmers' needs to researchers and disseminating the new techniques developed by researchers to the most appropriate clientele farmers.

The key elements of the FSR approach are:

- *to conceptualize the farm as an integrated system of production, storage, marketing, consumption, and capital formation which functions in a risky economic, institutional, social, and biological-physical environment with a given physical infrastructure and has to adapt to changing conditions;*

- *to focus on a few identified, addressable constraints in some key subsystems;*

- *to work in a team involving the major sciences being able to remove a constraint;*

- *to keep those scientists, mostly working on-station, informed about the farmer's real world; and*

Table 2.6. RAV II Life of Project Costs Contributed by the U.S. Government, Beginning August 1, 1990 ($000)

Item (Source)	Project Year 1	2	3	4	5	6	7	8	Total	Percent of Total
1. Personnel: long-term, short-term, home office	2,510	2,499	2,453	882	576	609	327	316	10,172	50.86%
2. Participant training: long-, short-term	642	763	768	646	726	476	259	53	4,333	21.67%
3. Vehicles, repairs	572	29	--	--	374	29	--	--	1,004	5.02%
4. Facilities rehabilitation	--	450	300	150	--	--	--	--	900	4.50%
5. Other research support: lab eqmt., supplies, etc.	249	27	27	29	24	13	13	14	396	1.98%
6. Office eqmt., supplies, household furnishings	413	90	93	35	33	28	21	23	736	3.68%
7. Audits, evaluations	60	--	168	--	--	170	--	107	505	2.53%
8. Networking/ research grants	100	150	150	150	150	100	100	100	1,000	5.00%
9. Contingency	232	201	204	94	93	72	33	25	954	4.77%
Total	4,778	4,209	4,163	1,986	1,976	1,497	753	638	20,000	100.00%
Percent of Total	23.89%	21.05%	20.82%	9.93%	9.88%	7.49%	3.77%	3.19%	100.00%	

Note: All estimates are adjusted for a 5.0 percent annual rate of inflation.

- *to involve both farmers and extension personnel as closely as possible in the research process* (Vogel, 1990:2-3).

Vogel (1990) attributed the key failures in the FSR approach under RAV I to high turnover among Zaïrian counterparts, lack of funds for fuel to travel to on-farm trials, and the lack of junior staff with training in the social sciences.

The main findings of an evaluation of the impact of agricultural research in Zaïre by Ariza-Nino (1989) were:

- new cassava varieties generated by PRONAM had a small impact at the farm level;
- PRONAM-improved varieties are undoubtedly superior to existing varieties;
- farmers are eager to obtain the new varieties;
- production and delivery of cuttings is insufficient to meet farm demand;
- difficulties exist in expanding acreage under new varieties, even after farmer uses and wants to expand usage;
- rapid on-farm self-propagation has not occurred;
- a shift in resources toward outreach is needed; and
- more emphasis should be placed on Bandundu.

The conclusions of the socio-economic studies coordinated by Bartlett (1988) were that rather than concentrate on only one variety as the preferred, PRONAM should instead develop several varieties aimed at regional differences in modes of utilization and soil types. Further, it was suggested that breeding programs target several modes of utilization and soil types. Finally, criteria that should be added to decisions on variety selection during breeding include durability in the soil, dry season ponds production, high branching, and fat tubers.

RAV I developed several new seed varieties for cassava, maize, peanuts, beans, soybeans, and cowpeas. Thirty-eight Zaïrians received graduate degrees, and 70 RAV/SENARAV personnel attended short courses. The quality of the scientific personnel of the national programs of SENARAV was improved, and the facilities for research were upgraded. Foundation seed were distributed to 30,000 farmers through 139 governmental and non-governmental organizations (USAID, 1990).

The shortcomings of RAV I were identified during the process of completing RAV I and initiating the next phase (RAV II). These shortcomings were:

> *... weaknesses in the administration of research programs and research resources, the low level of financial commitment to the project by the GOZ, constraints to travel and mobility of research personnel that contributed to a generally weak technology transfer/outreach effort, little interdisciplinary team research, inadequate monitoring and evaluation, and underdeveloped feedback mechanisms that could provide researchers with valuable information concerning farmers' constraints and circumstances* (USAID, 1989:5).

The RAV II design team responded to these problems with the following recommendations:

> *First, a low-level financial contribution by the host government clearly fails to promise sustainability for the project after external funding ends. The lesson here is that the host government must support RAV II generously. Second, incremental funding from the GOZ must be assigned with highest priority to help make the SENARAV staff mobile, permitting it to devote more effort to off-station research and related outreach efforts. Third, and as staff mobility is enhanced, researchers' understandings of the constraints and circumstances of farmers will be enhanced, and that should improve the relevance of the project's technology-generating activities. Finally, the relevance and adaptability of new technologies should be closely monitored and evaluated for farm-level impact to ensure a fully developed feedback mechanism from farmer to researcher* (USAID, 1990:14).

RAV II's mandate was to continue to work toward increasing the DOA's applied agricultural research capabilities through the national commodity programs (PRONAM, PNM, and PNL). RAV II provided for technical assistance, long- and short-term participant training, station rehabilitation and development, commodity procurement, and support for scientific exchange and research networking.

The RAV II approach to developing and transferring technologies to small farmers had four components:

- *improved technology transfer directly linking RAV outreach units with development agencies, NGOs, and the private sector in order to increase the effectiveness and rate of technology adaptation and movement to extension agencies, including USAID projects;*

- *applied research-generating technologies adapted to farmers' needs as identified by a client-oriented, geographically specific research programming process;*

- *effective management of research through the full installation of a zero-based program budgeting process, consolidation of the national commodity programs' facilities and personnel, and improved scientific review to target short-, medium-, and long-term research objectives; and*

- *establishment of a basis for sustained financial sustainability through assistance aimed at increasing research output, controlling costs, increasing sales of seeds, cuttings, and research services, and improving the reliability of non-AID financing through direct GOZ budgetary support and other measures* (USAID, 1989:iv).

Farming systems and outreach, considered lacking under RAV I, were to be given greater attention under RAV II. Research was to be more responsive to the needs of farmers and marketers of agricultural products for urban areas. The use of on-farm trials was aimed at this perceived shortcoming. Attention was to be focused on the long-term sustainability of the new techniques being generated and SENARAV's long-term ability to persist in its pursuit of quality research after the termination of USAID funds.

The project paper outlined the following primary project activities:

- *improve and maintain germplasm and the varietal purity of cassava, grain legumes (beans, groundnut, cowpeas, and soybeans), and maize;*

- *provide sustainable, low-input and improved management practices designed to increase soil fertility and conserve Zaïre's natural resource base;*

- *improve the overall productivity of farming systems, from the point of view of both farm earnings and the farm family's nutritional status;*

- *develop sustainable biological control and integrated pest management systems for major crop diseases and pests;*

- *enhance the linkages between on-station research, on-farm research, and outreach, and ensure that the farmer is included as a full partner in the development and testing of technology;*

- *increase and strengthen linkages between SENARAV and the IARCs, other national and regional research programs in Africa, and public- and all private-sector agricultural research programs in Zaïre; and*

- *draw on the resources available through U.S. Title XII institutions to provide SENARAV with direct access to a large pool of expertise worldwide in research, extension, and training* (USAID, 1990:15).

An important link with other USAID/Zaïre agricultural programs was fostered. As RAV II generated improved seed and appropriate techniques, two regional projects (Bandundu and Shaba) could play important roles in adapting these techniques to the crop and regional conditions with which they were quite familiar.

In Bandundu, centered around Kikwit, the Area Food and Market Development Project (Projet de Développement de la Production et Commercialization Agricoles Regionale-PROCAR) was initiated in 1984. PROCAR focused on improvements in production, marketing, and processing of agricultural products through NGOs. These organizations were identified for their capability to deliver needed services to small farmers and small marketers in the region. The primary food crops receiving attention under the PROCAR project were cassava, corn, peanuts, and rice; secondary crops included coffee, fibers, rubber, and vegetable crops. Extension agents were trained to increase the diffusion of new seed varieties and production practices to small farmers.

Project activities included (1) improvement in marketing efficiency through the development of distribution points convenient for small farmers and construction of a central market on the road between Kikwit and Kinshasa; (2) a pilot river program for improvement in the transportation and handling of agricultural products moving down the rivers of Bandundu to Kinshasa; (3) testing alternative food storage to decrease the spoilage of food products on-farm; and (4) improvement in soil fertility through recommendations on adding trees and lengthening fallow periods.

In Shaba, the emphasis was on increasing the marketable surplus for urban areas and improving the capability to deliver this surplus. The Central Shaba Agricultural Development Project implemented this strategy through extension services, construction of food crops storage facilities, road renovation, and seed production. The area covered by the project included the area formerly supported by the North Shaba Rural Development Project (PNS). Restoration of infrastructure for producing, processing, and marketing agricultural surplus to urban areas in Shaba was the principal project activity. It was initiated in 1986, with a planned project horizon of 15 years. Specific proposed activities included private-sector seed production; farmer-based extension services; community storage facilities; road improvement; and centers for production and support services.

In addition to the two regional projects, RAV II was to continue to build on the relationship established under RAV I with the Agricultural Policy and Planning Project. The latter project assists the Department of Agriculture's Service d'Etudes et Planification in implementing and coordinating agricultural policy and planning.

An important link between RAV II and the Service d'Etudes et Planification that was not sufficiently accomplished under RAV I is the collection and analysis of farm-level data. A more consistent, standardized process that would allow for greater regional comparisons was beginning to take shape under RAV II with the training of teams of SENARAV personnel to promote greater communication between farmers and the research stations. When USAID programs were terminated in September 1991, these "R&D teams" were standardizing a minimum data set on agronomic, economic, and social variables to be collected in all regions.

USAID began its involvement in policy analysis with the GOZ through the African Economic Policy Reform Program (AEPRP). The $15 million AEPRP project was intended to provide a link between the Commodity Import Program (CIP) and reform in industrial and trade policy. This form of "cross-compliance" was aimed at allowing funds to flow through the private-sector CIP only if certain public-sector policy reforms had been achieved, or at least attempted. Additional cross-compliance measures were added to PL-480 Title I expenditures and the Private-Sector Support Program (PSSP). The latter program aimed at improving the attractiveness for private investment by forcing the GOZ to enact trade and price liberalization programs.

Small-sized enterprises, including agribusiness, are the focus of World Bank and IMF efforts to reform financial institutions and services to increase savings, credit, and investment. Counterpart funds are generated by these programs. Authorized jointly by GOZ and USAID, these funds have become an essential source of financing of economic development efforts in a public sector with very few financial resources.

Agricultural development policy must be formulated in the context of food production systems that have evolved over a long time in response to physical, political, economic, and cultural parameters. Population growth and migration to urban areas have occurred in a rather short time period, and the traditional food systems have not had, and probably will not have, adequate time to evolve without strategic intervention by the public sector. The vulnerability of the resource base to degradation after long periods of intensive production further exacerbates the problem of feeding the growing urban populations. The production base could even decrease or its growth decline as a result of the soil degradation resulting from current agricultural practices (NRMS Amendment, 1991). Per capita food production is not increasing; the deficit is increasingly being dealth with via growing imports or, in some cases, decreases in nutrition.

Economic development in Zaïre also faces substantial macroeconomic instability that often significantly affects food security. Thus, the agricultural productivity gains that may be obtained through increased efforts in improving seed varieties must be viewed in the larger context of the appropriateness of the technology relative to existing farm activities and of the farmers' and rural population's ability to take advantage of these potential benefits given the conditions of the national economy.

IV. Economic Impact of Agricultural Research and Extension

The potential impact of agricultural research and extension can be quantified using the economic surplus methodology of Norton et al. (1987). This section reports on an effort to use this method to develop estimates of the impact of RAV I and RAV II, under varying assumptions. Of particular importance is the effort to invest in improved soil-conserving techniques to arrive at an agricultural farming system that both improves yields and is sustainable through the protection of soil quality.

Agricultural research and outreach programs are becoming more sensitive to the long-term consequences of the technologies they generate and transfer to farmers. Yield-increasing technologies increasingly undergo a second level of screening that ensures that the resource base that will support the new technology can be maintained in the long run. Many agricultural development projects engender negative consequences (externalities) with regard to the environment and sustainability of the natural resource base that may not become apparent until well into the project, or even after the project ends. One of the major objectives of RAV I and RAV II was to ensure that such was not the case with the technologies generated and recommended by SENARAV.

The yield increases and cost reductions anticipated from the new varieties generated by SENARAV will not be achieved if strategies are not put in place to mitigate damage caused by the "overuse" of agricultural land and the use of inappropriate soil-degrading production practices on highly-erodible agricultural land. In addition, the resource base has also been degraded by traditional farming practices. Thus, the development and transfer of soil-enhancing and erosion-reducing practices appropriate for both traditional and new varieties continue to be a primary goal of the research and outreach program of SENARAV.

Such practices as agro-forestry (see Shannon et al., 1991) and soil-fertility enhancement have been and will continue to be investigated for their adaptability to Zaïrian farming systems. Many examples of these practices exist throughout Africa and other parts of the world. The dual challenge for SENARAV is to fine-tune these existing techniques to the diverse conditions in Zaïre and to convince farmers that it is in their best interest to use such methods.

Given the critical importance of Zaïre's tropical forests and biological diversity to Africa and the world, this research philosophy not only addresses the micro-level farm management decisions in the light of sustaining farm income, employment, and nutrition but also addresses the macro-level impacts of all these micro-level decisions on regional, national, and global quality of life.

One of the major thrusts of SENARAV has been to develop and facilitate extension of techniques that will help control erosion. Such techniques will help maintain soil fertility and prevent the loss of agricultural production that accompanies erosion and decreasing soil fertility. Farmers will obtain higher yields and higher returns to labor than would be possible in the absence of erosion control. They will be able to crop such parcels for longer periods of time and/or return to such parcels after a shorter fallow period than would have been possible without erosion control. In some areas these effects will reduce the frequency with which farmers who use a slash-and-burn system clear new land for cultivation.

When implemented on a substantial scale, erosion control will also have important effects on the watersheds in question. Run-off will be reduced and flooding will be less severe than would otherwise be the case. Siltation of surface water will be reduced and water quality will be improved. This in turn may allow increased fish production in the river systems and lakes, and promote a reduction in health problems related to water quality. In some areas increased infiltration and improved water quality may reduce the time and effort that women must devote to carrying water for family consumption. The time saved will provide an increase in leisure for these women or lead to further production and productivity increases.

The use of grasses and legumes for green barriers and ground cover has several positive impacts in addition to erosion control. Grasses and legumes may be used to expand and intensify livestock production which in turn may increase family income and provide manure as a soil fertility amendment. If not processed through livestock, grasses and legumes can be used directly as mulch to increase soil organic matter and water retention, which will increase crop productivity. Legumes will fix nitrogen and increase crop productivity and/or reduce expenditures on purchased fertilizer, where that is an alternative.

A. Methods

This section and the next outline the economic impacts of SENARAV research and extension and provide quantitative estimates of these impacts where possible. Quantitative estimates include (1) internal rates of return (IRR) and net present value (NPV) to SENARAV research programs with and without soil loss, (2) IRR and NPV soil conservation, and (3) sensitivity analyses. The quantitative measures are presented to provide an indication of expected economic impact; however, they must be viewed in the light of the myriad difficulties in ex ante estimates of returns to research and outreach programs.

Internal rates of return (IRR) and net present values (NPV) were calculated from 20-year cash flows for SENARAV research programs at selected levels of potential soil loss impacts on production costs with and without soil-conserving practices. Sensitivity analyses were conducted for those variables judged to be either most critical or most uncertain.

Economic surplus methodology is preferred to the more common approach (using enterprise budgets to estimate changes in net returns per acre and then multiplying by the expected acreage of new varieties), due to its ability to quantify (1) the benefits of lower food prices to consumers and (2) the benefits of agricultural resource substitution to more high valued uses. In addition, there is the likely possibility that farmers may in fact use the yield increasing varieties on sufficient acreage to meet subsistence needs and substitute the remaining land to more profitable cash crops. For basic food crops like manioc in Zaïre, this substitution of land and labor to other activities, made possible by the lower resources needed to produce the basic food crop with new varieties, can be an important benefit.

In many areas of the world, both in developed and developing countries, advances in new varieties are often negated to some degree by deterioration of the resource base. To the extent that farmers do not conserve or enhance their soil, the vertical downward shift of supply from new varieties is offset by a vertical upward shift from soil degradation. The benefits to natural resource conservation investments can be quantified as the damage avoided. The latter is the difference between economic surplus with and without soil loss net the costs of the soil conservation investment.

B. Results

Quantitative estimates of internal rates of return (IRR) and net present values (NPV) for RAV II research programs under alternative soil damage levels on new varieties are presented in Table 2.7. Baseline assumptions used for key parameters in the estimates presented in Table 2.7 are given in Table 2.8. The difference between the stream of benefits associated with "no impact" of SENARAV research on soil loss (i.e., 0 percent improvement in soil loss as a result of the research) and the stream of benefits associated with alternative soil loss levels (1 percent and 3 percent) is used as an estimate of the benefits of the soil-conserving activities of SENARAV. These estimates are the soil-degrading damage avoided if soil-conserving and soil-enhancing technologies are developed and transferred.

Return estimates were developed for cassava, peanuts, and maize, the most important crops receiving research and outreach attention by the three national programs (PRONAM, PNL, and PNM) under SENARAV mandate. Returns to soil-conserving techniques are underestimated to the extent that peanuts, though probably the most important, are only one of several crops targeted by PNL. Results indicate that, without soil-conserving techniques, returns to cassava research fall from 42.5 percent to 40.3 percent, returns to peanut research are diminished from 20.9 percent to 19.8 percent, and returns to maize research decrease from 31.3 percent to 29.2 percent (see Table 2.7). Each of these decreases in returns is a result of the inability to avoid soil-degrading losses on new varieties.

Table 2.7. Internal Rates of Return and Net Present Values for SENARAV Research Programs for Selected Soil Loss Factors

Soil Loss Factor	Cassava		Peanuts		Maize	
	IRR	NPV	IRR	NPV	IRR	NPV
0%	42.5	44.7	20.9	7.6	31.3	16.7
1%	40.3	38.5	19.8	5.8	29.2	13.9
3%	35.8	28.1	15.0	2.8	25.1	9.4

Note: IRR = internal rate of return; NPV = net present value in millions of US$ discounted at 10 percent.

Table 2.8. Baseline Assumptions on Key Parameters for Internal Rate of Return Estimates for SENARAV Research Programs

Assumption on Key Parameters	SENARAV Research Programs		
	Cassava	Peanuts	Maize
Demand Elasticity	0.2	1.0	0.4
Supply Elasticity	1.0	1.0	1.0
Initial Quantity[1]	3,728	430.1	781
Initial Price[2]	90	250	139.5
Cost Reduction	35%	25%	40%
Probability of Research Success	60%	75%	70%
Max. Area under New Varieties	40%	40%	40%
Conservation Adoption Rate	1%	1%	1%
Soil Loss Factor	1%	1%	1%

[1]thousands of metric tons
[2]dollars per metric ton

Table 2.9 presents the sensitivity of SENARAV research programs to changir assumptions related to the probability of research success, supply and demar elasticity, cost reduction, and new variety adoption. Table 2.10 indicates tr sensitivity of returns to the soil-conserving research program, specifically, und selected ranges for soil loss avoided by new techniques developed by SENARAV ar the adoption rate of the new techniques. Demand elasticity is much less importar than supply elasticity due to the impact of increasingly inelastic supply on price New varieties that effect a substantial decrease in production cost for a highly suppl inelastic crop result in significant benefits to consumers through greatly reduce prices. Cost reductions and new variety adoption rates have largely the same impac on the vertical supply shift that occurs as a result of the new technology. Th probability of research success and cost reduction is related to the extent tha expectations of higher cost reductions will generally be associated with lowe probability of success. Internal rates of return to SENARAV programs are ver sensitive to probability of research success, cost reduction, and new variety adoptior

The baseline return to SENARAV's soil conservation program is 25.0 percent if it results in avoiding 1 percent compounded annual soil degrading losses on percent compounded annual increases in acreage using improved soil managemen practices (see Table 2.10). Results are very sensitive to both the conservation an new variety adoption rates. The lower ranges presented in Table 2.10 appear quit conservative: A 0.5 percent rate for both adoption rates would imply that soil los would only decrease supply by a little over 10 percent over a 20-year period and tha only about 10 percent of production of these crops would be accomplished wit improved varieties after a 20-year research and extension program.

The adoption rate for improved soil management practices on new an traditional varieties was estimated as increasing at a 1 percent compounded annua rate. The probability of research success that was used in the internal rates of returr for new crop varieties (cassava, peanuts, and maize) was not included in the returns to SENARAV's soil conservation program due to the rather negligible probability o complete failure to develop such new technologies. The soil conservation adoptior rate will be the ultimate indicator of success.

Benefits to soil conservation also include soil losses avoided on traditiona varieties. Due to the much larger percentage of acres in traditional varieties, extension emphasis might be focused on old varieties; however, farmers who adopt new varieties might also be more likely to adopt soil-conservation practices.

These results were calculated based on aggregate, national data for the three crops that received most of the research and extension effort of SENARAV and are thus most likely to receive the greatest attention in soil-conservation efforts. Returns presented here are specific to SENARAV programs. There are additional crops on which soil-conserving techniques might be considered. Soil-conservation efforts on many other crops would be pursued through other agencies. Regional and sub-regional analyses would be useful in targeting areas where farmers are more likely to

Table 2.9. Sensitivity of Internal Rate of Return to Changes in Key Parameter Assumptions

Peanuts		Cassava		Maize	
Value	IRR	Value	IRR	Value	IRR
		Probability of Research Success (%)			
65	16.1	55	37.6	60	25.5
75	19.0	60	40.3	70	29.2
85	21.7	65	42.8	80	32.7
		Supply Elasticity			
0.8	14.7	0.8	33.8	0.8	24.0
1.0	19.0	1.0	40.3	1.0	29.2
1.2	22.8	1.2	46.2	1.2	33.9
		Demand Elasticity			
0.8	19.0	0.1	40.2	0.2	29.0
1.0	19.0	0.2	40.3	0.4	29.2
1.2	19.0	0.3	40.3	0.6	29.4
		Cost Reduction (%)			
20	14.5	25	30.7	30	22.4
25	19.0	35	40.3	40	29.2
30	22.9	45	48.7	50	35.1
		New Variety Adoption (max. %)			
30	13.4	30	32.0	30	22.4
40	19.0	40	40.3	40	29.2
50	23.7	50	47.7	50	35.2

value = key parameter value from Table 2.8; IRR = internal rate of return.

Table 2.10. Internal Rates of Return to SENARAV Soil Conservation Program for Selected Soil Conservation Adoption Rates and Soil Loss Factors

Soil Loss Factor	Soil Conservation Adoption Rate (%)		
	0.5	1.0	1.5
0.5%	4.5	14.8	21.7
1.0%	13.1	25.0	33.9
1.5%	18.7	32.6	43.8

adopt soil-conservation practices and where these practices would have their greatest potential impact on economic well-being.

Two important limitations of this analysis are (1) the geographical distribution of soil loss and adoption and (2) the long-term nature of soil-conserving benefits and farmers' perceptions of its importance. When an aggregate national view is taken, the benefits to soil conservation may appear less significant than when such benefits are viewed locally. In many parts of the world, soil-conservation efforts are being targeted to areas where overuse of fragile soils is having ruinous effects. Farmers in such locations need assistance in addressing an apparent, perceptible loss in economic well-being. Identifying priority areas in Zaïre may be a strategy that will achieve the greatest return.

References

Ariza-Nino, Edgar J. 1988. Market-oriented Crop Improvement Research and Outreach-Enhancing Financial Sustainability. Washington, D.C.: R. R. Nathan Associates, Inc.

Ariza-Nino, Edgar J., and R. R. Nathan Associates. 1989. Impact of Agricultural Research in Zaïre. Applied Agricultural Research and Outreach Project 660-0091. Washington, D.C.: R. R. Nathan Associates, Inc.

Bartlett, C. D. 1988. "A Research Planning Framework for Farming Systems Research." Paper presented at 8th Annual Farming Systems Research/Extension Symposium.

Linsemeyer, Dean. 1974. "An Economic Analysis of Maize Production in the Kasai Oriental Region of Zaïre: A Research Proposal." Working Paper no. 2. African Rural Employment Research Network.

Norton, G. W., V. G. Ganoza, and C. Pomerada. 1987. "Potential Benefits of Agricultural Research and Extension in Peru." Amer. J. Agr. Econ. 69 (1987):247-57.

Shannon, Dennis A. Final Report: USAID Project 660-0091.

Shannon, D. A., W. O. Vogel, and K. N. Kabaluapa. 1991. "The Effects of Alley Cropping and Fertilizer Application on Continuously Cropped Maize." Tropical Agriculture.

Shapiro, David. 1990. "Population Growth, Urbanization, and Changing Agricultural Practices in Zaïre." Working Paper. University Park, Penn.: Pennsylvania State University, Department of Economics.

Tollens, Eric, and David Shapiro. 1992. The Agricultural Development of Zaïre: Agriculture in the Zaïrian Economy. New York: Gower Publishing.

U.S. Agency for International Development. 1990. RAV II Project Paper.

------. 1989. RAV II Project Identification Document.

Vogel, Wolfgang O. 1990. "Final Report of Farming Systems Research Activities." Research and Crop Management Program, International Institute of Tropical Agriculture.

World Bank. 1988. Agriculture Sector Memorandum Zaïre: Toward Sustained Agricultural Development. Washington, D.C.: World Bank.

ZTE/COGEPAR. 1987. Etude de la compétitivité de l'agriculture Zaïroise face aux produits agricoles importés. Kinshasa: ZTE/COGEPAR.

CHAPTER 3

GERMPLASM DEVELOPMENT

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I. Cassava

A. History and Importance of Cassava in Zaïre

Cassava is native to Latin America. It was first brought to Africa by two routes (Leakey and Willis, 1977). Cassava was introduced into the delta of the Congo River during the latter part of the sixteenth century (Jones, 1959) and during the same period was brought to the West African region through the Congo River and the Gulf of Benin.

Cassava (**Manihot esculenta Crantz**) is the most important crop in Zaïre, which is the third-largest cassava-producing country in the world and the largest cassava producer in Africa (FAO, 1975). More than 50 percent of Zaïre's cultivated land is dedicated to cassava production. In 1979, 11 million tons of fresh tuberous roots were grown in Zaïre, and it has been conservatively estimated that one million tons of cassava leaves are harvested and consumed in the country annually.

Cassava provides more than 50 percent of the caloric requirements for over 420 million people in 26 tropical countries (Hahn, 1979). Cassava is the dominant staple in Central Africa: It constitutes 50 percent of the average staple food consumption in Zaïre, the Republic of the Congo, and the Central African Republic. Cassava accounts for approximately one-third of the total staples in sub-saharan Africa (FAO, 1986).

In Zaïre, cassava is the number-one source of energy for the majority of the population. Cassava leaves, an important source of protein in Zaïre, are often used as a green vegetable. Cassava is also often used to make a form of traditional alcohol. One of the most popular cassava dishes is "fufu." This dish is prepared by first peeling the roots and soaking them in water for three to four days until fermentation takes place. The leaves are then cut into chips, dried, and ground into flour. This flour is cooked in boiling water, alone or mixed with other flours (e.g., maize, sorghum) to form a dough.

B. History of Cassava Germplasm Development Research in Zaïre

The Institut National pour l'Etude Agronomique du Congo Belge (INEAC) conducted research on 20 export crops; cassava was accorded only a minor role in this research. In 1954, INEAC maintained a cassava collection of about 200 assessions. This collection served as the genetic base for the cassava improvement program of the Institut National pour l'Etude et la Recherche Agronomique (INERA), which succeeded INEAC after Zaïre's independence.

The principal emphasis of INEAC's cassava research was the selection of improved varieties, mainly through mass selection from true seed. New genetic materials were obtained from various external sources, mainly Brazil and Ivory Coast, as well as locally (Sapin, 1958). The criteria for selection were reduced branching; strong stems; resistance to root rot and cassava mosaic disease (CMD); lodging; short, fat roots, regularly spaced around the plant; and high protein content in the leaves.

In 1969-1970, a major disease appeared in the Gungu region of the Bandundu province and spread to the Kasai and Bas-Zaïre provinces. Symptoms included the wilting of leaves and young shoots; gum exudation from infected leaves, petioles, and shoots; defoliation; and, in severe cases, tip dieback. Many cassava fields were devastated, and prices for cassava increased tenfold. In 1973, the Commissioner for Agriculture and USAID/Zaïre asked the International Institute of Tropical Agriculture (IITA) to assist with identification of the disease. A team of two scientists, Dr. S. K. Hahn and Dr. C. B. Williams from IITA, Ibadan, Nigeria, was sent to Zaïre to assess the problem. The disease was identified as cassava bacterial blight (CBB) caused by the bacterium **Xanthomonas manihotis pv. manihotis.**

In 1974, the Programme National du Manioc (PRONAM) was established through a cooperative agreement between IITA and the Government of Zaïre (GOZ). Funding for the program was provided entirely by the GOZ. PRONAM's broad objectives were to develop improved cassava varieties and technology, make the varieties available to farmers, and provide in-service and degree training to Zaïrian research and extension workers. Through a cooperative research program with IITA, Zaïrian researchers were trained at IITA's Root and Tubers Improvement Program. IITA also staffed PRONAM with four scientists: Dr. P. H. Haynes, an agronomist, who also served as director of PRONAM; Dr. H. C. Ezumah, a plant breeder; Dr. K. F. Nwanze, an entomologist; and Dr. Pacumbaba, a plant pathologist. Much progress was made as a result of IITA's involvement with PRONAM in its initial development as a research institution.

In 1977, the Government of Zaïre, facing serious economic problems, sought support for PRONAM from USAID/Zaïre. PRONAM scientists submitted a proposal in June 1978 recommending that supervision by IITA continue, with funding from USAID/Zaïre rather than from the GOZ budget. USAID approved the proposal for funding in the amount of $4.5 million (Cassava Outreach Project 660-0077).

In 1980, a second contract was signed (under Project 660-0077) by USAID/Zaïre and GOZ/IITA to expand PRONAM's capacity to conduct research on new technologies for cassava production and to disseminate the technologies to small farmers. PRONAM was able to expand beyond the M'Vuazi Station in Bas-Zaïre by opening new research stations at Gandajika (Kasai Occidental) and Kiyaka (Bandundu). By that time, eight IITA scientists were located at M'Vuazi. During this period, PRONAM continued to develop varieties adapted to the most important cassava-

growing regions in Zaïre: Bas-Zaïre, Kinshasa, Bandundu, the southern areas of Kasai Oriental and Occidental, southern Kivu, and northern Shaba.

In 1985, the Executive Council of Zaïre and USAID/Zaïre, under a contract with IITA, established a project for staple food crops that initially was external to the cumbersome INERA structure but eventually reintegrated with INERA. The new project, the Projet de Recherche Agronomique Appliquée et Vulgarisation (Project 660-0091), or RAV I, consisted of the existing PRONAM and Programme National du Maïs (PNM), plus a newly created Program National des Légumineuses (PNL). IITA provided more than a dozen scientists for RAV I until the completion of the contract in 1990.

In 1990, SECID/Southern University signed a contract with USAID/Zaïre, RAV II (Project 660-0124), to provide technical assistance in support of an agricultural research and extension project. The team consisted of 11 specialists: an agronomist, a soil scientist, a legume breeder, a cassava breeder, a farming system specialist, an agricultural economist, an entomologist, an extension specialist, a financial management specialist, a station management specialist, and a chief of party/research management specialist. RAV II, which was to conclude in September 1998, ended prematurely in September 1991 due to civil disturbances in Zaïre.

C. Crop Reproductive Biology and Germplasm Development Strategy

Cassava, which belongs to the genus Manihot, occurs only in the western hemisphere (between the southwestern United States and Argentina). Ninety-eight species have been described.

Cassava is a perennial shrub. The leaves are palmate, and the flowers develop at the site of apical branches that may be either staminate or pistilate. The female flowers normally open between 10 and 11 a.m.; the male flower remains enclosed from around 12 a.m. to 1 p.m. The male flower usually loses its pollen before the flower opens. It has been reported that the stigmas of the female flowers are receptive at the moment the flower opens but that they lose their receptivity within 24 hours.

In order to produce artificial crosses, the female cassava flowers ready for pollination are placed in sacs the evening of the day before or very early in the morning before 10 a.m. The day of the cross, after pollination, the sac is replaced to eliminate contamination. Fertilization takes place within eight to nine hours following pollination. The fertilized ovaries become evident within five days. Mature grains can be harvested after 70 to 90 days.

Manihot esculenta is the only cassava species widely used as a crop. It has various growth patterns from nearly coalescent sub-shrubs to small trees with trunk diameters of 25 centimeters and heights of 10 to 12 meters.

Cassava produces a dry, dehiscent fruit with three loculi. All Manihot species studied thus far possess 36 chromosomes. It has been suggested that cassava is an allotetraploid (basic number x = 9) (Magoon et al., 1969).

D. Ecology of Zaïre and Cassava Breeding Objectives

Zaïre is a huge country with many distinct agroecological zones. Separate breeding objectives must be considered for each of these zones. The three major regions in which cassava research was conducted under RAV II are profiled below.

Bas-Zaïre/Bandundu: This is a low-altitude (1,000 m), humid region with an average rainfall of 1,200-1,800 mm during the rainy season and a 90- to 150-day dry season. The land is composed of rolling hills and undulating slopes. Leached sandy soils (psamments, orthents) are found in the uplands; the lowland valleys are much more fertile and possess better moisture conditions. The principal cropping system is intercropping of cassava with corn and other vegetables in the valleys.

South Shaba/Shaba: Shaba province has a tropical, continental climate with a dry season lasting from 150 to 180 days. This area is principally mid-altitude (1,000-1,500 m) and sub-humid, with a rainfall of 1,000 to 1,200 mm; the rainy season lasts for six to seven months, from mid-October to mid-May. The most common type of vegetation is savanna and low-tree savanna. Extensive areas of deep, porous oxisols are found near the Lubumbashi area. These soils are some of the most productive soils in the tropics and form the basis for large-scale agricultural production, particularly corn and relatively high-input food crops.

Kasai Occidental/Kasai Oriental: The area is principally a low-altitude (500-1,000 m), humid region. The topography ranges from undulating to flat. The soils are mainly medium- to fine-textured alfisols and ultisols. Cassava is the principal crop grown in the area, often being intercropped with corn and other food crops.

E. Primary Diseases and Pests of Cassava in Zaïre

The three major diseases of cassava that are very important in limiting cassava production in Zaïre are described below. A detailed treatment of insect pests is provided in Chapter 4.

Cassava mosaic disease (CMD) is transmitted by the white fly (**Bemisia tabacci**). Cassava mosaic has been known in Africa since 1894. However, the virus was first identified in 1983 as a geminivirus at IITA. CMD incidence is related to the density of white flies and the inoculum potential in the area. CMD is widespread throughout Zaïre and other cassava-growing regions in the area. The losses caused by CMD have been estimated at from 20 to 90 percent.

Cassava bacterial blight (CBB) was first reported in Zaïre in 1973 by Hahn and Williams. The causal organism is **Xanthomonas campestris pv. manihotis**, which

produces classical angular watersoaked leaf spots, blight, wilting, dieback, gum exudation, and stem and root vascular necrosis. CBB incidence varies with environmental condition, location, variety, time of year, and cropping systems (Terry, 1978). During cropping seasons with heavy rainfall, CBB incidence is higher. CBB has caused from 50 to 100 percent yield losses of both leaves and tubers in some areas. A serious CBB outbreak CBB was directly responsible for PRONAM's creation.

Cassava anthracnose disease (CAD) is caused by **Collectotrichum spp.** The classical symptoms are circular depressions, which produce distortions of the leaves and petioles. The level and expression of the disease are directly related to environmental conditions. It is very difficult to predict when the disease will occur. It has been suggested that the Coreid bug, **Pseudothraptus devastans D.**, plays a role in the disease syndrome. It is difficult to duplicate the disease from year to year and from season to season, which makes it difficult to develop resistant material because of the production of false positive resistance reactions.

The cassava mealybug, **Phenacoccus manihoti**, was first identified in Kinshasa in 1973, though it had probably been present in Bas-Zaïre near the Angolan border for some time. Two species of green mites, **Mononychellus progressivus** and **M. tanajoa**, were responsible for outbreaks in eastern Zaïre in the mid-1970s.

Table 3.1 identifies each station by region, ecology, and the specific cassava problems it addressed.

F. Cassava Breeding Research

1. Research Objectives

The initial objectives of the breeding program at Programme National du Manioc (PRONAM) were to:

- identify and develop cassava varieties with high yield potential and good yield;
- identify the sources of resistance to principal pests and diseases and incorporate these resistant genes into susceptible varieties with desired characteristics;
- develop a practical program for exploitation of plant growth that will permit the attainment of optimal economic yield;
- develop a high-quality cassava with higher protein value, good palatability, and a very low level of hydrocyanic acid; and
- identify and train young Zaïrians to both work on cassava and play an important role in general agricultural development.

Table 3.1. Identification of Stations by Region, Ecology, and Problems

Station	Region	Ecology	Problems
M'Vuazi	Bas-Zaïre	Savannah	Primary screening, recombinations, multiplication for resistance to CBB, CMD, CAD, and MB.
Kimpese	Bas-Zaïre	Savannah	Testing of breeding materials; multiplication and distribution of improved varieties. CBB, CMD, CAD, and MB.
Kiyaka	Bandundu	Savannah	Testing of breeding materials; multiplication and distribution of improved varieties. CBB, CMD, CAD, and MB.
Gandajika	Kasai	Savannah/ Forest	Same as above.
Mulungu	Kivu	Low Mountains	Same as above.
Kaniameshi	Shaba	Mid-altitudes	Same as above.

CAD = cassava anthracnose disease; CBB = cassava bacterial blight; CMD = cassava mosaic disease; GCM = green cassava mite; and MB = mealybug

In order to achieve these objectives, an early effort was made to develop and implement an interdisciplinary approach to evaluate germplasm-utilizing pathologists, entomologists, agronomists, and breeders. The same seedling nurseries and clonal nurseries were utilized by scientists of all four disciplines to increase the ability to solve practical problems in the field.

In 1974, IITA dispatched a team of scientists to help initiate the cassava research program in Zaïre. Upon arrival, they found that most of the local varieties were susceptible to cassava bacterial blight (CBB), cassava mosaic disease (CMD), and cassava anthracnose disease (CAD). Because of these susceptibilities, there was an immediate need to increase the genetic base for cassava by introducing improved and exotic materials from other programs. IITA introduced large quantities of botanic true seeds, providing PRONAM with a wide enough genetic base to search for resistance to CBB, CMD, and CAD (see Table 3.2). The introduced seed materials formed the basis for the development of improved cassava varieties at PRONAM with built-in genetic resistance to CBB, CMD, and CAD as well as to insect pests such as green spider mites and cassava mealybugs.

Table 3.3 shows the breeding system that was utilized for screening the material originally introduced from IITA and selected for resistance from the seedling nursery. This scheme was modified in 1986 in order to reduce the time to release a variety from eight to five years (see Table 3.4).

2. Breeding Methods

The major constraints to stable cassava production in Zaïre are diseases, insects, weeds, and nematodes. In 1974, at the inception of the PRONAM breeding program, most of the local varieties were susceptible to the three major diseases in the area. An early attempt to locate resistant sources of material from the center of origin for cassava was initiated. Since IITA had already assembled a mass of materials from South America and identified and improved numerous sources resistant to many of the cassava diseases and insects, the logical decision was made to utilize this source of improved genetic materials. This germplasm became the major source of genetic variability for the PRONAM breeding program.

Introduction of vegetatively propagated materials involves the risk of concurrent transfer of pests and pathogens. Although all precautions are taken to prevent the introduction of diseases and pests, additional care must be take to ensure that viruses are not unknowingly introduced due to a lack of a screening method for viruses. It is not practical to consider modern technological interventions such as pesticides and insecticides, because farmers cannot afford these chemicals and they are not conveniently available. The cassava breeding program therefore identifies the factors that affect the incidence to diseases and pests and incorporates resistance to diseases and insects as a major means of increasing cassava production. Screening in the field is based upon the phenotypic expression of the disease and infestation level by insects.

Table 3.2. Cassava Seed Material Introduced in Zaïre, 1974-1985

Year	Number of Seeds	Source
1974	60,000	IITA, IBADAN
1975	2,500	IITA, IBADAN
1977	100,000	IITA, IBADAN
1978	100,000	IITA, IBADAN
1980	23,000	IITA, IBADAN
1982	4,000	IITA, IBADAN
1981	30,000	PRONAM & IITA
1982	38,000	PRONAM & IITA
1983	30,445	PRONAM & IITA
1985	6,182	IITA

Source: Data from PRONAM Annual Reports, 1974-1989.

a. Clonal Selection

Cassava is highly heterogeneous in that seeds introduced present a source of genetic variability and form the basis for genes suitable for increasing the genetic base to effect efficient selection. Seedlings, in a common plot, are evaluated by pathologists, breeders, entomologists, and agronomists working hand in hand to determine the agronomic characteristics and resistance to diseases and insects. The preliminary evaluation of the clones comprises the material used for the next level of the evaluation. The most promising clones are selected and placed in the advanced yield trial for at least three to four years.

b. Hybridization Between Varieties

Hybridization between varieties involves hybridization between a group of varieties selected. The hybrids may be made by means of hand crosses (artificial pollination) in the crossing block at the main station in M'Vuazi to combine and recombine desirable characteristics and retain a high degree of genetic variability. The appropriate parent must possess the greatest potential of transferring favorable genes. Open pollinated seeds are also collected and grown for evaluation purposes. The seeds are then planted in the field and evaluated for resistance to diseases and pests, root quality, leaf quality, and cyanide content. Because cassava leaves form a major portion of the protein source in the diets of many Zaïrians, a major consideration in the breeding program is the acceptability of the leaves.

Table 3.3. PRONAM Cassava Breeding Scheme Until 1986

Year 1	Seedling nursery: 20,000-100,000 seedlings	Screening for resistance to diseases and pests. Yellow tubers.
Year 2	Clonal yield (2 sites): 1,000-2,000 clones	Continued evaluation of disease and pest resistance. Initial yield observations. Levels of cyanide in leaves and tubers. Erect stems, branching at 1 meter.
Year 3	Preliminary yield trial (3 sites): 100-200 clones	Confirmation.
Year 4	Advanced yield trial (4 sites): 20-40 clones	Continued disease and pest resistance organoleptic tests. Leaf color. Dry matter determination.
Year 5	Uniform yield trial (5 sites): 10-20 clones	Confirmation.
Year 6	Multilocational yield trial (6 sites): 5-10 clones	Continued disease and pest resistance tests. Evaluation for yield and adaptation.
Year 7	On-farm trials	Evaluation for performance under conditions found in farmers' fields.
Year 8	Multiplication and distribution	Large-scale dissemination.

Table 3.4. Post-1986 PRONAM Cassava Breeding Scheme

Year 1	A large quantity (20,000-100,000) of botanic true seeds are utilized to form the germplasm base for cassava for a broad genetic base. Seedlings are screened for resistance to CBB, CMD, and CAD. Clones that remain after intense disease evaluation are selected for further studies.
Year 2	Selected clones obtained from the first year are placed in the clonal nursery in order to increase the material. In this trial, clones are reevaluated with special attention to selection pressure for disease and insects that reflect conditions where cassava is grown in Zaïre. Clones are also evaluated for other traits such as conformation, earliness, foliar retention, tuber color, hydrocyanic acid content, and dry matter content. These selections will drive the preliminary yield trial (year 3).
Year 3	In the preliminary yield trial, clones are evaluated principally for fresh root weight. Trial is conducted in a randomized complete block design with more than two replications. The selection at this stage will drive the advanced yield trial (year 4).
Year 4	In the advanced yield trial, clones are reevaluated for consistency in fresh root weight and other important traits. At this stage, the breeding program possesses sufficient material to carry out experiments in other environments.
Year 5	In the uniform yield trial, the best clones from previous years are reevaluated for important traits and multiplied for regional and farmer trials. Elite clones are evaluated in different environments by local farmers and governmental and non-governmental institutions. Outstanding clones are released.

In the crossing block, several crosses were made with clone 70453, which has shown some tolerance to cochenille. The crosses made, the number of clones tested, and the number of clones selected are shown in Table 3.5.

Table 3.5. Clones Selected from a Progeny of the Variety 70453 for Resistance to Cochenille

Cross	Number of Clones Tested	Number of Clones Selected
70453 x 02864	30	7
70453 x 30555	6	4
70453 x 4(2)0060/3	9	3
4(2)0060/3 x 70453	8	2
30467/12 x 70453	2	1
30572 x 70453	5	1
3085/28 x 70453	34	4
70453 open pollinated	726	131
Total	820	153

Source: PRONAM Annual Report, 1985.

c. Interspecific Hybridization

The use of interspecific hybridization was been reported as early as 1967 (by Magoon). This research showed that desirable genes may be found in wild species. The incorporation of genes from extremely wide crosses may offer a source of resistant genes for diseases and insects that may be introgressed into cultivated varieties.

In cassava breeding and development, the breeder's primary aim is to increase the yield of roots of the new varieties resistant to the major pests and diseases that plague cassava--mainly CBB, CMD, and CAD. Quality is often overlooked early in the selection process. The breeder should be aware of farmers' quality criteria before major resources are spent on the development of varieties that the farmer will neither eat nor grow. Farmers have occasionally rejected some new varieties.

d. Hybridization Between Parents Selected

The development of hybrids, or pollination, can be accomplished either naturally or artificially. The crossing block should be isolated with the parents selected to favor natural flowering. The isolation distance must be at least 30 meters from other manioc plantations, as described by Kawano et al. (1978). The number of parents included in the crossing block may vary from 10 to 20 with two replications to ensure that the quantity of seed is sufficient. This method, which is sometimes modified to resemble a type of polycross where a large number of individuals are grown under isolation, is designed to permit ranuom pollination. In order to achieve random matings, the nursery is made of several replicates. Whenever the polycross method is contemplated, it is necessary to consider the biology of each individual into the polycross to hedge against incompatibilities in flowering, selfing, and other factors.

e. Selection

The cassava plant is naturally a cross-pollinating plant that is usually vegetatively propagated by stem cuttings. Although cassava is a cross-pollinated crop like corn, the selection methodologies must be modified in order to accommodate the biology of cassava. Factors to consider in modifying the selection methods include:

- The selection of individual plants showing desirable characteristics in the F1 is possible, and the heterotic effect can be fixed by the means of vegetative propagation.

- The heterosis obtained is fixed in a permanent fashion that would not have been given a segregating population.

The problems encountered when considering cassava selection methods include the following:

- Several cultivars lack the flowering potential under natural conditions.

- Several diseases and insects can be transmitted by vegetative propagation.

- The transmission of important characters is difficult to discern due to cassava's heterozygotic and polyploidic nature.

- The free exchange of vegetative materials is difficult because of the risk of transport of pathogens from one site to the other.

Several methods of selection are applicable in a cassava improvement program: conventional methods; specialized methods; and breeding scheme for population improvement.

The selection of parents to include in the crossing block is the most important aspect of the breeding program. It forms the basis for favorable genetic and agronomic characteristics such as yield and quality of the root and quality of the protein in the leaves. It is also necessary to consider the biology of the clones to be included in the crossing block. Of primary concern is the flowering pattern of the proposed parent and the synchronization of the flowering pattern of the potential parent. It is therefore necessary to know exactly when to plant materials to be included in the crossing block.

The five objectives of selection are:

- high root yield;
- improvement of the plant in terms of foliage quality and physical characteristics of the roots, distribution of nutritive elements, and the quality of the transformed products;
- quality of the root in terms of hydrocyanic acid and consumer acceptability;
- time of maturity (earliness); and
- resistance to diseases and pests.

In the early part of the cassava selection program at PRONAM, the primary emphasis was development of cassava possessing desirable characteristics such as **high root yield** and **high quality of the final product** (i.e., pondu and chikwangue) for the various ecological zones of Zaïre. Root yields have been one of the most studied variables in cassava breeding programs. Root yields as high as 78 metric tons per hectare have been reported with a Colombian variety, Llanera (Ramos, 1970). This enormous yield suggests that a vast amount of genetic potential is available in the cassava population.

In studying the morphological characteristics of cassava, it is important to consider the **leaves and the general appearance of the plant**. Farmers prefer plants that perform well in intercropped systems and have rejected cassava plants that shade out competitors. A more erect plant with a canopy similar to that of the variety F100 is preferred over a plant with a canopy like that of the Kinuani variety.

Since cassava is consumed by most Zaïrians, any **improvement in the quality of cassava**, such as increased vitamin or protein content, would have a significant impact on the nutritional health of a major part of the population. PRONAM initiated a program in 1985 to evaluate yellow root cassava because it exhibited an elevated level of carotene and calcium and also a favorable HCN level, as reported by Oduro (1981). Oduro indicated that the level of carotene varies between 300 and 350 I.U. per 100 g of fresh weight depending upon the age of the plant.

Selection for **root quality** has traditionally been carried out during advanced stages of yield trials. At that time the number of clones is reduced to a manageable number in terms of the cost of sample evaluation. The selection procedure utilized by PRONAM is the same as that described by Hahn (1982) for root quality evaluation.

It is strongly recommended that the sodium picrate test for **hydrocyanic acid screening** be used to evaluate large samples of materials. Because cassava is toxic to humans due to the presence of cyanogenic glycosides, linamarin (up to 96 percent of the cyanogenic glycosides), and a much smaller amount of the closely related glycoside lotaustralin (up to 4 percent) (Conn, 1973), it is very important to include the study of this acid in the selection process. Linamarin and lotaustralin hydrolyze under the influence of the endogenous enzyme linamarase to liberate hydrogen cyanide (HCN).

The sodium picrate test can be utilized on the leaves of seedlings in the nursery and is a simple and rapid procedure at this point. Care must be taken to standardize the procedure in terms of age and location of the sample. Recent communication with Bokanga (IITA) indicate that when and where the samples are taken play a major role in the level of cyanamide detected. The plants determined to have low cyanamide contents are again tested to confirm levels by taking five samples per plant.

This method is used to retest the roots and leaves of the first clonal evaluation of the nursery selections. The clones making up the preliminary yield trials are evaluated for cyanamide content with the enzymatic assay method. With the advanced yield trial, the number of clones is reduced to about 35 to 40. The cyanamide contents of the roots and leaves are assessed. During the next step in the uniform yield trials, an additional assessment is made on the 10 to 15 clones in the uniform yield trial. At this point, quality assessments are made to determine the taste and farmer acceptability of the transformed products. Organoleptic evaluations are made with the assistance of some 30 local evaluators to determine the quality of the product based on color, texture, taste, and consistency. At this point, a decision may be made to continue or discontinue evaluation of the clone.

As far as **maturation**, cassava is usually harvested after one to two years. It has been reported, however, that in Colombia, cassava can be harvested after seven to 12 months (Magoon, 1970). Some varieties mature faster, reaching 85 to 90 percent of their total yield potential within the first nine month of growth (Singh, 1980).

Selection for **resistance** is the most efficient way to fight diseases and insects. **Manihot glaziovii**, a wild species of cassava, was used as a source of resistance against mosaic as early as 1940 by Nicholos and Storey. Hahn et al. (1973) indicated that the same source of resistance as reported by Beck in West Africa and Jennings in East Africa was in the process of being evaluated at IITA.

Cassava Bacterial Blight (CBB). Selection for resistance to CBB begins with the collection of isolates from various regions of the country as reported by Muimba-Kankolongo et al. (1987). New clones are artificially inoculated by leaf abrasion and

stem injection with an inoculum of the disease in all selection cycles of the breeding programs. This system provides a constant supply of pathogenic inoculum. The most virulent isolates of the bacterium are maintained for inoculation purposes. In nonresistant plants, dieback occurs within 48 hours. The degree of infection is assessed on a scale of 1 to 5: Clones receiving a score of 4 or 5 are rejected; clones receiving a score of 1, 2, or 3 are tested during the next cycle of selection. Inoculation with CBB bacteria is carried out at the main station at M'Vuazi.

Cassava Mosaic Disease (CMD). Cassava mosaic disease, transmitted by the white fly (**Besmisia tabacci**), is prevalent in all cassava-producing areas of Africa, with yield reductions of 10 to 80 percent (or higher). The plants selected are detopped at eight months to favor the expression of the mosaic symptoms. After screening, 23 percent of the plants show some resistance to the three major diseases affecting cassava as shown in Table 3.6.

Cassava Anthracnose Disease (CAD). Selection for resistance to CAD involves the artificial inoculation of clones in the laboratory with an inoculum of the fungus after exposure to the sap-sucking insect, **Pseudotheraptus devastans**. The exact procedure utilized for evaluation against anthracnose is described by Muimba et al. (1985) and listed in Table 3.7. Green sections of the cassava stems are inoculated by injecting them with a suspension of bacterial cells using a syringe. Detopping is not performed, as it would interfere with the yield evaluation, which is made during this stage. The cyanide content of both leaves and roots is also determined.

The vast majority of the selection work on resistance to disease and pests is carried out at the M'Vuazi station. The screening work is conducted in three basic stages:

- Stage one: produce genetically variable grain in the crossing block from controlled crosses and from open-pollinated materials;
- Stage two: screen materials obtained from stage one; and
- Stage three: evaluate resistant materials selected from stage two.

PRONAM has identified many sources of resistance to major cassava diseases in Zaïre. Some of the selected clones are Kinuani (30085/28), F100, 4(2)0426/1, 30572/149, 02864, 30010/10, 61665/4, and 41784/9. Two varieties, Kinuani and F100, have been officially released. Sixteen others are listed in the diffusion or pre-diffusion stages of development. Although Kinuani was originally released for general use in Zaïre, it performs best in Bas-Zaïre. F100 was originally released for the Bandundu region, but it has been accepted as an overall good producer for Zaïre in general. (The reactions of the best PRONAM selections to major cassava diseases in Zaïre are shown in Table 4.5. The reactions of PRONAM-released cassava varieties and clones to major diseases and pests are shown in Table 4.6.)

Table 3.6. Frequency Distribution of Clones in the Grain Nursery and Severity of Response to the Principal Diseases of Cassava in Zaïre

Disease	Classification					
	1	2	3	4	5	Total
Bacteria	53.03	27.89	10.32	5.69	3.05	100%
Mosaic	21.03	2.44	21.15	55.15	0.21	100%
Anthracnose	55.28	4.35	39.75	0.57	0.02	100%

Source: PRONAM Annual Report, 1985.

Table 3.8 shows various types of germplasm in different stages of development and the best sources of resistance to diseases and pests.

A discussion of the varieties developed and tested in several regions of Zaïre is appropriate here.

Bas-Zaïre. The highest-yielding clones in the second multilocational trial in Bas-Zaïre during the 1987-88 campaign were 40230/3, 30572/149, 82/053, Kinuani, and 82/578, with average yields over five locations in Bas-Zaïre of 15.04, 13.22, 11.93, 11.02, and 10.27 metric tons/hectare, respectively (PRONAM, 1988).

Bandundu (Kiyaka). The six highest-yielding clones or varieties in Kiyaka were F100, 30085/28, 30572, 30555, Mundjoka, and Munkondo, with yields of 22.4, 27.2, 13.1, 12.5, 6.2, and 14.0 metric tons/hectare, respectively. These varieties were planted at Kiyaka during the 1984-85 growing season.

The five leading varieties in the multilocational trial in 1988 at the forest site in Kiyaka were M82/28, F100, 82/287, 30085/28, and 82/270, with respective yields of 28.74, 26.75, 21.8, 17.9, and 16.84 metric tons/hectare. The forest site is presented because a better separation can be made between varieties than at the Kiyaka plateau site.

Average root yields for six cassava clones over four years (1986-1990) at Kiyaka are presented in Figure 3.1. The forest site produced a considerably higher root yield than the savannah site.

Kasai Oriental (Gandajika). The seven leading PRONAM varieties (multiregional trial in Gandajika in 1986) are 30085/28, F100, 4(2)0426/1, 30572, 30555, MSB, and Kauanga, with yields of 25.4, 25.4, 15.7, 12.1, 18.4, 23.7, and 32.5 metric tons/hectare, respectively (PRONAM, 1986).

Table 3.7. **New Rating Scale Proposed for Evaluation of Cassava Anthracnose**

Severity Category	Characteristic Symptoms
0	No apparent symptoms in the plant.
1	The green part of the plant shows the presence of necrotic lesions produced by the sting of sucking insects, but the insects are not yet colonized; the petioles bend at the point of insertion of the stem, and apical sections are distorted.
2	Oval-shaped superficial cankers are present on the green or lignified sections of the stem; the color of the cankers, which varies from brown to blackish or whitish, is due to colonization by the anthracnose organism.
3	The green or lignified sections show the presence of numerous deep cankers or long superficial wet bands that have been colonized, often accompanied by gum exudation; leaf necrosis and slight defoliation are apparent.
4	Colonized cankers are present in the form of fissures on the green or lignified sections of the plant. Defoliation is severe.
5	Dieback.

Source: PRONAM Annual Report, 1985.

The five leading clones during 1988 Season A were 61847/3/2, 61238/2/22, 82244, 61847, and 60368.

Kisangani (Haut-Zaïre). The six leading PRONAM varieties tested in the multilocational trial in Haut-Zaïre were 82/469, 82/578, 82/053, 02864, 30555/5 C, and F100, with yields of 42.6, 42.0, 39.6, 39.0, 37.0, and 18.6 metric tons/hectare, respectively, as presented in the 1987 PRONAM Annual Report. In a second multilocational trial at Kisangani, two clones, 30572/149 and 30572/93, produced respective yields of 31.6 and 28.2 metric tons/hectare--significantly higher yields than the local check.

Table 3.8. Various Types of Germplasm in Different Stages of Development and Best Sources of Resistance to Diseases, Pests, and High Altitudes

Germplasm at Diffusion and Pre-Diffusion Stages of Development

83/138	85/527	8316/039
83/584	Dinkondo 3	84/1252
F100	8301/216	85/0155
Kinuani	Tshilobo	85/0166
40230/3	Mubalamata/60882/10	85/0181
85/297	8301/022	PM004

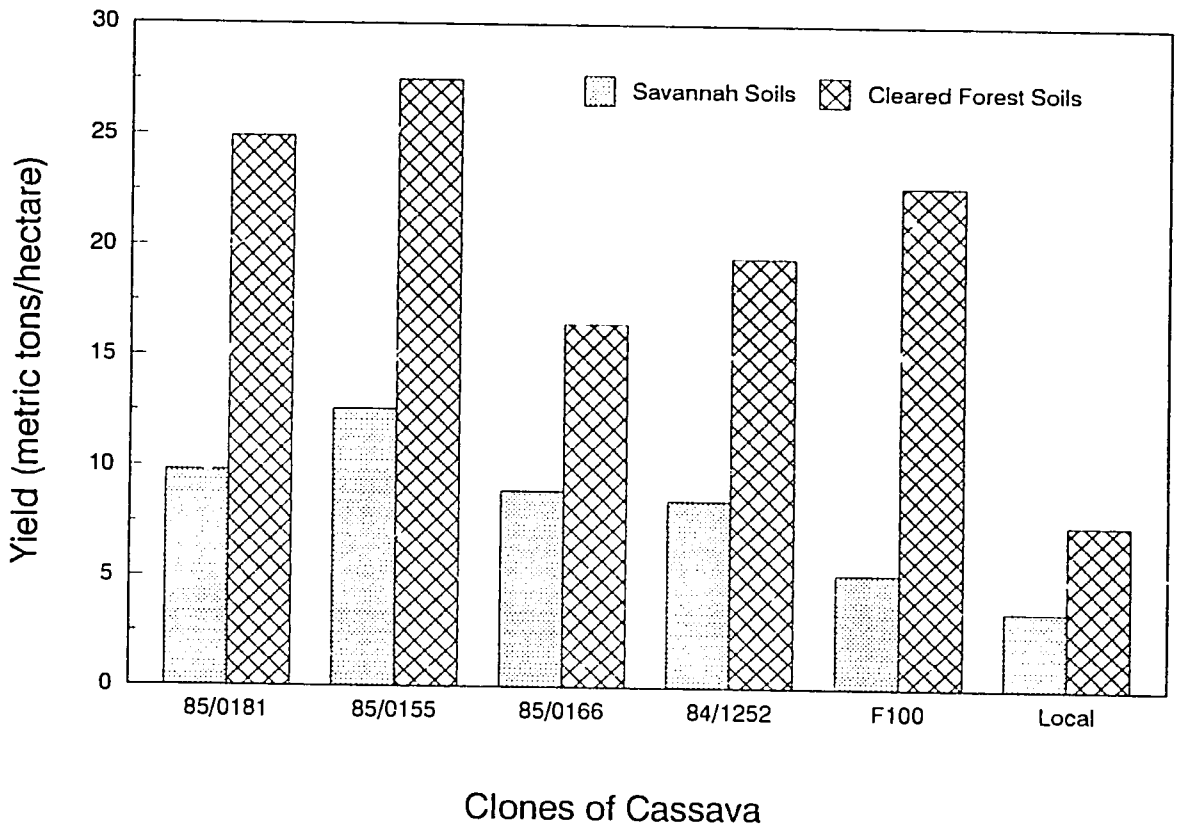
The Best Parents for Favorable Genes

70453	GJK82244	61847/3/25
A56	FCN84/85	Yangambi 2
02864	FCN27/84	A19
Yangambi 1	88/0932	Bulk 17
Farine à P.R.	MWP5	S097
Farine à P.V.	MWP6	A 6 Mois
AVM 157C	MWP7	A 6 Mois x S097
F156	Lwenyi/3	60441/8
84/256	HS 5219/16/22	02864/5
85/004/PM	5220/7	8316/039
86/004/PM	33787/6	8314/011
Mpelolongi	4(2)0426/1	84/068
Dinkondo Ngunza	60868/6/3	86/934
GJK82286	61238/2/22	F162
	F150	

Clones Adapted to High Altitude

85/008/PM	88/007PM	86/003/PM
86/006/PM	88/008/PM	M'Vulamingi
86/002/PM	85/007/PM	Cibongoyoka
86/001/PM	86/005/PM	Nanbiyombiyo
86/004/PM	Mpolili seed 13	

Figure 3.1 Root Yields of Selected Cassava Clones



Source: PRONAM (1991).

Note: Mean yields for 1986-1990 on cleared forest and savannah soils.

3. Variety Release Policy

The current variety release policy is a relatively new convention in Zaïre. The procedure for SENARAV-mandated crops is presented below.

1. The variety proposed for release is presented at an internal review for approval for presentation at the Scientific Review. There must be trial results from at least three growing seasons.

2. The variety is presented at the Scientific Review by the originating breeder with action recommendations.

3. At the Scientific Review, the variety is either approved or rejected for further testing.

4. After approval at the Scientific Review, the final process is then reinitiated for recommendation to the Ministry of Agriculture for possible release.

5. The originating breeder makes a final recommendation to the National Program Director for approval based upon data presented and accompanying documentation. The breeder may propose a name for the new variety.

6. The National Program Director makes a recommendation to the SENARAV Scientific Director for the proposed new variety based upon presented data and accompanying documentation.

7. The SENARAV Scientific Director makes a recommendation to the SENARAV Coordinator that the proposed new variety be released.

8. The Coordinator of SENARAV makes a recommendation to the Ministry of Agriculture that the proposed new variety be released.

9. The Ministry of Agriculture makes the final decision on whether to release the proposed new variety. If a positive decision is made, the Ministry of Agriculture holds a news conference to announce the release of the new variety.

10. The new variety is released.

4. Descriptions of Varieties Developed

Descriptions of F100 and Kinuani, two varieties developed under PRONAM admini-stration, are presented below.

a. Kinuani

Kinuani, which means "disease fighter" in the Kikongo language, is one of the better varieties released by PRONAM. It is an early-maturing variety with yields 30 to 40 percent higher than the local varieties; in fertilized fields, its yield can exceed 60 percent. As its name implies, Kinuani has a high level of resistance to disease, in this case, cassava bacterial blight. Farmers are pleased with Kinuani's high yields and the quality of the pondu, fufu, and chikwangue. They also like its growth habits, which provide good ground cover, requiring less weeding by farmers. The tubers of Kinuani have an average dry matter content of 26 to 28 percent, some 4 percentage points lower than that of the local variety.

Botanic and Agronomic Characteristics of the Variety Kinuani:

General appearance: Robust, leafy, branching at less than one meter.
Average height: 1-3 meters
Average number of branches per feet: 1-2
Color of young, immature leaves: Brown
Color of mature leaves: Dark green
Color of petioles: Reddish-brown
Color of young stems: Light green
Color of inside stem: Light green
Shape of nodes: Elongated
Average number of days before flowering: 90
Reaction to diseases and pests:
- Mosaic: Susceptible
- Bacteria: Resistant
- Anthracnose: Susceptible
- Green spider mite: Very susceptible
- Cochenille: Very susceptible

Number of grains/flower: 4-10
Percent concentration of HCN in leaves: Average
Percent concentration of HCN in tubers: Average to high
Yield potential (t/ha): 7-35 (depending on soil fertility)
Number of commercial (marketable) roots per plant: 2-5 (depending on soil fertility)
Color of tubers: Dark cream to cream
Date of maturity: 12 months
Quality: chikwangue: very good; fufu: very good; pondu: very good

b. F100

F100 was selected from the INERA collection inherited by PRONAM for release in Bandundu and was later found to be well adapted to conditions in Kinshasa and Bas-Zaïre. Yields are typically between 7 and 25 metric tons/hectare. F100 grows very upright, making it particularly well suited to cultivation in association with other crops. The long stems ensure that there is plenty of quality planting material for the

following season. F100 is popular due to the quality of its leaves (pondu) and its low water content (33-35 percent dry matter). Although it has a tendency to fall over when it reaches a certain height, this lodging can be overcome by intercropping F100 with maize or pigeon peas, or by heaping the soil up around the base of the stem.

Botanic and Agronomic Characteristics of the Variety F100:

General appearance: Upright with branching at 1.5 meters
Average height: 1.5 meters
- Valley: 227.6 centimeters
- Forest: 244.6 centimeters
- Plateau: 142.9 centimeters

Average number of stems per plant:
- Valley: 2.80
- Forest: 2.66
- Plateau: 1.98

Color of young, immature leaves: Green
Color of mature leaves: Green
Color of petioles: Reddish-green
Color of young stems: Dark green
Color of interior wood: Whitish
Shape of nodes: Triangular
Average number of days before flowering: 180-200
Reaction to diseases and pests:
- Mosaic: Resistant
- Bacteria: Susceptible
- Anthracnose: Susceptible
- Green spider mite: Susceptible
- Cochenille: Very susceptible

Average number of seeds/flower: 3
Yield potential (metric tons/hectare):
- Plateau (sandy poor soil): 7-10
- Valley (sandy humic): 15-20
- Forest (humic): 20-25

Average number of commercial (marketable) roots per plant:
- Valley: 3.5
- Plateau: 2.7

Color of tubers: Whitish
Date of maturity: 12 months
Quality: fufu: very good; pondu: very good; chikwangue: very good
Areas recommended for use: fertile valleys, forests, savannas

5. New Variety Multiplication

Table 3.9 indicates the number of cuttings of improved cassava varieties that were distributed in 1983-1984 through 1989-1990. Table 3.10 offers information on field multiplication by farmers in Bas-Zaïre in 1987-1988. Table 3.11 provides details on cassava multiplication in Bandundu in 1987-1988.

Table 3.9. Distribution of Cuttings of Improved Cassava Varieties to Peasant Farmers, Development Organizations, and Department of Agriculture Extension Agents in Bas-Zaïre, 1983-1990

Year	Free Distribution	Sale (meters of cuttings)	Total
1983-84	257,630	114,650	372,280
1984-85	461,500	390,750	860,250
1985-86	234,175	256,325	490,500
1986-87	338,370	111,250	449,620
1987-88	145,900	110,250	256,150
1988-89	112,145	43,350	155,495
1989-90	101,350	63,537	164,896

Note: One meter of cuttings can furnish four planting stakes.

Table 3.10. Field Multiplication by Farmers in Collaboration with PRONAM/ Agronomy in Bas-Zaïre, 1987-1988

Collaborator	Location	City	Number of Farmers	Area (hectares)
State Agronomist	Cataractes (Luozi)	Kimbanza	4	2.0
	Mbanza-Ngungu	Boko	3	1.5
		Gombe-Sud	2	1.3
	Madimba	Luila	2	0.7
		Ngeba	1	0.3
		Ngufu	3	1.2
P.A.A.	Cataractes (Luozi)	Kimbanza	1	2.0
		Mbanza-Mona	1	1.0
CEDECO/Kimpese	Solongolongo	Kimpese	3	6.0
		Luima	2	5.0
		Palabala	1	1.0
ITA/Gombe-Matadi	Mbanza-Ngungu	Gombe-Matadi	1	2.5
OXFAM	Mbanza-Ngungu	Gombe-Matadi	1	1.0
	Lukaya (Madimba)	Mfidi	6	3.0
Projet Italo-Zaïrois	Cataractes (Luozi)	Mongo	1	3.0
Total			35	32.6

Source: PRONAM Annual Report, 1987.

Table 3.11. Area of Cassava Realized from Extension Multiplication in Bandundu, 1987-1988

Multiplier	Region	Zone	City	Locality	Area (hectares)
Seed Farm at Lusanga	Kwilu	Bulungu	Lunyungu	Kisia	4.00
Kimbanguiste Church	Kwilu	Ngungu	Mungindu	Ngashi	0.40
Mennonite Church	Kwango	Kahemba	--	Kajiji	0.52
Baptist Church Independent	Kikwit	--	--	--	1.00
Mennonite English	Kikwit	Kikwit	--	--	0.42
PRAAL Gungu	Gungu	Gungu	Gungu	--	4.80
P.P.F.	Kikwit	Kikwit	--	Nzanda	0.80
				Katambo	0.10
ITA Lamba	Kwilu	Bulungu	--	Lamba	0.24
Total					12.28

Source: PRONAM Annual Report, 1988.

II. Maize

A. History and Importance of Maize in Zaïre

Maize (**Zea mays**) was first used as a source of food by ancient American Indians, and it played an important role in their culture and development. A major food crop, maize is used for food, feed, fuel, and fiber. Maize was introduced to Zaïre by Portuguese voyagers at the mouth of the Congo River in 1482 (Miracle, 1967). Maize production was expanded due to demand for corn as an export crop. In 1933, the Belgium Government established an agricultural research organization, the Institut National pour l'Etude Agronomique du Congo Belge (INEAC) to work on export crops including corn (Jurion and Henry, 1967). In 1965, the name of the organization was changed to Institute National pour l'Etude et la Recherche Agronomique (INERA).

Maize is a major food crop in Zaïre, particularly for the Shaba, Kasai Occidental, and Kasai Oriental regions. Most farmers intercrop maize with other staple crops such as ground nuts, manioc, yams, cotton, and beans.

B. History of Maize Germplasm Development in Zaïre

In 1971, the Government of Zaïre (GOZ) signed a 10-year agreement with the International Center for the Improvement of Corn and Wheat (CIMMYT) in Mexico; the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria; and USAID with the purpose of technology diffusion and application of Green Revolution principles in Zaïre and with the goal of future self-sufficiency in maize. Under the agreement, the GOZ was to take full control of corn research and development and training at the end of the project. CIMMYT researchers assisted in organizing the Programme National du Maïs (PNM) as an official government entity with the objective of developing new, insect-resistant varieties of maize adapted to conditions in Zaïre. Another mandate of PNM was to develop technological packages for the introduction of new maize varieties to farmers.

The program with CIMMYT had three major goals:

- Research--to develop a sound program of maize research fully integrating the disciplines of breeding, protection, and agronomy and geared primarily towards increasing production of maize per unit area in practical and socially acceptable ways.

- Production--to transform the fruits of research (i.e., improved genetic materials), combined with a sound economic package of agronomic and protective practices, into increased maize production at the farm level through regional on-farm testing with the assistance of national training officers and government extension workers.

- Training--to train a cadre of Zaïrian scientists and technicians to be fully capable of sustaining maize production by 1982.

Until 1972, the common maize varieties in Zaïre were GPS4, GPS5, Hybrid Double, and Hickory King. The first three varieties were developed by INEAC; Hickory King was a hybrid introduced from the United States.

In 1984, USAID agreed to finance agronomic research on the culture of corn, manioc, and legumes. As a result, three national programs were brought together under the Service National de Recherche Agronomique Appliquée et Vulgarisation (SENARAV).

C. Research Methods in USAID-Supported Germplasm Development

1. Research Strategies

Until 1972, the primary research strategy for the corn breeding program was to utilize introduced hybrids from Zambia and Zimbabwe. The variety recommended for South Shaba was Hickory King, a hybrid from the southern United States that could be easily recognized by its eight-row ears.

Early strategies involved the testing of introductions from CIMMYT. These materials were compared to the standard variety SR52, whose yields ranged from 8 to 14 metric tons/hectare. Central American varieties and hybrids were also evaluated. Again, SR52 was the top-yielding variety.

International maize nurseries from CIMMYT and international maize breeding programs from other parts of the world were evaluated in Zaïre. In the early days, fertilizers were utilized in local demonstration trials. Another strategy involved improvement of local varieties, since they possessed a sound base to build on in terms of their taste and acceptability.

The major activity involved incorporating of disease and insect resistance into local varieties. Germplasm showing some resistance to maize streak virus, ear rots, cut worms, army worms, borer damage, and leaf blights was evaluated and increased.

INERA had several populations of synthetic varieties. The two best synthetics from that collection were GSP4 and GSP5. (GSP is the abbreviation for Gandajika Synthetic Population. Gandajika is the location of the INERA station in Kasai Oriental.)

The first trials planted in Zaïre by PNM were observational variety trials at M'Vuazi, Bas-Zaïre, in 1972. These trials utilized chemical fertilizers; however, local farmers could not afford fertilizer, and none was locally available.

The breeding method utilized early in the program included hybrid development, modified-ear-to-row methods, half sibs, back-crosses, and recurrent selection techniques. PNM staff recognized early on that open-pollinated varieties would be more efficient and productive than hybrids, which must be regenerated each year.

The lack of good seed production, storage, processing and handling facilities poses a major problem for seed development. In the absence of such facilities, seeds must be regenerated in the field each year; this very expensive and ineffective practice is a major obstacle in the development of a progressive breeding program.

2. Research Objectives

The objectives assigned to PNM by mandate are:

- to identify the major constraints to maize production in Zaïre;
- to conduct agronomic trials to validate new technologies, at the station and on-farm, and to search for solutions to the problems;
- to develop high-yielding varieties; and
- to ensure the training of young Zaïrians.

The general objectives of the breeding section of PNM are to develop high-yielding maize varieties resistant to the major constraints to maize production in Zaïre (diseases and insect pests) and packages of technologies that local farmers can utilize. The goal of the program is to develop high-yielding, open-pollinated maize varieties resistant to diseases and insects and requiring little or no fertilizer.

The development of specific research objectives is first conceived by the researcher and then presented at the Internal Scientific Review. At this review, research plans and objectives are presented and acted upon by the general assembly of participating scientists. Later, a similar procedure is employed at the SENARAV Scientific Review held every year (or every two years, depending on the availability of funds). The last Internal Scientific Review was convened in the summer of 1991, and the last SENARAV Scientific Review was convened in August 1990.

3. Breeding Methods

In 1973, the first year of the program, the primary breeding method utilized was the introduction of varieties from other breeding programs and the evaluation of local materials. The following materials were screened during the first year of the program:

- 30 varieties and hybrids from East Africa
- 135 varieties from CIMMYT, Mexico
- 66 varieties and hybrids from Central America
- 74 varieties and hybrids constituting the International Maize Nurseries
- 8 varieties from Rhodesia (Zimbabwe and Zambia)
- 4 varieties from the International Institute of Tropical Agriculture (Nigeria)
- 10 local varieties

The second breeding procedure utilized was the hybridization method. One of the earliest varietal crosses developed in Zaïre was Shaba Safi, a cross between SR52 from Rhodesia and H632 from Kenya. This hybrid was a high-yield cross with good resistance to leaf blight, but it was susceptible to lodging. To overcome this problem, Shaba Safi was crossed with the best short-plant selections from CIMMYT. The first of these crosses was tested during the 1972-73 growing season and released under the name PNM 1 in an effort to provide a variety to farmers in the Shaba region. The pedigree of PNM 1 was Tuxpeno 1 (Mix 1 x Col. Gpo. 1) x Eto x Shaba Safi. PNM 1 yielded 9.5 metric tons/hectare and was shorter and more resistant to lodging.

One of the CIMMYT populations, Tuxpeno 1, was well adapted to the Kasai regions. The 10 highest-yielding families, which all yield over 9 metric tons/hectare, were increased, and another variety was released to the farmers of the Kasai regions under the name Salongo.

A mass selection program was initiated in the 1974-75 growing season to establish populations from the five selected varieties.

Simple mass selection, the oldest and simplest of all recurrent selection systems, was probably used by ancient native cultures for maize improvement. It was used by early farmers, who saved seed ears from high-yielding plants at harvest time. Early maize breeders thought this system was ineffective for yield improvement but effective for other traits.

Selection criteria included ear height, plant height, ear aspects, ear rots, and resistance to streak virus and lodging. In the 1975 growing season, selected ears were used to set out crossing blocks for each of the five varieties using modified-ear-to-row selection.

The modified-ear-to-row selection procedure, suggested by Lonquist (1964), involves single-replication testing in multiple environments with an isolated nursery. Each HS family is grown and detasseled. Male rows planted from a balanced composite of seed from all HS families are interspersed among female HS families and provide the pollen source. Selection is made among HS families based on yield performance and also among plants within HS families based on visual yield potential. Simultaneous yield testing and intermating permits advancement at the rate of one cycle per year.

In 1987 and 1988, the PNM breeding activities changed slightly. The basic strategies included:

- back-cross improvement of existing PNM varieties known to be well adapted in the regions of recommended use but with serious disease susceptibility;

- combining ability studies of white and yellow populations from IITA and CIMMYT;

- varietal cross trials of elite experimental materials;

- progeny row testing of families (primarily full-sib) from proven populations;

- a selection methodology study of TZMSR-W for South Shaba;

- half-sib family maintenance of foundation seed for PNM of improved varieties; and

- maintenance and evaluation of germplasm from national sources (PNM, INERA), other African countries (Tanzania), and international organizations (IITA and CIMMYT).

IITA plant breeding specialist Dr. Ken Johnson expanded the scope and depth of maize improvement activities as listed below:

- Sib-mating of all open-pollinated varieties in testing trials to ensure future seed supplies as well as small-scale seed increases of the best varieties for availability to the extension trials the following season.

- Recombinations to the F2 of selected families from progeny to testing trials received from CIMMYT and IITA. When PNM-derived families are available, this activity will switch their recombination and leave previous progeny recombinations to the donor organizations.

- Back-cross improvement of existing PNM varieties known to be well adapted but with serious disease susceptibilities--most notably Shaba I, Kasai I, Salongo II, and Bandundu, which have problems with streak virus.

- Combining ability studies with 11 promising white population and eight yellow population to determine their combining ability.

- Family row formations (primarily full-sib) in order to develop progeny testing capability in populations proven advantageous in Zaïre but not readily available from the international research center. These populations include TZMSR-W, for South Shaba; DMR-LSR-W, for Kasai Oriental; TZMSR-W, for Bas-Zaïre; and TZSR-Y, for the Bandundu region.

- A study was also initiated to evaluate the selection methods comparing half-sibs, full-sib, S1, test-cross, and mass selection in the TZMSR-W population at the Kaniameshi station.

- Multiplication of foundation seed for recommended PNM varieties was shifted to a half-sib family row selection basis, a methodology introduced in the early days of CIMMYT management.

Earlier disease and insect evaluations had been based on natural or background levels of infestation. Many times, the materials that had been screened as resistant broke down the following generation because the resistant plants were improperly scored due to the lack of disease or insect pressure. The PNM breeding program was modified to correct for this problem. A system to rear insects was developed in order to ensure that a threshold pressure was maintained so as to provide a true reading. The objectives were:

- to evaluate local and introduced materials for susceptibility, tolerance, or resistance;
- to observe all entries in selection trials to use as sources of resistance in varietal development or sources of inoculum (susceptibility) in future PNM selection research;
- to develop specific methodologies to increase disease incidence in selection trials for Zaïrian conditions in general and each agroecological zone in particular;
- to provide the PNM Breeding and Testing Section with disease evaluation information on all trial entries as an aid in selection;
- to survey each of the five regions of maize research for disease incidence and severity in order to determine annual changes, degree of economic loss, and perceptions of local farmers;
- to identify new diseases of maize at an early stage of dispersion in order to prepare varietal resistance solutions; and
- to assist the breeder in developing resistant varieties.

4. Research Methods in Germplasm Development

The mass selection program began during the 1974-75 growing season. This program was initiated to establish populations from the five selected varieties. For each variety, a one-half-hectare selection block was planted at the Kisanga station (Shaba) at a density of approximately 53,000 plants per hectare. Selection criteria included ear and plant heights, resistance to streak virus and to lodging, ear aspects, and ear rots. Table 3.12 shows the number of plants selected for each variety.

One of the early recorded hybrid breeding methods was initiated in 1969 by Muleba Nyanguila, who produced a multiple-cross variety involving H 63, a three-way cross from Kenya, and SR 52, a single cross from Rhodesia. This multiple cross was named Shaba Safi and released in 1973 to farmers in the Shaba region.

Table 3.12. 1974-75 Mass Selection Program: Number of Plants Selected by Variety

Variety	Number of Plants Selected
PNM 1	650
Tuxpeno x Eto	588
Tuxp (Mix 1 x ColGpo 1) Eto	598
(Tuxpeno x Eto) Shaba Safi	655
(La Poste x Eto) Shaba Safi	726

The first year of testing had materials from 30 varieties and hybrids from East Africa, 135 varieties from CIMMYT, 66 from Central America, 74 from the International Maize Nursery, 8 varieties from Rhodesia, 4 varieties from IITA, and 10 locally collected varieties. The hybrid SR52 was used as the check. Shaba Safi turned out to be the best open-pollinated variety with short plants that did not lodge.

CIMMYT arrived in 1972. The director of the project, Dr. Thomas G. Hart, remained with the program until 1981. He also served as the director of PNM. Mukinde, the current director of PNM, was trained at CIMMYT in 1972.

In the early years, hybrids were utilized in the breeding program. However, these introduced hybrids tend to break down due to inbreeding depression. Hybrids developed in the West have posed problems for the PNM program because they must be developed each year to be effective. Zaïre has neither the infrastructure nor the marketing strategy to sustain a hybrid corn development program. In an effort to influence the acceptance of the early hybrid development work, germplasm was given to farmers free of charge. This practice proved to be a problem because it caused farmers to become accustomed to being provided with free seeds. The relationship between the farmers and PNM suffered as a result.

Shaba Safi, which was highly susceptible to lodging, was crossed with 270 varieties and hybrids from around the world. The best 24 of these materials were selected and produced F2 generation to be tested. SR 52 and H 632, both parents of Shaba Safi, were grown in a crossing block to produce new seed of Shaba Safi. SR 52 female parents were emasculated by detasseling. Nineteen metric tons of seeds were harvested. The original cross was not made again. Shaba Safi was crossed with Tuxpeno 1 (Mix 1 x Col Gpo 1) x Eto x Shaba Safi to produce lodging-resistant progeny.

In 1974, INERA had two synthetic varieties, GPS 4 and GPS 5, abbreviations for Gandajika Population Synthetic. During this same year, PNM and the Office National Des Cereales (ONACER) jointly introduced Shaba Safi (H 632 x SR 52). PNM

1 was developed and subsequently released to replace Shaba Safi in most of the Shaba region. PNM 1 produced 9.5 metric tons/hectare and was shorter and more resistant to lodging than Shaba Safi.

In the 1975-76 growing season, selected ears were used to get out-crossing blocks for each of the five varieties using modified-ear-to-row selection.

The Tuxpeno x Eto population was planted at Gandajika in Kasai Oriental, and Tuxpeno (Mix 1 x Col. Gpo. 1) Eto was planted at Kaniama in Shaba (North).

During 1975, seed samples of PNM-improved maize varieties were given on request to the Government of Malawi, IITA/Nigeria, the Programme National du Manioc, and missionary groups. Additionally, about 13 metric tons of seed of PNM improved maize varieties were sold to various organizations, and another two metric tons of PNM 1 seed were given to participating farmers in the supervised credit plantings in the southern portion of Shaba for the 1975-76 season.

It was found that the progeny of one of the CIMMYT populations, Tuxpeno 1, was well adapted to the Kasais. The 10 highest-yielding families, yielding more than 9 metric tons/hectare, were increased, and another variety, Salongo, was released in 1975 to farmers of the Kasais.

On July 1, 1977, PNM officially became part of INERA.

D. Descriptions of Varieties Developed

Six varieties of maize have been developed and released since the inception of the breeding program. These varieties and their pedigrees are shown in Table 3.13.

Tables 3.14 through 3.20 offer detailed descriptions of the improved varieties since the inception of the program.

E. Identification and Prioritization of Breeding Objectives

A survey of farmers was conducted in 1989 to determine the most effective selection criteria for maize considering the regional preferences and diverse ecologies and climates. Listed in Table 3.21 are the results of the survey. As shown in the table, yield and grain color are the two primary characteristics that farmers consider in selecting a variety to grow. Grain color is the primary consideration in the Bandundu region.

F. Availability and Use of Germplasm Resources

Promising genetic material has resulted from testing IITA materials for comparison with PNM materials and other local varieties. Some of the promising varieties include 8321-21 and TZB Gusau SR, in South Shaba; TZSR-W and TZSR-Y derived varieties, in Bas-Zaïre and Bandundu; and the yellow hybrid 8329-89 season, in Bandunu.

Table 3.13. Varieties Developed by the Breeding Program

Variety Name	Pedigree
Shaba Safi	H 632 x SR 52
Salongo	Bulk of 10 best-performing open families of Tuxpeno 1, cycle II. Selected at Gandajika, Kasai Oriental in January 1974.
Salongo II	Bulk of remnant seed held at CIMMYT, Mexico, from original 10 families of Tuxpeno 1, cycle II. Seed increase was conducted at CIMMYT, Poza Rica Station, Mexico, and air freighted to PNM/Zaïre.
PNM I	Tuxpeno 1 x (Mix 1 x Colima group 1) x Eto x Shaba Safi
Kasai I	Tuxpeno 1 x Eto
Shaba I	(Tuxpeno 1 x Eto) x Shaba Safi

Table 3.14. Description of the Variety Bandundu

Area to grow	Bandundu (average to low altitude)
Pedigree	Selection from full-sibs from TZSR-Y
Color of grain	Yellow
Type of grain	Dent
Average height of plant	1.67 m
Average height of ear	0.83 m
No. of days to flower	56
Vegetative cycle	4 months
No. of ears per plant	1
No. of rows per ear	14
Average length of ear	16.5 cm
No. of grains per ear	520
Weight of 1,000 grains	306 g
Average yield (metric tons/ hectare) at station	4.1
Average yield (metric tons/ hectare) in farmer conditions	2.5

Source: Director Mukinde, 1992.

Table 3.15. Description of the Variety Ikenne

Area to grow	Bandundu (average to low altitude)
Pedigree	Selection from the family IK 83 TZSRY
Color of grain	Yellow
Type of grain	Dent
Average height of plant	2.11 m
Average height of ear	0.59 m
No. of days to flower	59
Vegetative cycle	4 months
No. of ears per plant	1
No. of rows per ear	12
Average length of ear	16.5 cm
No. of grains per ear	520
Weight of 1,000 grains	306 g
Average yield (metric tons/ hectare) at station	5.9
Average yield (metric tons/ hectare) in farmer conditions	3.0

Source: Director Mukinde, 1992.

Table 3.16. Description of the Variety Babungo-3

Area to grow	South Shaba, Kivu (high altitude
Pedigree	Selection from families full-sib of TZMSR-W
Color of grain	White
Type of grain	Dent
Average height of plant	2.30 m
Average height of ear	1.26 m
No. of days to flower	73
Vegetative cycle	6 months
No. of ears per plant	1
No. of rows per ear	12
Average length of ear	19.0 cm
No. of grains per ear	560
Weight of 1,000 grains	300 g
Average yield (metric tons/ hectare) at station	6.0
Average yield (metric tons/ hectare) in farmer conditions	4.0

Source: Director Mukinde, 1992.

Table 3.17. Description of the Variety Salongo-II

Area to grow	North Shaba, Kasai, Bandundu, Bas-Zaïre
Pedigree	Bulk of remnant seed held at CIMMYT, Mexico, from original 10 families of Tuxpeno 1, cycle II. Seed increase was conducted at CIMMYT, Poza Rica Station, Mexico, and air freighted to PNM/Zaïre.
Color of grain	White
Type of grain	Dent
Average height of plant	2.28 m
Average height of ear	1.23 m
No. of days to flower	65
Vegetative cycle	4 months
No. of ears per plant	1
No. of rows per ear	14-16
Average length of ear	16.5 cm
No. of grains per ear	530
Weight of 1,000 grains	325 g
Average yield (metric tons/ hectare) at station	8.0
Average yield (metric tons/ hectare) in farmer conditions	3-4

Source: Director Mukinde, 1992.

Table 3.18. Description of the Variety Kasai-I

Area to grow	North Shaba, Kasai, Bandundu, Equateur, Haut-Zaïre (mid and low altitude)
Pedigree	Tuxpeno x Eto
Color of grain	White
Type of grain	Dent
Average height of plant	1.98 m
Average height of ear	1.10 m
No. of days to flower	68
Vegetative cycle	4 months
No. of ears per plant	1
No. of rows per ear	14-16
Average length of ear	16.5 cm
No. of grains per ear	515
Weight of 1,000 grains	340 g
Average yield (metric tons/ hectare) at station	8.0
Average yield (metric tons/ hectare) in farmer conditions	3-4

Source: Director Mukinde, 1992.

Table 3.19. Description of the Variety Shaba-I

Area to grow	South Shaba, Kivu, High Altitude
Pedigree	Tuxpeno x Eto x Shaba Safi
Color of grain	White
Type of grain	Dent
Average height of plant	2.25 m
Average height of ear	1.28 m
No. of days to flower	73
Vegetative cycle	6 months
No. of ears per plant	1
No. of rows per ear	14-16
Average length of ear	18.9 cm
No. of grains per ear	569
Weight of 1,000 grains	440 g
Average yield (metric tons/ hectare) at station	9.0
Average yield (metric tons/ hectare) in farmer conditions	4-5

Source: Director Mukinde, 1992.

Table 3.20. Description of the Variety PNM-I

Area to grow	South Shaba, Kivu (high altitude)
Pedigree	Tuxpeno 1 x (M1 X Col. GPO x Eto x Shaba Safi)
Color of grain	White
Type of grain	Dent
Average height of plant	2.25 m
Average height of ear	1.35 m
No. of days to flower	70
Vegetative cycle	6 months
No. of ears per plant	1
No. of rows per ear	14-16
Average length of ear	19.17 cm
No. of grains per ear	566
Weight of 1,000 grains	396 g
Average yield (metric tons/ hectare) at station	9.0
Average yield (metric tons/ hectare) in farmer conditions	4-5

Source: Director Mukinde, 1992.

Table 3.21. Maize Selection Priorities by Research Station, 1989

Research Stations and Regions				
Kaniameshi (S. Shaba)	Kaniama (N. Shaba)	Gandajika (K. Oriental)	Kiyaka (Bandundu)	M'Vuazi (Bas-Zaïre)
Yield	Yield	Yield	Yellow	Yield
White grain	White grain	White grain	White grain	White grain
Streak res.	Mildew res.	Mildew res.	Streak res.	Yellow grain
Borer res.	Streak res.	Shimbu res.	Termite res.	Borer res.
Flint-dent	Weevil res.	Striga res.	Blight res.	Stalk rot
Blight res.	Borer res.	Streak res.	Yield	Weevil res.
Ear rot	Blight res.	Termite res.	Dent/flour	Early maturity
Husk cover		Weevil res.	Forest adap.	
		Borer res.	Savannah adap.	
		Husk cover		
		Early maturity		

The PNM variety Shaba I was improved for both streak and **H. turcicum** resistance at the Kaniameshi station. The first back-cross was made in 1988 after a previous initial cross to TZMSR-W as a donor parent. A bulk of BC1F1 seed was also evaluated in the national trial.

An alternative method to back-crossing was initiated at the Lubumbashi site for introducing maize streak resistance into Kasai I. Maracay 7921SR x Los Banos (1) 8232 was made to regenerate Kasai I with the streak resistance available in the female parent.

In the PNM nursery near Lubumbashi, varieties from various national and international sources have been maintained for seed and evaluated for agronomic and disease resistance traits. In 1987, the nursery included 78 INERA entries, 48 IITA entries, 47 CIMMYT entries, 18 Tanzanian entries, and 3 Brazilian entries.

Over 100 PNM-derived inbreds (primarily from Shaba I) were maintained by further inbreeding (S9), the 40 best were compared to 10 IITA inbreds, and all were top-crossed to a promising South African hybrid (designated HSA).

In addition to the border-row sib-mating within varietal trials to maintain small quantities of seed for further testing, small-scale seed increases of varieties proven over two years were initiated to provide sufficient seed for further extension trials.

Several varieties and lines have been identified as resistant to maize streak virus, bacterial streak, bacterial blight, and downy mildew through the international trials conducted during the first phase of RAV I.

G. Variety Release Policy

The variety release policy for maize is identical to that for cassava (see page 70).

In the PNM nursery near Lubumbashi, varieties and inbreeds have been maintained and evaluated for agronomic and disease resistance traits. In addition to border-row sib-mating within varietal trials to maintain seed for further testing, small-scale increases of varieties, proven for two years or more, were carried out to provide sufficient seeds for further cooperative trials.

Information on maize varieties released by PNM, by station, is presented in Table 3.22. Since a firm variety release policy was not totally in effect, and because Babungo (3) 83 TZMSR-W showed superior performance in the South Shaba region, it was proposed for release in 1988 to RAV Coordination in Kinshasa. The National Seed Office (BUNASEM) was multiplying Babungo 3 on 12 hectares in South Shaba and seed of IK 83 TZSRY-1.

Table 3.22. PNM Maize Variety Release Progress

Region (Station)	Varietal Priority	Variety	Performance (years of testing)	Released	Reason for Action
South Shaba (Kaniameshi)	White var.	Bab(3)83 TZMSR-W	33% over Shaba I (4)	Yes	Farmer Approval
	White hybrid	HSA*IITA501	66% over SR52 (1)	No	Insufficient Years
North Shaba	White var.	Poza Rica 8232	17% over Kasai 1 (3)	No	Susceptible to Downy Mildew
	White hybrid	8321-21	20% over Kasai I	No	Insufficient Advantage
Kasai Oriental (Gandajika)	White var.	TZB Gus SR	35% over Salongo II	No	Insufficient Years
	White hybrid	8321-21	41% over Salongo II	?	Susceptible to Downy Mildew
Bandundu	Yellow var.	IK83TZSRY-1	21% over Salongo II	Yes	Confirmed by Cooperators
	Yellow hybrid	8329-15	20% over Bandundu (3)	No	Insufficient Advantage
	White var.	Acr 83 TZSRW-1	37% over Kasai I (3)	No	Unstable Performance
Bas-Zaïre	White var.	TZB Gus SR	24% over Kasai 1 (2)	No	Unstable Performance
	White hybrid	8505-5	24% over Kasai I (2)	No	Insufficient Years
	Yellow var.	IK83TZSRY-1	28% over Bandundu (3)	?	Confirmation Required

III. Grain Legumes

U.S. assistance to grain legume development research in Zaïre can be divided into three periods:

- the INERA Support Project (1979-1984);
- RAV I (1985-1990); and
- RAV II (1990 until the evacuation of technical assistance staff in September 1991).

Grain legume research during the INERA Support Project concentrated chiefly on bean and soybean testing at Mulungu, the high-altitude research station in the Kivu region. Its lasting contributions were (1) the identification of several bean and soybean varieties that served as check varieties for RAV I, and (2) long-term training of the interdisciplinary research team at the Mulungu station, a team that continues to function effectively.

During RAV I, the Programme National des Légumineuses (PNL), was founded and became a successful program with a strong small-farmer orientation and substantial accomplishments. The primary germplasm development activity was the introduction and testing (on-station and on-farm) of 35,000 germplasm assessions of the four principal grain legume species at six locations. Other significant PNL activities, including alley cropping research, are covered in Chapter 5.

PNL's germplasm development resources during RAV I were allocated to beans (56 percent of all field work and close to 100 percent of all grain legume research at the Mulungu station), soybeans (17 percent), peanuts (16 percent), cowpeas (10 percent), and other legumes (mung beans, Bambara groundnut, others) (1 percent). Resource use for peanuts increased during the RAV I years in response to the importance of that crop to Zaïre.

The main grain legume selection objectives were, for beans, resistance to fungal and bacterial diseases and adaptation to drought and humidity; for peanuts, resistance to foliar leaf spots and virus diseases and tolerance to low soil fertility; for soybeans, resistance to shattering and lodging, nodulation with indigenous soil bacteria, and appropriate maturity; and for cowpeas, insect and parasitic plant resistance. A serious constraint that could not be directly addressed was seed longevity (beans and soybeans). Four bean varieties, one peanut variety, two cowpea varieties, and two soybean varieties were recommended for release.

During RAV I, PNL also began a hybridization program in each of the four legume species. The first lines from these crosses were in preliminary yield trials during the one season of RAV II.

As a result of RAV I activities, PNL was developed into an excellent, up-and-running organization with trained, motivated staff capable of carrying out germplasm development research activities without daily supervision and requiring guidance chiefly in the research planning and analysis phases. RAV II was too short-lived to have developed a character or record of accomplishments. Budget cuts, labor strikes and subsequent project revisions took their toll on research. In spite of these adverse circumstances, PNL demonstrated its ability to maintain an orderly research program on its long-term work plan.

A. Importance of Grain Legumes in Zaïre

The most widely grown grain legume in Zaïre is the peanut or groundnut (**Arachis hypogea**), followed by common beans (**Phaseolus vulgaris**), cowpeas (**Vigna unguiculata**), and mung beans (**Vigna radiata**). Soybeans, not one of the traditional legumes, are widely perceived in the countryside as extraordinarily nutritious. Demand for seed is high and increasing, though production is often limited to very small plots for grain to be used in small quantities for fortifying other staple foods consumed by children and the sick.

1. Peanuts

Peanuts are considered the most important protein crop throughout Zaïre. They were introduced into Central Africa from South America approximately four centuries ago and are now grown from the Angolan and Zambian borders to the rain forest, from low to moderately high elevations. Peanuts are most important on lighter soils throughout the country (which, however, are also the least fertile) and are often cultivated in association with cassava. Average on-farm yield of peanuts in the Kasai region is approximately 800 to 1000 kg/ha (Camacho, pers. comm. 1992); their protein content ranges from 20 to 30 percent. Peanuts are most often toasted and consumed as a snack rather than eaten with meals.

Their short growing period, suitability for intercropping, protective pod (which increases seed storage life), popularity, and ease of preparation for consumption make peanuts well suited for small-farm cultivation. Between 1960 and 1985, peanut production more than doubled, with an estimated annual production of 450,000 metric tons by 1986 (Wedeman et al., 1988). In the Shaba region, peanut production does not meet local demand for consumption and oil extraction (PNL, 1988). Poor adaptation to low soil fertility and susceptibility to diseases are the factors that most limit peanut production.

2. Beans

Like peanuts, beans were introduced into Central Africa from South America, probably during the era of the Portuguese coastal trade. Local cultivars ("land races") have become distinguished, and beans are accepted as part of the local diet, eaten with staple energy foods and vegetables. The protein content of beans ranges from 20 to 25 percent.

In the last quarter of the twentieth century, beans became the second most important protein crop in Zaïre after peanuts; but production, about 150,000 to 200,000 metric tons per year, did not shown a substantial increase in this period (Wedeman et al., 1988). The constraints that most limit bean production include a range of diseases that attack the crop at every altitude; low soil fertility; a shortage of materials to provide supports for high-yield-potential, climbing beans; and the short seed longevity in the tropical climate.

In the eastern highlands of Zaïre (Kivu province) and neighboring Rwanda and Burundi, the per-capita consumption of beans is the highest in the world--an estimated 50 kg per year. Population density over the eastern highlands ranges from 200 to 350 persons per square kilometer; but it reaches a high 500 to 800 persons per square kilometer on the fertile volcanic soils of north Kivu, where population growth is 2.5 to 4 percent a year. Beans furnish 40 to 65 percent of daily protein in Kivu. The increasingly small size of individual land holdings (0.5 to 1.5 hectares, often in as many as eight parcels) has caused concern that high-protein beans may be increasingly replaced by low-protein root crops, if yield per area of beans cannot be increased. A recent estimate of bean production in Kivu was 222,000 metric tons on 266,000 hectares, or an average bean yield of 835 kg/ha (Camacho and Kilumba, 1990a).

In Shaba, Bas-Zaïre, and Haut-Zaïre, beans account for about half of the production of grain legumes by farmers farming less than one hectare (Camacho and Kilumba, 1990a). On-farm yields are far lower than those in Kivu, however, perhaps 400 to 700 kg/ha or less (author's estimate and Camacho, personal communication, 1992).

3. Soybeans

Soybeans were planted in botanic gardens and on INEAC stations in Zaïre from very early in the twentieth century (Engelbeen, 1948). The first soybean experiment at Gandajika was planted in 1937 (Camacho and Kilumba, 1990b) available were not adapted to the tropics (Engelbeen, 1948). Because their protein content is the highest of the grain legumes (about 40 percent), soybeans were reintroduced beginning in the late 1960s and 1970s by Catholic and Protestant missionary agricultural and nutrition projects. Adaptation has been slow because of the unacceptable taste of soybeans when prepared in locally familiar ways.

Estimated production by 1988 was no more than 10,000 metric tons (Wedeman et al., 1988). But production may be increasing: Estimates were 11,200 metric tons for 1981 and 13,500 metric tons in 1982 (IRAZ, 1986). On-farm yields may range from 800 to 1,000 kg/ha (Camacho, 1992).

Soybeans are relatively free from diseases and pests in Zaïre. The chief constraints to production of soybeans introduced from the Far East and the United States were their adaptation to long temperate summer days and their incompatibility with most indigenous African **Rhizobia**. The tropical soybeans now being introduced are adapted to the short equatorial days, but poor nodulation with native soil **Rhizobium** strains remains a constraint. In addition, soybean seed loses viability rapidly in the tropics. Otherwise suitable varieties germinate poorly after storage on-farm over the four-month dry season.

4. Cowpeas

Cowpeas are the only one of the four grain legumes that is indigenous to Africa and Zaïre. Cowpeas are the most drought tolerant of grain legumes and have the highest yield potential on poor soils, such as dry, sandy soils. On-farm yields in the Kasais range from about 100 to 600 kg/ha (pers. obs, 1991; Camacho, pers. comm., 1992). On-station yields of insecticide-protected cowpeas at Gandajika, an infertile site, reached 1,500 and even 2,000 kg/ha (Shannon, unpub. data, 1985/86/87), where bean and peanut yields are commonly 500 to 900 kg/ha. However, on-farm cowpea crop losses of 60 to 100 percent are common due to a host of insect pests at every stage of development. Cowpeas are grown almost exclusively in association with other crops, often in complex species mixtures, which affords some degree of protection from insect damage. An additional constraint on poor soils where cowpeas are most valuable, is the parasitic plant **Alectra vogelii**.

In the Gandajika area of Kasai Oriental, where beans are not grown by the local farmers, cowpeas were the most important crop after maize and cassava, grown by 94 percent of a sample of 146 small farmers (Kilumba and Kubengu, 1985).

B. History and Current Status of Grain Legume Germplasm Development Research in Zaïre

1. INEAC to 1960

The Institut National pour l'Etude Agronomique du Congo Belge (INEAC) conducted research on peanuts and assembled a peanut germplasm collection at the Gandajika station and probably other stations as well. Rosette virus was recognized as a serious cause of yield losses (INEAC, 1936).

INEAC conducted bean research, chiefly on bush (determinate) beans, primarily at Mulungu (Kivu), M'Vuazi (Bas-Zaïre), and Nioka (Haut-Zaïre), from about 1945 until 1960 (Berti, 1985). Rust, anthracnose, and damping off were identified as important

causes of bean yield loss. A large number of local bean cultivars were collected, germplasm was introduced from South America and other sources, and crosses were made. Originally, re-selections were also made out of established local and introduced bean varieties, but this method was dropped during the 1940s due to insufficient genetic variation within varieties.

In the INEAC breeding program, the bulk method was originally used to advance hybrid populations, but it was considered to require excessive land area and was replaced by a "new technique [that] permitted selection of lines much earlier" (how early generation selection saved space was not described) (Berti, 1985). An experiment in making bean crosses without removal of anthers from the seed parent was "perfectly successful" in producing hybrids, and the procedure was adopted (INEAC report, 1954, cited in Berti, 1985). "Remarkable progress" in vigor, disease resistance, and yield was reported from the INEAC bean breeding program (INEAC report, Mulungu, 1952; cited in Berti, 1985); nonetheless, the lines recommended for distribution through the end of INEAC's work were local collections and introductions.

At Mulungu, where beans are commonly grown in mixtures, a mixture of the Ibundu, Beurre d'Alger, Nain de Kiyondo, and Colorado varieties was recommended to combine the advantages of high yield and plasticity. The small-seeded and black-seeded genotypes that yielded highest at Mulungu were unacceptable to the population. (If the breeding progress cited above took the form of small, black-seeded lines, perhaps this is the reason why no elite INEAC-bred bean lines were ever recommended for distribution.)

At M'Vuazi, where large, white-seeded beans are preferred, Cuarentino, was recommended as the best line suitable for distribution, although dark-seeded types had higher yields.

In the 1930s and 1940s, INEAC evaluated soybean varieties from the Far East and the United States at Yangambi, Gandajika, M'Vuazi, Nioka, Mulungu, and other stations. These varieties were not adapted to the short tropical days; those with the lightest grain color having "the most interesting culinary and dietary qualities" were least adapted. Enrichment with collections from the tropics and a crossing program to improve ecological adaptation were recommended (Engelbeen, 1948).

INEAC assembled a cowpea germplasm collection at Yangambi and Gandajika. Howver, this author has not seen the INEAC reports that might provide information on the sources of the collections or any research that was conducted.

2. INERA from 1960

The founding of the Institut National pour l'Etude et la Recherche Agronomique (INERA), the successor to INEAC, was accompanied by a "very brusk slowdown in research" (Berti, 1985), probably due to lack of trained personnel and unsettled conditions. Given the difficulty of the years shortly after independence and the short

shelf life of grain legume seed in the humid tropics, it is a credit to the staff of this institution that many lines from the original grain legume germplasm collections were preserved.

After 1971, INERA gave new priority to research on food crops (Camacho and Kilumba, 1990a). Bean research began again at Mulungu in 1976 (Mbikayi, 1988) and was largely limited to Mulungu and M'Vuazi. At M'Vuazi, there was a return to selection within varieties, notably the local white varieties Tendezi and Tuta. Seed of the best selections was multiplied for distribution. At Mulungu, new material was introduced (the Mulungu bean collection numbered 280 accessions in 1977), and, contrary to pre-independence findings, light-seeded genotypes appeared to yield best (Berti, 1985). Cuarentino, the white-seeded bean originally selected at M'Vuazi, was one of the best at Mulungu as well, along with Nain de Kiyondo.

3. INERA Support Project (1979-1984)

The USAID/Zaïre INERA Support Project (660-0064) was centered at Mulungu. Some variety trials took place at the Gandajika and M'Vuazi stations, and with collaborators in various parts of the country. [Reports or other documentation from the project were unavailable to the authors of this compendium.] The major activity "appeared to be soybean variety testing," in cooperation with the International Soybean Organization (INTSOY), bean variety testing at Mulungu, and liaison with numerous collaborating organizations to which seed and information was provided (Shannon, 1986). In addition, adaptation trials of mung beans, wing beans, sweet peas, faba beans, leucaena, lupines, and alfalfa were planted at Mulungu. Some, such as faba beans and sweet peas, were not adapted; none were given priority as research resources.

Two international programs that have become important cooperators for grain legume germplasm development in Zaïre were started in 1983. The Centro Internacional de Agricultura Tropical (CIAT) began a Regional Program for Bean Improvement in the Great Lakes Region of Central Africa, sponsored by Canada and Switzerland. Headquarters were established in Rubona, Rwanda, a few hours' drive on paved roads from the Mulungu Station in Kivu, Zaïre. The objectives of the CIAT Great Lakes Regional Bean Program include cooperation with the three national programs of Rwanda, Burundi, and Zaïre, and strengthening of these national programs through collaborative research, material support, and training.

The second cooperating international program formed in 1983 was the Institut Régional d'Agronomie et Zootechnologie (IRAZ), a program of the CEPGL countries (Communauté Economique des Pays des Grands Lacs; Rwanda, Burundi, and Zaïre), headquartered in Gitega, Burundi. Its sponsor countries have given IRAZ the mandate of assembling and maintaining a germplasm collection of their major food crops. In collaboration with the International Board for Plant Germplasm Resources (IBPGR), IRAZ collected germplasm of major crops of eastern Zaïre, including beans and other grain legumes, in 1985-86, and in 1987 collected germplasm of principal crops of

western Zaïre, including peanuts and beans. A total of 167 grain legume accessions from Zaïre are conserved in cold storage at IRAZ (IRAZ, 1988).

At the termination of the INERA Support Project in 1984, the agronomist technical advisor to the project was transferred to Kinshasa. There, he supervised variety trials in Mulungu, M'Vuazi, and Gandajika, and with collaborators in Shaba and elsewhere, in a transitional, year-long period between the end of the INERA Support Project and the founding of PNL and beginning of RAV I in 1985.

4. RAV I (1985-1990)

In 1985, the Executive Council of Zaïre and USAID/Zaïre (under Project 660-0091, RAV I) established a research and extension program for staple food crops. This program was initially established outside the cumbersome INERA structure, with the understanding that it would eventually be reintegrated with INERA. The new organization, the Service National de Recherche Agronomique Appliquée et Vulgarisation (SENARAV), consisted of the existing Programme National du Manioc (PRONAM) and Programme National du Maïs (PNM), along with a new program, the Programme National des Légumineuses (PNL). The INERA researchers who had worked on grain legumes at Mulungu under the INERA Support Project remained INERA employees but were administratively seconded to PNL direction.

PNL headquarters are in Gandajika, about 100 km from Mbuji Mayi, the capital of Kasai Oriental region. Gandajika is a mid-altitude savannah site with highly infertile soils. Additional research sites are Kaniama (a mid-altitude savannah site with fertile soils); Mulungu (a cool, high-altitude site); M'Vuazi (a low-altitude, high-rainfall site); Kiyaka (a mid-altitude, forest region site; and Lubumbashi (a mid- to high-altitude, dry, savannah site).

Agronomist Kilumba Ndayi has served as PNL national director since the inception of the program. Technical advisory staff was provided by the International Institute for Tropical Agriculture (IITA). The first technical advisor was agronomist Dennis Shannon, who supervised the first PNL germplasm improvement work. Shannon was joined after the first three RAV I seasons (in December 1986) by plant breeder Luis Camacho, who became head of the PNL Selection and Breeding Section until his departure in May 1990.

PNL has responsibility for research to increase on-farm production of grain legumes, including cropping systems in which legumes are grown as companion crops and/or primarily as contributors to soil fertility. PNL has germplasm improvement responsibility for four primary grain legumes: peanuts, beans, soybeans, and cowpeas.

RAV I **peanut germplasm development research** began at Gandajika in 1986 with INERA and ICRISAT materials. In 1987, peanut evaluation was extended to Kaniama and M'Vuazi, and by 1988 to Kiyaka and Lubumbashi (Kaniameshi).

Throughout RAV I there was a steady increase in resources and attention devoted to peanut germplasm development.

Bean improvement research during RAV I continued in a closely collaborative mode with CIAT at Mulungu. By 1987, the newly established PNL had begun bean research in earnest at Gandajika (PNL headquarters) and at M'Vuazi, and by 1988 bean trials were established in North and South Shaba (Kaniama and Kaniameshi) as well. Bean research activity was high throughout RAV I.

Soybean research began at Mulungu and Gandajika in 1986 and was in progress at M'Vuazi in 1987 and at Kaniama and Kaniameshi by 1988. Soybean germplasm development research maintained a constant level of activity throughout RAV I.

During RAV I, **cowpea research** remained concentrated at Gandajika in Kasai Oriental, the chief cowpea-growing region. Cowpea germplasm development activity increased from a modest beginning in 1986 through 1988, after which it remained constant.

In 1989, INERA began grain legume research at lower altitudes at the Yangambi station in Haut-Zaïre (PNL, 1989b). Cowpeas, unknown in the Yangambi area, were introduced at this time and were readily adapted as a substitute for beans, which have many production problems in the hot, humid climate of Yangambi (PNL, 1989b).

A 1988 recommendation (Wedeman et al., 1988) to regroup the four PNL breeding sections into two--a bean/cowpea section and a peanut/soybean section--in order to permit more efficient use of trained personnel was implemented in 1991.

5. RAV II (1991)

USAID support to SENARAV was continued under the RAV II project (USAID/Zaïre Project 660-0124), an eight-year project that was cut short due to civil unrest in late September 1991.

From January 1991 through April 1992, plant breeder Ann Marie Thro served as technical advisor to the PNL and as advisor to its Plant Breeding Section. Thro was stationed at Gandajika. Kadima Ngeleka served as head of the breeding section after his return from long-term training at Texas A&M University in 1990.

As of April 1992, the SENARAV and PNL leaders were making an effort to hold the program together--an effort that was somewhat successful. The bean program in Mulungu was less affected by the suspension of U.S. assistance because approximately 30 percent of its operating budget comes from the CIAT Great Lakes Regional Bean Improvement Program. However, peanut, soybean, and cowpea research at Mulungu, and bean research at other stations, have no such support and have been reduced to germplasm preservation operations.

C. Grain Legume Research Objectives

The long-range goals of the Programme National des Légumineuses are (1) to improve the nutritional status of the population of Zaïre by increasing production of high-protein grain legumes on small farms throughout the country, and (2) to provide rotation crops for soil improvement. These goals are to be accomplished through technology development (varieties with improved yield and quality, and improved cultural practices) and technology diffusion (extension). Prior to 1985, this research mandate fell to INERA.

The general objectives of PNL's Breeding and Selection Section for the four key legumes are high grain yield and stable (reliable) yield under small-farm conditions. These general objectives encompass more specific objectives such as disease and pest resistance and adaptation to prevalent and improved cropping systems.

1. Allocation of Priority Among Grain Legume Species

Grain legumes were chosen for research support by USAID and the Government of Zaïre (GOZ) as a practical and effective way of increasing protein availability for a mostly rural population farming largely on dry soils and confronted with more or less minimal agricultural production and marketing conditions. Within the grain legumes category, further prioritization had to be made on some basis. These decisions were made at different times by different people using different criteria. Some of the reasoning is discussed below.

a. Order of research priority: soybeans (#1, short term), peanuts and beans (both #1, long term); cowpeas (last priority, minimal).

This was the recommendation of the first technical advisor to the PNL (Shannon, 1990). It was based upon the following considerations:

- Demand for soybean seed is growing rapidly in Zaïre as the crop is advocated by NGOs and as appropriate preparation methods become better known; and IITA soybean lines proved to be well adapted to Zaïre. Lines producing yields 30, 40, and 50 percent higher than American and oriental soybean varieties introduced between 1915 and 1979 by INEAC/INERA could be selected directly from IITA introduction nurseries with no further breeding work. Thus, improved lines could be made available inexpensively within a very short period of time. An early PNL success with soybeans would bring éclat and credibility to the young program.

- In the long term, greater importance should be accorded to peanuts and beans, since these crops are dietary staples, there are many causes of yield loss in these legumes, and long-term research is necessary to increase yields.

- Last priority was accorded to cowpeas in spite of their traditionally profound importance in the savannah areas, because little can be done to increase cowpea production until insect resistance is available. IITA and cooperating institutions have been devoting immense resources to the search for insect-resistant cowpea genotypes for a decade or so, with little success presently in sight though the effort continues (Dashiell, IITA Grain Legume Program Leader, personal communication, 1992). The chance that a program as small as the PNL can succeed where a major international effort has so far failed is vanishingly small. Rather, PNL should watch developments at IITA and stand ready to test any insect-resistant lines that may become available.

b. Order of research priority : peanuts (#1), beans (#2), cowpeas (#3, or dropped if cutbacks are necessary), and soybeans (#4, or dropped if cutbacks are necessary). This was the recommendation of the authors of the Threshold Report (Wedeman et al., 1988).

> This recommendation was based on the indisputable importance of peanuts and beans throughout Zaïre and the likely futility of much research on cowpeas until there is some practical means of controlling losses to insects. The recommendation that soybeans be last priority or dropped was based on the judgment that soybean demand would remain limited, that insect damage was serious, and that nodulation and seed viability problems would be difficult to overcome.

c. Order of research priority: beans (#1), soybeans (#2), cowpeas (#3), peanuts (#4).

> This was the reality of RAV I, based on actual numbers of plots of each species from 1986 through 1990. It reflects, more than anything, the empirical reality of performing research in Zaïre and the particular contact networks of the researchers. These reasons are related, since outside personal contacts are especially critical to research in the isolation of Zaïre, where there are no practical means of independently obtaining information and germplasm.

The dynamic presence of the CIAT bean network, which infused funds, germplasm, ideas, and contacts into bean research in eastern Zaïre (and increasingly involving western and central Zaïre, i.e, the M'Vuazi and Gandajika stations, in network activities), was a major factor in the size and vitality of the PNL bean program. In addition, the RAV I technical advisory staff was affiliated with IITA and thus had contacts with its Grain Legume Program in support of PNL soybean and cowpea research. Strengthening the comparatively weak contacts with ICRISAT, the international center with the mandate for peanut research, was a goal of RAV II.

Resources devoted to peanut research were steadily increasing and would probably have continued to do so throughout RAV II, with the return from training of PNL breeders to be assigned to this crop. Resources devoted to soybean and cowpea research remained constant, and bean research actually used somewhat fewer resources after the very large comprehensive germplasm screening effort of the first years. (The bean decline is--or would have been, given continuation of RAV II support--probably only a lull, until the crosses made with the best lines from the screening program and now in early generations are advanced to the point of large-scale line evaluations.)

2. Development of Specific Research Objectives

General objectives must be focused into specific ones before research can begin. From the beginning, with its mandate very much in mind, PNL looked to the village farmers to define its specific breeding objectives. PNL in its first years used FRS/E (farming systems research/extension) techniques to identify villages close to the station (i.e., accessible with limited transportation resources) that were representative of major soil types in Kasai and of different population pressures. Within these villages, they identified soil fertility, specific insects and diseases, and short storage life of planting seed as major production constraints that could be addressed by plant breeding (Shannon, 1990). PNL also surveyed preferences for seed size, seed texture, and aspects of culinary quality in Kasai. The interdisciplinary PNL team at Mulungu was similarly alert to the local farm situation, and PNL M'vuazi, with the return from training of its plant breeder, had begun an active program of farmer involvement.

The objectives listed below are cited by PNL in its official documents. The author's estimates of high (+), medium (±), or low (-) probability of technical success (i.e., the "researchability" of the problem) are indicated, given PNL resources as they were under RAV I and II. Also noted [( )] are cases in which the author lacks the information necessary to estimate probability of success.

PNL Bean Breeding Objectives

Major resource allocation during RAV I & II:

Resistance to angular leaf spot (+) (with CIAT)
High-yielding bush beans for high-altitude regions (+)
Suitability for mixed cropping (climbing beans) (+)
Stable lines with high yield in stress environment (±)
High-yielding large-seeded cultivars (-)
High-yielding lines w/drought resistance conferred by morphological characters (-)

Some resource allocation during RAV I & II:

Resistance to common bacterial blight and web blight (±)
Resistance to ascochyta blight, BCMV, and rust (±)
All desired traits in combined w/locally accepted seed color (varies by region) (±)
Acid-soil tolerance (+)

No resource allocation during RAV I & II (no facilities):

Seed longevity (indirect selection was practiced) (-)
Resistance to post-harvest bruchid weevils (-)
Reduced cooking time (-)

PNL Soybean Breeding Objectives

Major resource allocation during RAV I & II:

Spontaneous nodulation (±)
Nonshattering pods (±)
Lodging resistance (±)
Grain yield (+)

Some resource allocation during RAV I & II:

Seed not green or black ("non-nutritional factors") (+)
Early maturity (+)

No resource allocation during RAV I & II (no facilities):

Seed longevity (indirect selection was practiced) (-)

PNL Peanut Breeding Objectives

Major resource allocation during RAV I & II:

Resistance to **cercospora** (±)
High-yielding, large-seeded cultivars (±)
Tolerance to low soil calcium levels ( )
Grain yield (+)

Some resource allocation during RAV I & II:

Resistance to rosette ( )
Shelling percentage (+)

No resource allocation during RAV I & II:

Adaptation to mixed cropping (-)

PNL Cowpea Breeding Objectives

Major resource allocation during RAV I & II:

Adaptation to mixed cropping (±)
Acceptable yields with reduced insecticide application:
    in mixed cropping (±)
    in pure stand (-)
Aphid resistance (-)
Early maturity (+)
Grain yield (±)

Some resource allocation during RAV I & II:

All desired traits in combination with desired seed color (red) (±)
Alectra (parasitic plant) resistance (±)

No resource allocation during RAV I & II (no facilities):

Resistance to post-harvest bruchid storage weevils (-)

Some otherwise commendable objectives not adopted by the PNL for various reasons include selection for shorter cooking time of beans and cowpeas (because of the high demand for time and fuel to run the tests), and selection of varieties specifically adapted to the environmental conditions of the long growing season (Season A) or to the very different conditions of the short growing season (Season B) (impractical at this time because of very rapid loss of germination of grain legume seed in on-farm storage).

A review of germplasm development research must provide some background on diseases for which resistance breeding is a critical objective. PNL's assessment of the most serious production-limiting diseases in the various environments of Zaïre is shown in Table 3.23. The screening sites for high, mid-, and low-altitude germplasm screening are, respectively, Mulungu, Gandajika and Kaniama, and M'Vuazi.

Table 3.23. Diseases Affecting Four Key Legumes

Crop	Disease	Causal Organism
	High Altitude	
Beans	Angular leaf spot (ALS)[1]	Phaseoisariopsis griseola
	Ascochyta blight (S)	Ascochyta phaseolus
	Anthracnose (A)	Colletotrichum lindemuthianum
	Rust (R)	Uromyces apendiculatus
	Halo blight (H)	Pseudomonas phaseolicola
Soybeans	Pyrenochaeta leaf spot[2]	P. glycines
	Mid-Altitude	
Beans	Common bacterial blight (CBB)	Xanthomonas campestris
	Angular leaf spot (ALS)	P. griseola
	Bean common mosaic virus, black root (V)	BCMV
	Web blight (WB)[2]	Thanatephorus cucumeris
Cowpeas	Scab	Sphaceloma sp.
Peanuts	Cercospora leaf spots[3]	
	early	Cercospora arachidicola
	late	Cercosporidium personatum
	Groundnut rosette virus[4]	Virus
	Low Altitude	
Beans	Web blight (WB)[2]	T. cucumeris
	Common bacterial blight (CBB)	X. campestris
Peanuts	Cercospora leaf spots	
	early	Cercospora arachidicola
	late	Cercosporidium personatum
	Groundnut rosette virus	Virus

[1]Can cause yield losses of 20 to 60 percent.
[2]No good source of resistance known; cultural control of Pyrenochaeta was effective (Pyndji, cited in Shannon, 1990).
[3]Can cause yield losses to 25 percent.
[4]Can cause yield losses as high as 100 percent.

3. Climate and Germplasm Development Strategy

Throughout most of Zaïre, there are two growing seasons in an agricultura year. The long growing season (referred to as Season A, or in high altitudes as "the bean season) begins in September with the first rains after the long May-September dry season and ends with the short (sometimes absent) dry season in December-January. The short growing season (Season B) begins in January-February and ends in May or June. Rains in this season are less reliable than those in the long season. The true dry season generally lasts from May or June to September, when the cropping cycle begins again.

The long cropping season is referred to as Season A because it begins the natural agricultural year; it also provides the first harvest in the calendar year, in January (though Season A crops have actually grown most of the season in the previous calendar year). Season B is the second season in the natural agricultural year as well as the second harvest in the calendar year.

In South Shaba, the dry season is prolonged and there is only one growing season, Season A. At low altitudes, such as in Bas-Zaïre, there is a second short season, Season C, from May to September.

Plant breeding theory and research suggest that higher production would be obtained if different varieties were recommended for each season, because the genotype (variety) best adapted to the conditions of Season A will not be the same genotype that is best adapted to the very different conditions of Season B (or C). Furthermore, the genotype with the highest average yield over both seasons may not be the highest yielder in either one. Thus, some production is lost through the compromise. However, other factors--rapid loss of seed germination ability when stored under ambient conditions in the tropics, the absence of better on-farm storage facilities, difficulty of transporting seed, and lack of a national seed industry that could deliver high-quality seed to farmers at planting time--all constrain PNL to recommending genotypes that will produce the highest yield over both seasons.

The custom of not saving grain legume seed, and instead consuming seed and repurchasing seed in the market at planting time, disrupts the chain of variety introduction via distribution of seed samples to farmers. Seed must be provided by the research organization or seed service for several years until, if successful, the new variety dominates the market and thus is what farmers obtain when they buy from the market. This custom also makes it impractical to recommend different varieties to optimize production in different conditions or seasons, since farmers take what they get and will not be able to specify a particular variety to the market seller, who is likely to buy and sell according to seed size and color and culinary quality rather than on-farm performance. The objective must be, rather, to try to provide a succession and diversity of varieties in the desired market types so that with time, the offering in a typical market will represent a mixture whose components will among them be able to exploit most farm environments successfully. Since grain legumes are self-

pollinating, the different varieties will not interbreed in production fields (unlike maize), so the special characteristics that each variety contributes will be stable and not lost over time.

D. Grain Legume Research Methods

In this discussion of grain legume research methods, a distinction will at times be made between selection methods and breeding methods. Each of these is a component of germplasm development research. **Selection** will refer to all methods used to identify the best line or population from a group of lines or populations that differ genetically from one another. **Breeding** will refer to the methods used to create the genetically different lines or populations in the first place: genetic recombination achieved through crosses or even, more recently, in-vitro methods, as well as the subsequent management of the recombinant material to isolate the most desirable new combinations. Thus, selection is a part of most breeding programs, but breeding need not be a part of a selection program if diverse material can be obtained in some other way, e.g., by cooperation with an international center or other organization that conducts a breeding program, or by collection of cultivars from throughout a region or the world.

Cross or **mating** will refer to a particular parent combination; numerous pollinations may repeat the same cross. **Hybrid** will refer to materials derived from planned crosses between parents of contrasting genotypes. The term **variety** is used in grain legume research in Zaïre in the sense of **cultivar**.

1. INERA Support Project

Research during this period concentrated on beans and soybeans and was conducted mostly at Mulungu with some work at Gandajika. Soybean germplasm was obtained from INTSOY and possibly other sources. Bean germplasm was obtained from the United States, CIAT, and the INERA collection of local lines. Some crosses were made in soybeans at Gandajika, but between unadapted parents. At Mulungu, pure line selections were made within existing soybean varieties such as Sable and Jupiter. This activity was terminated during RAV I.

There is a record of one series of INERA **peanut trials** at Yangambi in 1981 Seasons A and B. At Gandajika, the peanut germplasm collection was maintained and some lines were identified as rosette resistant, although these observations could not be confirmed during RAV I.

Two **bean trials** were conducted at Gandajika and one at M'Vuazi, but efforts were concentrated at Mulungu. In close collaboration with CIAT, the INERA program at Mulungu made progress in identifying high-yielding bean lines, mostly of South American origin, and developed an active cooperative program in bean breeding and pathology.

Soybeans from several international sources (INTSOY, IITA) were tested in Mulungu, at Lubumbashi, Gandajika, M'Vuazi, Yangambi, and numerous cooperating sites.

One series of **cowpea trials** was conducted at Yangambi in 1981 Seasons A and B with IITA and INERA lines.

2. RAV I

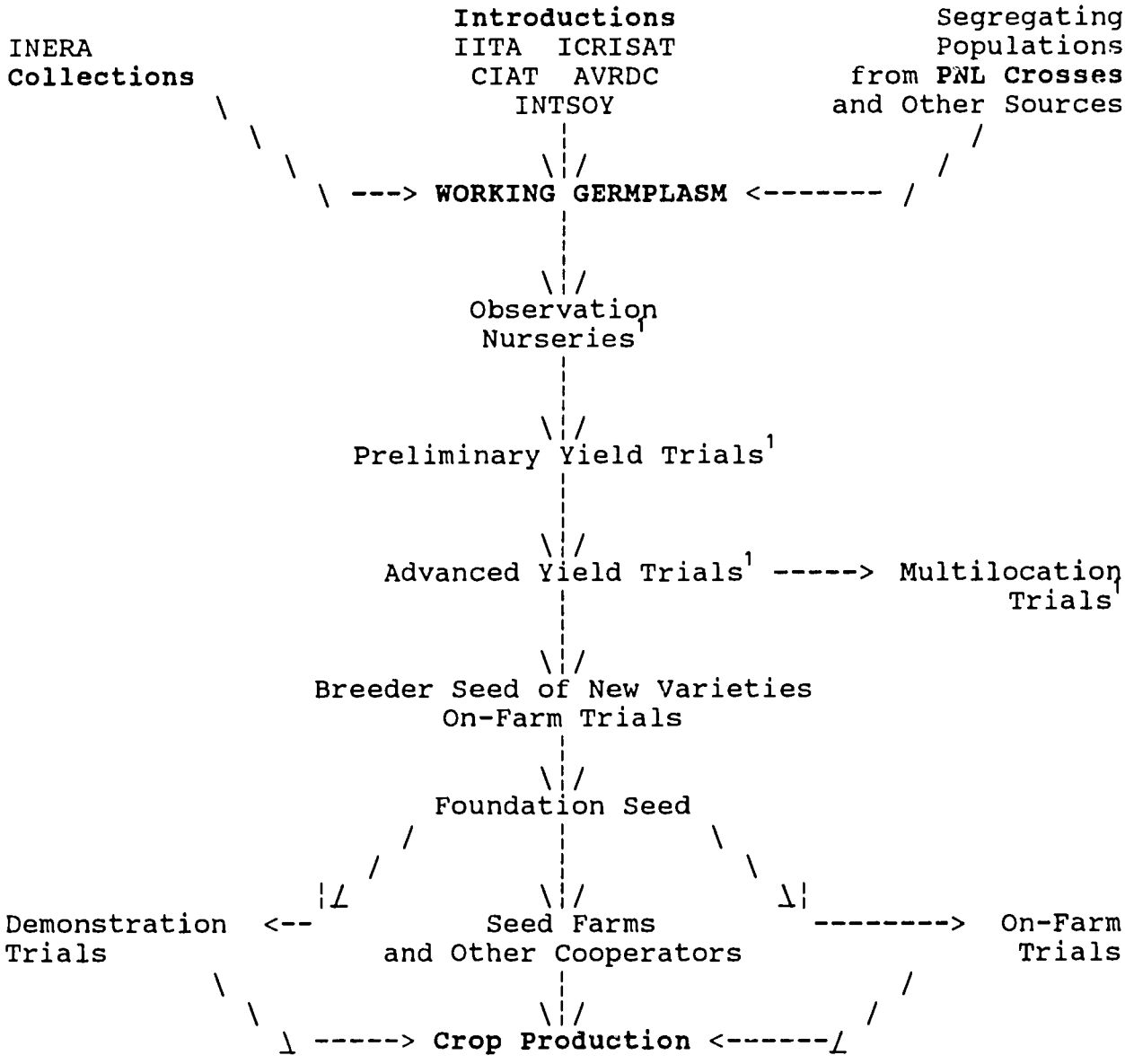
Grain Legume Germplasm Materials. The chief grain legume germplasm sources during RAV I were international nurseries and hybrid populations from the international agricultural research centers (IARCs) with mandates for research on each of the major PNL crops: beans (CIAT), peanuts (ICRISAT), and soybeans and cowpeas (IITA). In addition, soybean germplasm was obtained from the Asian Vegetable Research and Development Center (AVRDC) and INTSOY. INERA collections were a source of local varieties and introductions, some dating back to INEAC days.

Grain Legume Selection Methods. PNL developed a general testing scheme (Figure 3.2) for use with all materials: introductions, local varieties, and hybrid materials from its own crossing program and obtained from cooperating programs. The PNL scheme was based to some extent on the CIAT plan introduced for bean germplasm development research at Mulungu during the INERA Support Project.

Field plots were extremely heterogeneous, due not only to considerable soil variation but also to the difficulty of preparing a uniform surface with the hand tools most often used at the stations. To circumvent this problem without introducing the complexities of analyzing lattice designs, large groups of entries for yield testing were split into separate experiments of 12 to no more than 25 entries, with common checks. The best lines from each experiment were evaluated in the same experiment in the next testing stage. One or two checks were included in each trial. These checks were generally a variety that was commonly grown in the locality, whether a land variety of unknown origin or a widely distributed INEAC or INERA introduction.

Preliminary and advanced yield trials were each conducted for two seasons for each group of new candidate lines, a system that provided two sets of data for each of the two seasons. All entries equal or better than the check in advanced on-station yield trials were eligible for inclusion in on-farm trials. Occasionally, this was half the entries in the trial. The philosophy of presenting 10 or 12 lines in an on-farm trial was twofold. First, it was considered instructive to the program for farmers to have as wide a choice as was manageable, as it gave PNL more information about farmer preferences. Second, it was recognized that farmers often grow grain legumes in mixtures; thus any farmer might eventually use several improved varieties with complementary characteristics. PNL bean units at Mulungu and M'Vuazi were experimenting with bringing farmers on-station to look at segregating populations of diverse plant types and discuss the farmers' opinions of the advantages and disadvantages

Figure 3.2. PNL Variety Development and Seed Distribution Strategy



[1] Conducted for two seasons

of different traits, i.e., to cooperatively develop a "farmer's ideotype" as an input to the development of breeding objectives.

Truly comparable experiments across seasons and, particularly, across locations were rarely conducted. The desirability of such trials was discussed at PNL's Internal Review in 1991; more will probably be conducted in the future. Because it had no data that could be correctly used for combined analysis, during RAV I, PNL based its recommendation decisions on average yields of an entry compared to average yields of the check(s) over the same set of experiments.

Depending on circumstances, the sequence in the "variety development" scheme was rarely followed exactly. The observation nursery stage was also a seed increase stage; it might be by-passed if sufficient seed was available for lines that were known to be likely to be adapted to the local environment. Such lines were sometimes placed directly in preliminary yield trials. If sufficient information was available from other PNL sites about a given group of lines, these might also be put directly into preliminary or even advanced yield trials.

Analyses of variance were calculated for randomized complete block design (RCBD) trials, often using hand calculators. Partly because of lack of training of the staff who remained on station while a number of PNL breeders were away for long-term training, and partly because of the length of the calculations, interactions and orthogonal comparisons were often omitted, with loss of information. The MSTAT series of statistical programs was used for computer data analysis. Data analysis by computer often included Duncan's means separation test and stability analysis, though interactions and comparisons were still often not calculated.

PNL Bean Research

Bean selection was conducted at Mulungu, Gandajika, Kaniama, M'Vuazi, and Kaniameshi, in order of resources allocated to bean germplasm development research.

Bean source germplasm for PNL research was obtained chiefly from CIAT in collaboration with the CIAT Regional Great Lakes Program. Some CIAT material was obtained as stable pure lines; other material was received as segregating populations from hybridizations made by CIAT. Additional germplasm was obtained from the INERA collection of local lines and the best introductions from earlier research. PNL recombined these germplasm sources in its own crossing programs at Mulungu and Gandajika.

Bean research plots were evaluated for grain yield, maturity, growth habit, seed quality, and symptoms of the prevalent bean diseases. In association trials, data were also collected on yields of the associated crops. A beginning had been made at Mulungu to obtain economic data to accompany yield data of association trials, in order to permit identification of economically superior systems.

Sophisticated bean pathology research was carried out at the Mulungu station, where the MS-level PNL pathologist and the Ph. D. pathologist of the CIAT Great Lakes Regional Bean Program maintained excellent collaboration. Most of the work concentrated on angular leaf spot and included disease loss estimates, pathogen variability studies, and use of field observation and controlled inoculation to identify resistant lines for use in the breeding program. The PNL bean breeder then crossed the best resistant lines to locally preferred susceptible lines in a back-cross program with the dual purpose of providing variable material for selection of superior segregates and of providing material for genetic studies of host plant resistance.

Selection for resistance to common bacterial blight and web blight in the germplasm was of necessity conducted at stations where there was no trained pathologist. Selection was based on observations in selection plots, rather than inoculation trials, and resistance was inevitably confounded with possible escapes, particularly because susceptible checks, spreader rows, and other field techniques were not always used.

In 1990-91, a collection 75 of the best varieties in the CEPGL region (PRELAAC-3, Pepinière Régional d'Evaluation des Lignées Avancées en Afrique Centrale No. 3) was screened for acid soil tolerance in collaboration with the INERA/PNL soil scientist at Mulungu. The 25 most acid-tolerant lines were retested a second season.

PNL Soybean Research

Soybean germplasm was evaluated at Gandajika, followed by Kaniameshi, M'Vuazi, Mulungu, and Kiyaka, in order of extent of activity.

In 1986, PNL began intensive variety testing using the INERA collection and also international trials from INTSOY, IITA, and AVRDC. RAV I also tested large numbers of advanced progeny of IITA crosses.

Data were recorded on grain yield, spontaneous nodulation evaluated at 70-75 days after planting, height above 50-54 cm without fertilizer, shattering score, lodging score, and days to maturity. In some seasons, IITA nurseries were scored for symptoms of bacterial pustule (causal organism **Xanthomonas campestris**), soybean mosaic virus, and cercospora leaf spot. Data on IITA nurseries were returned to IITA headquarters, at least in some years (e.g., the 1988 trials), for combined analysis with data from other countries to identify the best widely adapted IITA lines.

Spontaneous or promiscuous nodulation (with indigenous rhizobia, without **Rhizobium japonicum** inoc.) could not be scored or selected at Mulungu, where inoculum had been used (perhaps during the INERA Support Project) and all fields were contaminated with **R. japonicum**

PNL Peanut Research

PNL conducted peanut evaluation chiefly in the mid-altitude savannah region, at Gandajika and Kaniama, with additional lower-altitude work at M'Vuazi and Kiyaka. Tests were also conducted at Kaniameshi in 1989 and 1990.

Initially, germplasm for PNL's peanut research was obtained from INERA and ICRISAT. Work started in the 1985-86 season with evaluation of an early-maturity trial from ICRISAT (ICGS(E) lines). Foliar disease-resistant lines (ICGS (FDRS) lines) were obtained from ICRISAT and evaluated during the 1986-87 and subsequent seasons.

Data were taken on pod and grain yield, shelling percentage, percent empty mature pods, percent sound mature kernels, number of plants in a line attacked by rosette, and cercospora symptom scores. Empty mature pods were considered an indication of calcium deficiency; a low score was considered to be an indication of tolerance to low soil calcium, or possibly calcium use efficiency.

In Gandajika in 1986, INERA selections were rescreened for rosette resistance. However, the incidence of rosette in the trial was too low for selection. In RAV I and II, additional INERA peanut lines were screened for disease resistance on-farm.

PNL Cowpea Research

Within Zaïre, cowpeas are most important in the Kasai regions, where PNL began its cowpea research with a survey of 146 small farmers (Kilumba and Kubengu, 1986). For logistical reasons, the survey was confined to the areas surrounding the Gandajika station. Questions were asked about the relative importance of the cowpea crop, agronomic practices including seeding dates and rates and rotations, and problems perceived by the farmers, with the solutions proposed by the farmers. The researchers then listed possible agronomic or genetic research solutions for each problem. The principal constraint to cowpea production was insect damage in the field and in storage. Genetic solutions suggested by PNL staff included selection of indeterminate varieties to reduce weed competition and permit escape from insect damage; selection of late varieties for Season A and early varieties for Season B; selection of **Alectra**-resistant varieties. PNL staff did not, however, use any method for selecting which of the possible genetic solutions to pursue.

Because of their importance in the Kasais, cowpeas were evaluated chiefly at Gandajika, with some work at M'Vuazi and Kaniama. Because cowpeas are not adapted to high altitudes, they were not tested at high-altitude sites. Cowpea trials were conducted with lines from IITA and the INERA collection and divided into early and medium maturity groups. Data were collected on grain yield and days to maturity in all trials. In specific experiments, data were collected on disease reaction, aphid damage, bruchid storage weevil damage, and **Alectra** infestation.

The principal insect pests of cowpea in Zaïre are, in the field, aphids (**Aphis craccivora**), flower thrips (**Megalurothrips sjostedtis**), pod bugs (**Riptortus dentipes**) and pod borers (**Maruca testulalis**), and weevils (**Callosobruchus maculatus**) in storage. In PNL trials, cowpea lines were selected that showed intermediate insect damage, i.e., that might possess moderate resistance. Complete resistance to these insects has not yet been identified in **V. unguiculata** by any research program, and damage-free entries are generally escapes.

Because cowpeas cannot be evaluated for any other character in the presence of the many insect pests to which they are susceptible, early maturity lines were tested with one spray of deltamethrin to control flower thrips and **Maruca** and two sprays of endosulfan to control pod-sucking bugs and **Maruca**. Medium-maturity varieties received two sprays each of deltamethrin and endosulfan (Shannon, 1990). On-farm trials received similar insecticide treatments. Field selection for resistance to insects proved impractical because insects rapidly moved from unsprayed plots back into sprayed plots within a few days after spraying.

An **Alectra**-infested field in the village of Kaniaka, near Gandajika, was used to evaluate resistance (measured as absence of infection) and tolerance (measured as satisfactory yield in the presence of infection) of cowpea lines to this parasitic plant.

In the 1989 cropping year, the PNL began testing promising lines in association with maize (PNL, 1989a). To favor natural selection for genotypes adapted to mixed cropping with reduced insecticide application, segregating populations from (introduced x local) PNL cowpea crosses were advanced in association with maize and with only one insecticide application. (Three applications are necessary to obtain a cowpea crop in pure culture.)

Other PNL Legume Research

An observation nursery of pigeon peas, obtained from ICRISAT in 1986, was protected with endosulfan spray as necessary in order to obtain seed.

Breeding Methods in PNL Grain Legume Research. During RAV I, PNL made numerous crosses in all four major grain legumes. Records at times conflict in detail, but there were certainly as many as 350 different crosses or matings, and thousands of separate pollinations.

Crosses were made in screenhouses in Mulungu and Gandajika. F1 plants were grown for F2 seed, most often in the screenhouse but sometimes in the field, where risk of plant loss is greater but F2 seed yield is greater.

The back-cross method was used in PNL projects designed to transfer disease resistance from introduced bean donor parents to locally adapted recurrent bean parents and seed longevity from introduced cowpea donor parents to locally preferred cowpea recurrent parents.

Many PNL crosses in all four grain legumes, however, were "good x good" single crosses designed to create new variation for quantitative characters such as yield or to combine multiple characters from different parents (e.g., yield, multiple disease resistance, seed color and size).

Depending on the material, hybrid populations (whether from IARCs or created by PNL) were handled using the pedigree, bulk, or single-seed (or single-pod) descent methods. The procedure for one population often varied from generation to generation, as the breeder's resources and purposes required.

A procedure commonly used at Mulungu to handle F2 bean populations received from CIAT was as follows: negative selection (discard of only the most clearly unadapted plants) was practiced in the F2; the population was advanced in bulk to F3 and negative selection practiced again; and F3 plants were then harvested individually. If F3:4 lines were sufficiently uniform the next season, they were put into preliminary yield trials. Heterogeneous lines were selected again in the F4. A similar procedure was often followed with hybrid populations of the other grain legumes; the first single plant harvest was often delayed until F4.

During the RAV I to RAV II transition period at Gandajika, checks were sometimes omitted from plantings of early generation material (such as F2 populations), with the reasoning that it was too early to be making selections among highly heterozygous plants whose progeny would still segregate widely. Yet decisions and selections were nonetheless made.

Grain Legume Seed Multiplication and Variety Diffusion Methods. The Plan National Semencier (National Seed Plan) of Zaïre, created in 1984 (Anota, 1992), consists of five elements: (1) the research organizations INERA and SENARAV; (2) the centres semenciers, or seed production centers; (3) the commercial distribution and sales sector; (4) seed users (the market, mostly small farmers); and (5) the Service National des Semences (SENASEM) (originally called the Bureau National des Semences, BUNASEM), the agency responsible for regulation and execution of the Plan National Semencier.

The role of the research organizations, including PNL, in the Plan National Semencier, is to create or identify superior crop varieties and to produce breeder and foundation seed (semences de souche, pré-base et base). The separate crop sections (beans, peanuts, cowpeas, soybeans) of the PNL Breeding and Selection Section produced and maintained breeder seed of each of their recommended varieties, while production of foundation seed was the responsibility of a single Seed Unit, also in the Breeding and Selection Section.

Foundation seeds of all crops were produced at Gandajika. Beans are also multiplied at Mulungu on the station. (See Elukessu (1992) for a description of PNL's guidelines for its seed multiplication activities.)

In 1989, eight seed production centers operated in Zaïre. Six of these (four supported by IDA and the UNDP and two privately operated) were equipped for tasks from sowing to seed processing. The other two, supported by AGCD and FED, were still in the process of being equipped. SENASEM's long-term plan is for all the centers to be privately managed and self-financed, with seed prices set to cover production costs. Encouragement of seed crop production as part of the economic mix of activities on small and medium-size farms is also part of the long-term plan.

Presently, SENARAV oversees the seed production centers. In its quality control activities, SENARAV has a central seed analysis laboratory and laboratories at several of the production centers. It also conducts two types of replicated field tests, the DHS (distribution, homogénéité, stabilité) and the VAT (valeur agronomique et technologique) to describe and standardize varieties and verify their production value.

Ultimately, the desired role for SENASEM itself is chiefly legislation, inspection, and certification. In this area, some of SENASEM's current goals are to increase farmer awareness of the value of commercially produced seed (as high-quality seed); and encourage the profession of marchand grainier, or seed sellers, at the local market level whom farmers will recognize as sources of reliable seed.

A goal of the Plan National Semencier is to develop the commercial distribution and sales sectors so that marketing channels will become self-financing and permanent. At present, seed production centers distribute their seed through other government programs and missions, which purchase the seed for their agricultural projects and must subsidize sales to small farmers. The poverty of the majority of farmers makes it impossible to fix a price that considers both the cost of production and the ability of farmers to pay.

Because the Plan National Semencier is presently indeed a plan and not yet a reality, PNL uses an informal distribution network composed chiefly of various development groups active in each region. Some of these collaborators, such as the Peace Corps in Kasai Oriental, require PNL to furnish seed in quantities sufficient for on-farm trials. Others, such as the GTZ Kabare Project in Kivu, further multiply the seed themselves to support their own outreach activities.

Seed of grain legume varieties recommended by PNL has also been distributed through on-farm trials, both the PNL Breeding Section's on-farm selection trials and the PNL farming system's research section, and through organizations that cooperate with PNL in extension work.

Grain Legume Germplasm Preservation. Germplasm preservation of grain legumes in Zaïre is a labor-intensive activity due to the lack of storage conditions. Seed multiplication is preferably done in Season A because yields are higher and rainfall in the Season B is less reliable, but the short dry season between the two seasons is variable in timing and duration; thus seed are often spoiled by maturing during late rains or from rain and high atmospheric moisture during post-harvest seed

drying. The seed is, stored under ambient conditions, under which it does not retain viability for half a year; thus, an accession of species such as beans and soybeans must be grown out every season (that is, twice a year) just to be retained in a collection. Cowpeas and peanuts generally have longer seed viability and can be grown out once every other season (that is, once a year).

During germplasm rejuvenation grow-outs, extensive descriptor data, including seed quantities harvested and on hand, were recorded in individual notebooks.

PNL Documentation Methods. Documentation of grain legume germplasm development research consisted chiefly of the annual reports. These documents were important because, as just noted, field notebooks consisted of very flimsy paper that did not last long, even in the files. Thus, primary data were highly perishable. Annual reports were prepared by each researcher and edited by the technical advisor and director.

3. RAV II

The RAV I-RAV II transition period lasted from May 1990--when the RAV I technical advisor to PNL departed--to February 1991--when the RAV II TA arrived, in the midst of the planting season for the single RAV II cropping season (1991 B). During the transition, grain legume germplasm development activities continued according to the two-year 1990-92 work plan prepared by PNL in collaboration with the departing RAV I technical advisors, a plan finalized during SENARAV annual review meetings in August 1990.

The PNL bean unit work plan for 1991-92 was prepared largely in collaboration with the CIAT Great Lakes Regional Bean Program. On his departure from RAV I, Camacho, the RAV I technical advisor to PNL, was appointed as the breeder for the CIAT Great Lakes Program. His presence continues to add stability to PNL bean research.

E. Results of Grain Legume Research

1. INERA Support Project

The highest-yielding bean varieties on station at high altitudes were Nain de Kyondo, D6, BAT 41, ICA COL 10103, BAT 873, and A 21 bush beans; and Nyayosi 35, Linea 22, and Linea 24 climbing beans. At low altitudes, the highest-yielding varieties on-station were BAT 873, BAT 41, ICA COL 10103, Melocal E1, Rushala, and Ntendesi. In farmers' fields at high altitude, Rubona 5 yielded most in some trials but least in trials on forest soil farms. Introductions from the United States, such as Pinto and Great Northern, were not adapted because of their susceptibility to rust and anthracnose (Shannon, 1986).

INERA staff at Gandajika maintained the INERA **peanut** collection and conducted some selection for resistance to rosette virus. (The search for rosette resistance had been one of the objectives of the INEAC collection.) The INERA results, however, were inconsistent with observations made during RAV I (Shannon, 1986). In one series of trials at Yangambi in 1981, G 17 was best of one group in Season A but the poorest in Season B, and G 17, A 65, and P 43 were all susceptible to rosette. Peanut lines HC 928-52, HC 918-140, and HC 928-144 (source) were considered suitable to replace A 56 due to large seed and high shelling percentages (Shannon, 1986).

Perhaps because of the shortness of the second growing season in many parts of Zaïre, **soybean** varieties selected during the INERA Support Project tended to be early and short (Shannon, 1986). These results were in conflict with results of INEAC research in the 1940s showing that late varieties were the most promising. Recommended varieties were UFV-1 from Brazil, Jupiter, and IAC-6 for low elevations; Tokyo Vert (an INEAC introduction), Bossier, Davis, Columbus, Haut Mulito, Sable, Imperial, and UFV-1 for high elevations; and UFV-1 for mid elevations (IRAZ, 1986).

INERA evidently conducted little **cowpea** research during this period, but the INERA cowpea germplasm collections were maintained. There is a record of one series of trials at Yangambi in 1981 that evaluated IITA and INERA material.

2. RAV I

a. Grain Legume Germplasm Improvement Research

During RAV I, the PNL Plant Breeding and Selection Section planted and harvested between 20,000 and 25,000 yield plots in 526 trials. These figures include 5,612 bean plots in 221 bean trials; 1,740 soybean plots in 127 soybean trials; 1,602 peanut plots in 96 peanut trials; and 1,038 cowpea plots in 76 cowpea trials. About 1,000 plots were grown in 13 on-farm trials. About 1,900 different bean lines, 580 soybean lines, 550 peanut lines, and 350 cowpea lines were evaluated. Four bean varieties, one peanut variety, two cowpea varieties, and two soybean varieties were recommended as a result of these activities, yielding selection intensities of 0.2 percent for both beans and peanuts, 0.3 percent for soybeans, and 0.5 percent for cowpeas.

During the same interval, PNL made 121 bean crosses, 103 cowpea crosses, 79 soybean crosses, and an unknown number of peanut crosses. The first candidates for advanced yield testing from these crosses were to become available at the end of Season 1992 B.

Four new **bean** cultivars were recommended for release: two climbing bean lines for high altitudes, and one bush bean and one semi-climbing bean for mid-altitudes (see Appendix B, Tables B.1 and B.5). All four are selections from among introduced

CIAT lines. Additional cultivars are in the final pre-release testing stages (see Appendix B, Tables B.1 and B.5).

Numerous bean lines had been identified as resistant to diseases, notably from the angular leaf spot work at Mulungu. Mixtures of local bean lines with a resistant introduced line were found to effectively reduce loss from this disease; proportions of 25, 50, and 75 percent resistant line were equally effective. However, good sources of resistance to common bacterial blight and web blight of beans were not found (see Appendix B, Tables B.1 and B.10).

Climbing beans were shown to have twice the yield potential of bush beans at Mulungu (average yields of 2,000 to 4,000 kg/ha for climbing beans vs. more commonly 1,000 to 2,000 kg/ha for bush beans, on station), but only on fertile soils with provision for climbing support (Camacho and Kilumba, 1990). PNL researchers suspect that this may be due to the larger photosynthetic factory developed by climbing beans and the possibility that upper leaves in dryer environment may escape some diseases, especially web blight. The finding opens up new research needs for climbing beans, including better tolerance to soil stresses such as acidity, and a yield challenge for bush beans. However, the lower stems of climbing beans, especially the recommended variety Aliya, were found to be attractive to rats, who killed entire plants by biting through the stems, particularly at early pod fill, but did not touch the leaves or pods.

The most acid-tolerant bean lines in a trial of 75 high-altitude-adapted lines were Nangurubwa, III 714 (ACC), Imbirambira, DOR 351, and AFR 340.

By 1990, 44 bean lines selected at Mulungu from CIAT hybrid populations had reached the advanced yield test stage. Yields of the selected lines ranged from 926 to 2,104 kg/ha (Mbikayi et al., 1990).

Many of the bean crosses evaluated by PNL were made at CIAT for the Great Lakes Cooperative Bean Program; some were made specifically for PNL, although these are not identified in the records. PNL also began its own hybridization program during RAV I, when most bean crosses were made at Mulungu, chiefly for the purpose of transferring disease resistance into locally preferred lines. (See Appendix B, Table B.6, for a list of crosses made or evaluated by PNL; any crosses from which no selections were made were not listed in the source PNL reports and are therefore not in the table.)

Two new soybean selections were recommended as varieties for mid-altitudes. The new lines, selected from IITA germplasm, are resistant to pod shattering, nodulate freely with native soil rhizobia in Zaïre, and have good yield potential and yield stability (see Tables B.2, B.5, and B.10). However, they are medium maturity, and their seed has a very short storage life on-farm in Zaïre (a general problem with soybeans). PNL researchers continue to search for suitable early-maturity lines that will perform better in the short growing season (Season B) and for sources of seed longevity.

Table 3.24. Bean Breeding Timeline

CIAT segregating populations observed at Mulungu:	
1986 Season A	126 F3 to F6 bean lines observed; selections made.
1986 Season B	61 F4 to F7 bean lines observed.
1987 Season A	66 F2 bean lines (or populations?) observed, including 24 (or 42?) CIAT F2 bush bean populations and 14 CIAT F2 climbing populations.
1987 Season B	66 F3 bean lines observed.
1988 Seasons A & B	No activity.
1989 Season A	91 F2 and F3 bean populations observed; 21 of these destroyed by disease pressure.
1989 Season B	70 F3 and F4 bean populations observed.
1990 Seasons A & B	Selection of advanced bean lines from CIAT hybrid populations (?)
PNL bean hybrids (approximately 121 crosses):	
Gandajika 1989 Season A	12 F1 hybrids --> F2 seed produced. Obj.:incorporate disease resistance into otherwise desirable bean varieties.
Gandajika 1989 Season B	12 F2 bean populations grown; 83 new F1 bean hybrids produced.
Gandajika 1990 Season A	12 F3 and 83 F2 bean populations grown; 40 F4 lines observed (? Mbikayi et al., 1990); 8 new F1 bean hybrids produced.
Gandajika 1990 Season B	12 F4, 83 F3, and 8 F2 bean populations grown; 9 F4 lines evaluated, Kaniama (Mbikayi et al., 1990).
Gandajika 1991 Season A	No records.
Gandajika 1991 Season B	Early-generation bean hybrids showed exceptional drought tolerance.

Table 3.24, continued

Mulungu 1990	15 F2 bean populations from R x S crosses between resistant CIAT lines and susceptible local lines.
Mulungu 1991	Planned: back-cross of each of the above bean populations to the recurrent (local) parent, to BC 4 before selfing and seed increase.
M'Vuazi 1991 Seasons B & C	Back-cross program using adapted/preferred local variety Ntendezi (large, white seed) as recurrent parent and 3 CIAT bean lines with better seed longevity as donors; F1 seed of ? crosses.
Bean crosses evaluated by PNL (origin unrecorded):	
Mulungu 1989	1,055 single plant bean progenies (source?) observed; 439 lines (42%) selected.
Mulungu 1990 Season A	477 F2, F5, and F6 bean lines observed; 55 bush/ semi-climbing F5 lines and 66 climbing F5 lines observed; 22 bush lines and 9 climbing lines selected as resistant to ALS and other diseases (Pyndji, 1991) (these materials probably from CIAT).

Note: Question marks in table indicate that the information provided in data sources was either unclear or incomplete.

At Mulungu, soybean selection progressed more slowly than at the mid- and low-altitude stations. Most lines tested were susceptible to **Pyrenochaeta glycine** leaf spot. Crop rotation and good sanitary practices were adequate to control the disease (Shannon, 1986; PNL Annual Reports, 1981-1985, cited in Shannon, 1986). As with beans, soybean lines that performed well at high altitude were a different set from those that did well at mid- and low altitudes (see Tables B.2 and B.4). At mid- and low altitudes, the adapted lines were generally IITA lines; at Mulungu, where IITA lines were not adapted, adapted lines were of mixed origin, probably obtained via the INTSOY program in the INERA Support era (INTSOY ceased its germplasm activities shortly after RAV I began). Seed of 24 of these lines was increased at Mulungu in 1989 to provide enough for testing. UFV-1, an introduction from Brazil, did well throughout Zaïre.

By the last year of RAV I, the newly recommended varieties Afya and Munanga (IITA lines select by PNL) were being used as check entries in soybean trials.

Table 3.25. Soybean Breeding Timeline

Segregating soybean populations from IITA:	
Gandajika 1987 Season A	Selected 24 of 119 F4 lines, harvested F5 seed; 354 F8 soybean lines (all IITA); selected 10% (± 35 lines) for preliminary yield trial next year (record of trial?); selected "several individual plants" (from the F8 lines?) to develop new lines.
Gandajika 1987 Season B	24 F5 soybean lines were advanced to F6 (F6 seed harvested).
Gandajika 1988 Season B	24 F6 soybean lines advanced to F7; ± 35 early, medium, late selections among F8 lines previous year were advanced a generation.
Kaniameshi 1988 Season A	27 soybean lines observed.
Gandajika 1988 Season B	24 F7 lines advanced to F8 (F8 seed harvested); early, medium, late selections made in F8 lines previous year advanced to F10 (± 35 lines); 388 selections from 40 unselected F3 populations from IITA/Brazil were advanced a generation.
Gandajika 1989 Season A	24 lines advanced a generation, from F8 to F9; seed increase of 198 early, 14 medium, 30 late soybean lines (242 total) for preliminary trials next season; from Brazilian populations, individual F5 plants selected to generate 127 F6 soybean lines.
Gandajika 1989 Season B	1989B sowings of 1989A soybean material swept away in torrential rains after planting; some selections made in resulting mixed stand.
Kaniameshi[1] 1989 Season A	281 F4 selections from IITA soybean crosses observed.
Gandajika 1990 Season A	F8 selections from IITA soybean crosses.[2]
Kaniameshi[1] 1990 Season A	82 F5 selections from IITA soybean crosses observed.

Table 3.25, continued

Gandajika 1990 Season B	F9 selections from IITA soybean crosses.[2]
PNL/Gandajika soybean hybridizations (approximately 79 crosses):	
1987 Season B	59 F3 soybean lines observed; 40 lines harvested (selection? natural attrition?).
1988 Season A	± 20 F4 soybean lines; F2 seed from 16 F1 soybean hybrids; objectives: to combine earliness, high yield, seed size, promiscuous nodulating ability.
1989 Season B	F5 soybean lines; four new F1 crosses.
1990 Season A	Lines in F6 and in F2.
1990 Season B	New F2 soybean lines; lines in F7 and F3.

Note: Question marks in table indicate that the information provided in data sources was either unclear or incomplete.
[1]The Kaniameshi station is frequently referred to as Lubumbashi in PNL materials because of its close location to this city.
[2]No further detail provided in source material.

PNL observed numerous segregating populations of soybeans from ITTA and from its own crossing program. In the earlier PNL crosses (beginning in 1987), the objective was to transfer non-specific nodulation, seed size, and shattering resistance to otherwise high-yielding varieties. In the later series of PNL soybean crosses, the otherwise outstanding line IAC 73-5115 was used as parent in crosses to improve its seed longevity (the parent conferring improved seed longevity is not specified). The first selections from PNL soybean crosses appeared in yield trials in the 1990-91 crop year; data from this year were not available to this author.

A high-yielding Spanish-type **peanut** line, JL 24, selected from introduced ICRISAT lines, was recommended for release as the cultivar Bubanji (see Table B.3). This line was used as an updated check entry in PNL trials in the last seasons of RAV I. Work continued in search of disease-resistant lines and high-yielding, large-seeded types.

Early in RAV I, an INERA line, A 65, that had been tested in the INERA Support era, was identified as superior to G 17, the line in widespread on-farm use; A 65 was

Table 3.26. Peanut Breeding Timeline

PNL/Gandajika peanut hybridizations (approximately 40 crosses):	
1989	± 14 peanut crosses made.
1990	± 10 new peanut crosses made; advanced 42 "lines" in generations from F1 to F4.
1991	± 13 new peanut crosses made; 1989 crosses advanced to F5 (9 lines from 6 crosses) and F6 (14 lines from 8 crosses).

consequently adopted as a check in many RAV I PNL peanut trials (see Tables B.3 and B.10).

Absence of infection was a frequent constraint on PNL rosette resistance selection; this disease is devastating only in widely separated years (Bock, 1989).

Peanut hybridization proved difficult at Gandajika because the female parents must be prepared at night; the Gandajika greenhouses are not equipped with lights, so emasculation was done at last light, on flowers as yet very small. Nonetheless, a number of crosses were made (see Table B.7) with the objective of combining high yield with other desirable characters (PNL, 1989/90). There is no record of receipt of hybrid populations from other sources for evaluation by PNL.

PNL recommended the **cowpea** variety Muyaya, of unknown origin, in 1988. The variety was distributed in Kasai Occidental, where it showed a 30 percent yield advantage over locally grown varieties in PNL trials, through the PRODALU project (Projet de Développement de la Lulua). In 1990, PNL recommended two more cowpea varieties, Jamashi and Mujilanga, selections from the INERA collection. These two varieties were selected after five seasons of testing (Table B.4).

The cultivar Jamashi was identified as tolerant to the parasitic plant **Alectra vogelii** (showing little or no yield reduction when infected), and line H 295 was identified as resistant (no infection). The year of the aphid resistance nursery, 1988, was a year in which aphids were not a problem; thus the nursery could not be evaluated. The bruchid trial, which showed no differences between entries, had a high CV of 40 percent, suggesting to the researchers that the experimental technique was too imprecise. Nonetheless, over time PNL was able to draw some conclusions about the insect-resistance performance of cowpea varieties. IITA lines IT81D-1137, a line that yielded 480 percent more than the local check in a 1988-89 trial on the Bateke Plateau near Kinshasa, had excellent grain quality and showed bruchid

resistance in Zaïre, and IT84S-2246-4 showed some resistance to flower thrips and bruchids; these lines were used as parents in a number of crosses made at Gandajika.

Two other cowpea lines that showed insect resistance in PNL tests (TVX 3236, low level of resistance to flower thrips; IT 82D-716, resistance to bruchids, low level of thrips resistance) have rough, beige seed coats. Because cowpeas preferred in the Kasais are those with smooth, red to brownish-red seed coats (in other regions of Zaïre, smooth, white-seeded types are grown), a test of acceptability was conducted with 30 SENARAV workers and 10 women from a nearby village. The rough seed coat cowpea lines required less cooking time than the smooth seed coat lines--an advantage because of the shortage of cooking fuel and the labor required to gather it. But red seed color was preferred for two reasons: the color was associated with "giving blood," and red-seeded lines required less palm oil in cooking.

Cowpea breeding began at Gandajika in 1987 with a greenhouse crossing program to incorporate genes for resistance to **Sphaceloma** scab disease and preferred grain size, color, and cooking quality into genotypes with high yield potential. In later seasons, objectives included earliness and plant architecture (Table B.9). Hybrid populations from crosses were advanced in bulk. Single-plant harvest for line extraction from the earliest crosses was begun in Season B of 1991 and was to have continued in Season A of 1992, with sufficient seed increased to place the first lines in yield tests by Season A of 1993.

In the observation trial at Gandajika in 1986, all **pigeon pea** entries were highly susceptible to pod-sucking insects, **Heliothus** pod borer, and mealy bug. Because of these results and because pigeon pea was not observed to be an important crop in Kasai, research on this legume was not pursued.

Because of the importance of **mung beans** (haricot asiatique, or Kambululu, in Tshiluba) in the Kasai region, a preliminary trial was conducted in 1985-86 with lines from the INERA collection and five introductions from AVRDC.

A trial of 15 lines from AVRDC was conducted in Gandajika during both seasons of the 1987-88 crop year. Although it was a dry year, all of the AVRDC lines far out-yielded the local variety, with VC1482E and VC3061A topping the list. The trial was repeated in 1989/90 with similar results; V2984 and VC2750A joined VC1482E and VC3061A as highest-yielding entries.

Because of the significant yield advantage gained from the introduced lines over the local variety (about 300 percent in 1987-88 and 160 percent in 1989-90) for a relatively small research investment, PNL planned to follow the two on-station trials with on-farm trials in 1990-91. The plan was dropped due to cutbacks at the start of RAV II.

Table 3.27. Cowpea Breeding Timeline

PNL/Gandajika cowpea hybridization (approximately 140 crosses):	
1987 or 1988 A	22 cowpea crosses to combine earliness, plant architecture, high yield (from IITA lines) with desired seed type and disease tolerance (from local lines); advanced by single pod descent.
1988 Season B	New cowpea hybrids; F2 of cowpea crosses made previous season.
1989 Season A	New cowpea hybrids; $\leq$ 103 F2 and F3 of crosses made previous season.
1989 Season B	Generation advance of 41 F2, 81 F3, and 22 F4 cowpea populations.
1990 Season A	Generation advance of 41 F3 and 81 F4 populations; 22 F5 cowpea populations with H 204 (Jamashi), as male or female parent x IITA lines advanced in association with maize to favor natural selection for tolerant genotypes.
1990 Season B	Generation advance of 41 F4 and 81 F5 populations; 22 F6 populations advanced in association with maize.
1989-90 (season unspecified)	F2 generation of **Alectra** crosses H4 x H204 (S x T), H36 x H204 (S x T), and H295 x H204 (R x T); back-crosses planned to H204 and H295.
1991 Season A	(RAV II follow-up on RAV I cowpea crosses): 15 F7 populations advanced in association with maize (12 populations lost over generations--unadapted to assoc.; 5 of the remaining populations divided into 2 lots each by seed color = 15 populations).
1991 Season B	15 "association" populations increased, pure stand w/insecticide protection, for 92A on-farm trials. Individual plants harvested in 5 unselected **Alectra**-tolerant x susceptible hybrid cowpea populations advanced to F8 and F9 by single pod descent.

b. Grain Legume Seed Multiplication and Variety Diffusion

Although data for PNL seed multiplication are incomplete, the scale of the operation can be observed in the 1987 and 1988 annual reports. Seed not reported as sold or donated was either used in PNL research or stored.

PNL seed multiplication, 1987, Gandajika:

2,190 kg of 2 varieties of peanut (G17, A 65) produced on 4.7 ha; 1,209 kg sold, 723 kg donated.

3,218 kg of 5 varieties of soybean (SJ127, TGX536-02D, TGX814-26D, Jupiter-R) on 6 ha; 2,326 kg sold, 469 kg donated.

622 kg of 3 cowpea varieties (Muyaya, TGX 3236, IT82-716) on 2 ha; 419 kg sold, 186 kg donated.

PNL seed multiplication, 1988:

Gandajika:
1,153 kg of 5 varieties of peanut (G 17, A 65, A 1052, P 43, Blanche de Kaniama) produced on 4.7 ha; 331 kg sold.

1,147 kg of 7 varieties of soybean (SJ 127, TGX814-26D, TGX849-294D, UFV-1, Jupiter-R, TGX536-02D, TGX573-209D) produced on 4.5 ha; 311 kg sold.

795 kg of 3 varieties of cowpea (Muyaya, H36, H4) produced on 4.2 ha; 317 kg sold.

Seed produced in 1988 at Gandajika was sold to 13 projects and organizations (Ets. Kalala M., Projet Coton, Projet Ituri, CEDERO OMEDJADI, PRAS-LUSAMBO, Projet Shaba Central, Domaine de Muyaya, Hotel de Luxe, Paroisse Ilunga I, Paroisse Mulumba, Paroisse Kasonji, Comité agricole/Mpasu) and "diverse" individuals.

M'Vuazi:

437 kg soybeans produced; 387 kg sold, 45 kg donated.
100 kg peanut seed produced; 40 kg sold.

Kiyaka:

180 kg soybeans produced; 114 kg sold, 17 kg donated.
1,014 kg peanut seed produced; 450 kg sold, 143 kg donated.

Kaniameshi:

580 kg of 3 varieties of soybean (SJ 127, Hernon, Jupiter-R) on 0.8 ha.

200 kg of peanuts (G17) produced on 0.2 ha.

140 kg of beans ("local variety") on 0.3 ha.

PNL Seed Multiplication, 1989-90:

According to the 1989-90 PNL annual report, PNL was in some way associated with cowpea seed multiplication at the SENASEM farm at Lusanga (17 ha of Vita-7, 2 ha of IT83D-442, and 1 ha of Mujilanga (H4)).

Almost all seed multiplication and variety diffusion activity in Zaïre is conducted by PNL, SENASAM, and NGO collaborators. A listing of seed distribution collaborators is provided in Table 3.28. On-farm trials that leave farmers with the harvested seed of the varieties tested on their fields are not as effective as they might be because many poor farmers in Zaïre consume or sell their entire grain legume harvest and repurchase seed in the market at planting time. Sperling et al. (1992) found that 45 percent of S. Kivu farmers bought 100 percent of their bean seed in the market every time they planted. In the market, farmers search for the best quality seed they can afford, but refined choice of variety is rarely possible nor a priority compared to healthy seed that will germinate well.

Grain legume varieties distributed by SENASEM seed production centers through 1989 (Anota, 1992) were P43, A65, G17, and A1052 peanuts, all pre-RAV I recommendations by INERA, from whose collection they came; Ntendezi, PV14 (both INERA) and D6 beans; Hernon, Jupiter, Patience, SJ127, SJ61/1, UFV 1, and SAM86 soybeans (all pre-RAV I and early RAV I recommendations); and Muyaya, Variété local, and Gandajika cowpeas (all early RAV I recommendations). This list should now be changing to include the 1990 and 1991 PNL-recommended varieties.

Varieties distributed by the development group networks through 1991 were, in Kivu, Nain de Kiyondo, Kakaja, Kirundo, A 197 bush beans, and Aliya and Cihembe climbing beans; and in Shaba and Kasai, Wambedi, A 21, EMP 143 bush beans, and Aliya and Cihembe climbing beans (Mbikayi, 1992).

c. Grain Legume Germplasm Preservation

The most complete report of activity of this section is from the 1987 PNL Annual Report. In the 1986-87 crop year, PNL grew for seed rejuvenation 404 soybean lines; 350 peanut lines; 64 cowpea lines; 51 mung bean lines; 40 lines of different Vigna species; 133 bean lines; 71 lines of other **Phaseolus** species; 60 lines

Table 3.28. PNL Seed Distribution Collaborators

Kivu

Most effective:
- FESODEBU (Femmes organisées pour le développement de B__)
- CBK/CEDERU
- Usine de Kirigye

Very effective:
- ADI

Effective:
- Projet KABARE/GTZ
- GPER
- COOPANOKI
- Sucrerie de Kiliba
- Ferme de Kisamba (SENASEM seed production center)

Shaba

Most effective:
- (H-)Interland Minier[1]
- Projet Nord Shaba
- SENASEM

Very effective:
- Projet Shaba Central

Effective:
- Projet Lubudi/SAGRICHIM

Ineffective or inactive:
- Seventh-Day Adventists

Haut-Zaïre

Effective:
- Projet Ituri

Kasai Occidental

Most effective:
- PRODALU (Projet de Développement de la Lulua; contact: Manyabe, Muteba)
- Action Tudibambe

Very effective:
- Centre Nkata/Luiza
- Oxfam

Effective:
- CEDERIM Mueka

Kasai Oriental

Most effective:
- AIDN (Agence Indigène pour le Développement du N'Gandajika; contact: Lukusa)
- Traction Bovine Kabinda (Mennonite Central Committee)

Very effective:
- PRODEK (Projet du Dével. Est-Kasai; contact Medi)
- Peace Corps
- PRODAIB LUPUTA

Effective:
- PMKO (Projet Maïs Kasai Oriental; contact: Mudimbiyi)

Ineffective or inactive:
- Projet Rural Diocesain
- Domaine de Muyaya
- UCOOPAGRI
- Projet Mulumba Lukoji

Not rated:
- Centre Chrétien de Santé
- SENASEM Ferme de Mpoyi

Source: Mbikayi (1991).

[1]Appears in both spellings in RAV I reports.
Note: Judgments as to effectiveness of collaboration are those of PNL Director Kilumba (pers. comm., March 1992). Unexpanded acronyms could not be identified by this author.

of pigeon pea, bambara groundnut, and other grain legume species; and an unspecified number of lines of 11 forage legume species. The total was about 1,200 accessions. Extensive descriptor data were recorded for each accession.

d. Grain Legume Documentation and Institutional Memory

RAV I established a strong and commendable tradition of preparation of annual reports. Toward the end of RAV I, computers were introduced to aid in word processing as well as data analysis (using the MSTAT program).

However, there were still many shortcomings in the research documentation. Even in later records (ca. 1990), tables frequently do not specify which legume is the subject of the data in the table (this not always clear from context without leafing back several pages) or whether data are for Season A, Season B, or the average of both; in earlier records, tables sometimes omit even the year. Origin of the lines tested is only occasionally mentioned, and crosses made are not well documented. Reports generally include only the number of populations evaluated and the generation; parents, if mentioned, are not identified as to the reasons for selection, and the purpose of each cross is rarely recorded. There are no summaries or highlights, so the reader must read the entire report in order to draw conclusions about the year's work. No reference is made to earlier work of which the work reported might be a continuation, a confirmation, or a reflection. Thus, long study is required before an outsider can become sufficiently familiar with the reports to make such judgments unaided.

3. RAV II

a. Grain Legume Germplasm Improvement Research

Additional data was obtained that confirmed the decision to release the climbing bean Cihembe for high altitudes and the semi-climbing bean Kyakulwa for mid-altitudes.

PNL bean hybridization work was begun at M'Vuazi and continued at Gandajika as well as at Mulungu. At Mulungu, the 15 R x S crosses between angular leaf spot-resistant CIAT lines and locally preferred lines were back-crossed to the local parent, advanced a generation, and screened to select resistant lines for testing and further back-crossing.

At M'Vuazi, a new series of bean hybrids was planned to transfer the improved seed viability of CIAT bean introductions to Ntendezi, a locally preferred variety in Bas-Zaïre having large white seeds. White-seeded CIAT lines had been screened at M'Vuazi for three seasons; "4416" appeared to be one of the best yielders.

The PRELAAC Great Lakes Regional Bean Nursery had begun to be grown in all regions of Zaïre and to include lines selected in all regions of Zaïre; this was one

manifestation of the trend to involve mid- and low-altitude stations in the CIAT cooperative project.

During RAV II, additional INERA **peanut** lines were screened on-farm. Some of these INERA lines, including A 1543, appeared distinctly free of **cercospora** symptoms in farmers' fields in June (late season).

Superiority of **soybean** variety IAC73-5115 was confirmed with additional data, and a PNL decision was made to recommend this variety and continue hybridization to improve its seed viability in storage.

A research plan was prepared for line extraction in Season A 1991/92 (the season being planted at time of evacuation), and testing of lines from RAV I hybrid **cowpea** populations advanced four generations in association with maize. Testing of selections from these populations would have been complete by January 1993.

b. Grain Legume Seed Multiplication and Variety Diffusion

Drought, labor strikes, and lack of fertilizer and pesticides contributed to very poor seed multiplication yields during the single RAV II harvest season.

By 1991, D6 bush beans had been added to the list of varieties distributed by development group networks in Kivu.

c. Grain Legume Germplasm Preservation

With the shortfall of resources after the evacuation of RAV II personnel and suspension of U.S. development assistance to Zaïre, PNL recognized the priority importance of germplasm preservation over ongoing research. Absent adequate storage facilities, plans were immediately made and carried out to rejuvenate all grain legume germplasm in the field to provide fresh seed for continuing conservation efforts.

d. Grain Legume Documentation and PNL Institutional Memory

Plans for improving the usefulness of the PNL annual report to different user groups were hindered by a confusion of lines of authority and responsibility during RAV II. Additional computers for data analysis and document preparation were supplied to PNL during RAV II. The secretarial staff received training in word processing; the new technology met with no acceptance problems.

Appendix A contains a list of personnel associated with grain legume germplasm improvement in Zaïre during the years of USAID support.

F. Germplasm Development

RAV II was too young to have established a research character; and, with the exception of a trained interdisciplinary team at Mulungu that continued to function effectively through RAV II, the INERA Support Project left few traces. Of necessity, then, this discussion will center on grain legume germplasm development research during RAV I.

It is appropriate to state at the outset that PNL/RAV I did a remarkable job. RAV I left an up-and-running grain legume research program with sound established research procedures and an experienced, highly motivated staff. A large number of appropriate germplasm introductions were evaluated over time and space in large numbers and, of these, one to four superior lines were recommended in each of the four grain legume crops. These superior varieties were made available to agronomists, extensionists, farmers, and NGOs. Crossing programs were begun in all four legumes.

Because PNL selection activities and administration procedures were in place and operating, successful vs. unsuccessful procedures had become distinguishable. The breeding operation was still too young to permit more than a theoretical discussion of the probability of success.

1. Research Priorities and Objectives

This author agrees with the research priorities presented by Shannon in his final report (1990): long-term priority for beans and peanuts, short term priority for soybeans, and a "go-slow" on cowpea germplasm development research (but continued cowpea integrated pest management research) until better insect resistance is available (see Section C, "Grain Legume Research Objectives"). It appears that the PNL director held the same view, because resource use in RAV I showed a trend in that direction (see Section E, "Results of Grain Legume Research").

Some activities inconsistent with this prioritization are the continuation of cowpea research and the large number of multiple-objective soybean crosses made by the PNL. A crossing program implies a long-term investment and is in contradiction to the statement that IITA soybean varieties are well adapted for use as cultivars with no further improvement. More recently, the objective of the crossing program has become better defined and addresses a specific and important deficiency (poor seed longevity). With limited resources, this new and limited direction is more appropriate. For the time being, introduction of practical methods for producing products such as soymilk, soy-supplemented products or tofu may be as essential for increasing soybean production, or more so, than development of new varieties. The Threshold Report authors seem to have been unaware of the growing popularity of soybeans and to have overestimated production difficulties; they were perhaps also unaware of the availability of freely nodulating material for IITA and that poor seed viability is equally a problem with beans (Wedeman et al., 1988).

While improved cowpea yields would have the potential to dramatically improve the village food situation in Kasai, in particular, such gains are unlikely to be realized at this time. The resources released from cowpeas should yield gains in peanut and bean production that will benefit the Kasai and all of Zaïre.

2. Selection of Specific Research Objectives

The lack of much previous grain legume germplasm development research in Zaïre has left many researchable problems in grain legume production for which technical solutions could be found. It was perhaps a wise choice to select an agronomist as PNL national director. The first RAV I technical advisor to PNL, also a strongly farmer-oriented agronomist, conducted several in-depth surveys of cropping practices in the Kasai region (Shannon, 1990). Thus from PNL's inception, the technical needs of small farmers were determinants of selection and breeding objectives.

Examples of research objectives that benefitted by farmer input are selection for bean and cowpea genotypes adapted to multiple cropping and selection for better retention of bean and soybean germination ability during on-farm storage. This farmer-orientation also seems to have helped maintain researcher morale through the conviction that their work matters to someone and can make a difference.

Farmers' needs, however, cannot be the only guides to an effective germplasm development program. The strong farmer orientation has resulted in adoption of one or two research objectives that are, for genetic reasons, unlikely to return investment in a modest program like the PNL. An example is simultaneous selection for both large seed size and high seed yield in beans. These traits have a genetic correlation of close to -1, so population sizes in the hundreds of thousands are required to permit even a small chance of success (PNL works with populations sizes in hundreds, at most). Another example is selection for insect resistance in cowpeas. IITA, with its far greater resources, has sought insect-resistant cowpea genotypes with no success for about a decade.

There is a clear need for a decision-making method that considers multiple criteria. Farmers' priorities should be examined in light of breeders' assessments of the probability of research success and the time and resources required. A cost-benefit analysis should be made, comparing the investment required with the genetic gain and on-farm benefits expected.

A word of caution: Pressure to publish can divert any germplasm improvement program from objectives that are technically feasible and important to farmers, to less immediately important but more original or unique topics. An example was the attention given by the PNL RAV II technical advisor (this author) to planning cowpea/**Alectra** genetic studies. If the goal of the PNL is to become known on by-lines, this diversion of resources is essential; but the trade-off should be well understood and firmly accepted or rejected, or unacceptable loss of on-farm effectiveness will result.

3. Research Materials and Methods

a. Grain Legume Germplasm Materials

PNL made highly effective use of germplasm available from international centers and INERA. Local varieties were also used, but it is not clear from the records whether local material was used by chance in one of the station collections or if it was systematically acquired and evaluated. If the latter, there were relatively few local varieties of each legume, which is in fact a possibility.

b. Grain Legume Equipment and Facilities

Lack of proper conditions for seed drying, cleaning, and storage for research and germplasm conservation is probably the most serious facilities constraint on PNL. All harvested seed must be air-dried on corrugated metal sheets already in very poor condition. The damaging effects of rain or atmospheric humidity cannot be combatted with forced or heated air. Most seed cleaning is done by hand by groups of school children. Any line that is to be kept in the program must be grown every season--that is, planted and harvested twice a year--at great cost in land and labor.

Appropriate greenhouse facilities and lighting will be critical if PNL wishes to continue and expand its crossing program, since night is the optimum time to prepare flowers of some species for pollination the next morning. Electricity is also needed to permit development of a basic plant sciences laboratory with microscopes, balances, drying ovens, etc.

c. Grain Legume Selection Methods and Field Plot Technique

The basic PNL selection scheme is sound and has been a good guide for PNL. The following comments address specific details of techniques in selection experiments.

There is a striking deficiency of combined analyses of genotype performance over locations or years. Most genotypes are in fact grown over several locations and years before a decision is made. However, sets of entries and experimental designs varied from place to place and year to year. This was partly because staff in the early years were not yet sufficiently trained to understand the importance of the additional information that can be obtained when experiments are planned to permit combined analysis (particularly when genotypes are to be selected for wide adaptation in order to be recommended for large areas), and partly because of the lack of facilities for analyzing large data sets. Both deficiencies have been corrected, and research plans should begin to include experiments that are designed for combined analysis to improve PNL's ability to study genotype performance over environments.

Heterogeneity among plots needs to be better addressed. This could be accomplished through improved seed bed preparation methods and use of statistical designs.

Plots in bean association experiments (3-m rows, 4 rows to a plot) are not large enough. This size would be sufficient for bush beans in pure culture, and possibly for climbing beans if surrounded by other climbing bean plots. But in experimental plots of pure bean culture (or a different planting arrangement of association culture) randomized together, a plot of this size is entirely border effect.

Check varieties were often not planted with early generation segregating populations, because early generations are not genetically stable and phenotypes seen one season may not be recoverable in later generations. Nonetheless, selections are made in early generations; therefore, checks, consisting of the parent genotypes, if available, plus the best variety in common use, should always be planted.

The check varieties in yield trials should be updated now that five years of work have clearly established some lines as superior to the checks adopted at the start of RAV I; this is in fact being done. In addition, the original checks should be retained and included from time to time in selected trials to provide a historical reference point from which to measure genetic progress from PNL's work across decades.

PNL is over-extended given its present resources. All sites except Kaniama are a two-day journey from headquarters at Gandajika. (Mulungu is a three-day journey.)

It is recommended that the number of crops per station be reduced (see Table 3.29). Adopting these recommendations will mean that some important services to local agriculture are not provided until transport, communications, and funding are improved.

d. Analysis of Grain Legume Data

In the early years of RAV I, data analysis was limited to the simplest analysis of variance of main effects. Much information on interactions and contrasts was neglected. With the return of trained staff and the arrival of computers, analysis of data from PNL selection experiments was becoming more complete.

Heterogeneity in experimental fields was addressed by dividing large groups of entries into sets of smaller randomized complete block designs with common checks. Use of experimental designs that control variation in more than one direction would permit a smaller total number of plots and more precise comparisons. The availability of computers will make use of these more complex designs feasible.

A statistical methods workshop series planned by Almoubarakou Touré, the RAV II Agronomy/Cropping Systems technical advisor, was cut short by the evacuation in September 1991. Germplasm development researchers would benefit from an in-service course on how to get the most out of a given experiment or data set, given their operating conditions. This should include, at a minimum, assumptions, calculations, and inferences for interactions and correlations, and the planning and analysis of lattice and latin square experiments. Other topics that would be useful to PNL are a study of various statistical methods to facilitate the study of genotype x environment interactions; the use of covariates; calculations of missing values; use

Table 3.29 Recommended Crops to be Researched by Station

Station	Crops				Total
Gandajika	(Beans)	Peanuts	Soybeans	Cowpeas	3
Kaniama[1]	Beans	Peanuts	(Soybeans)		2
M'Vuazi	Beans	Peanuts	Soybeans	(Cowpeas)	3
Kiyaka		Peanuts	(Soybeans)	(Cowpeas)	1
Kaniameshi[2]	Beans	Peanuts	Soybeans		3
Mulungu	Beans		Soybeans		2
Stations Retained	4 (of 5)	5 (of 5)	4 (of 6)	1 (of 3)	
Difference	-1	0	-2	-2	

Note: Parentheses indicate that continuation of current activity is not recommended.

[1]It is recommended that Kaniama be closed. If this recommendation is not followed, the crops shown in the table should be researched.

[2]Recommendation contingent on closing the Kaniama station.

of transformation; and methods such as land equivalent rations (LER) for calculating the value of entries in association culture studies.

e. Breeding vs. Selection of Grain Legumes

Both of the RAV I technical advisors to PNL were strongly in favor of a breeding program. They believed that PNL should not rely totally on germplasm received from international centers; rather, PNL should make its own crosses to generate its own unique hybrid populations and thereby provide additional variation for its evaluation and selection program. This author believes, however, that given the present scale of PNL operations, a PNL breeding program should be limited to the transfer of specific, highly heritable qualitative or single gene traits from donor parents to adapted recurrent parents. This is the type of breeding program most likely to produce the desired results when the numbers of lines and plots that can be grown are small.

Because the frequency of desirable genotypes in a hybrid progeny decreases with each additional gene involved, "good-by-good" crosses to create new genotypes for several traits at once or for quantitative traits with low heritability (like yield and maturity) require very large numbers of plants and plots at certain stages to provide an acceptable probability of success. PNL had some 7,000 plots over five sites and four legumes in Season A of 1991. The severe limitation that this scale of operations

would place on a PNL breeding program is clear when one performs the calculation to arrive at 350 plots per legume per site.

For example, in 1989 PNL/Gandajika station was increasing 240 soybean lines from IITA/Brazil hybrid populations, preparatory to preliminary yield tests the following year. But two replicates of 240 lines is 480 plots, or approximately the entire number of plots allocated to soybean research at Gandajika in 1991; three replicates would have been 720 plots. How then could PNL have anticipated resources to test 240 soybean lines in one season or even in one year? And this is a modest number of lines.

An exception to the general inadvisability of PNL making crosses to transfer quantitative traits such as yield would be if the locally adapted or preferred parent had such a low value for the trait that a value intermediate between the high and low parents were acceptable, i.e., genetic progress would be achieved even if the high parent value were not recovered. The probability of achieving an intermediate value is high enough that even with limited population sizes, the required genotypes could be recovered.

The exact numbers of populations and breeding lines actually grown by PNL in any given season are difficult to reconstruct because different reports contain different numbers. The figures reported here (see Section E, "Results of Grain Legume Research") are at least representative of the scale of operations. In past PNL reports, a distinction was sometimes made between populations, lines, and varieties; the more exact terms cultivar and genotype, and the useful, inclusive term entry, were not used. Clear terminology is necessary for clear thinking and clear reporting. Researchers returning from long-term training should be encouraged to use the most appropriate terms.

4. Seed Multiplication and Distribution

Seeds are the *sine qua non* of effective crop improvement. The seed multiplication and distribution situation in Zaïre is far from good due to the lack of a trained seed technologist and adequate infrastructure.

PNL's role in grain legume seed activities within the Plan National Semencier is threefold: it develops improved varieties to be multiplied and distributed; in so doing, it must maintain a germplasm collection; and it produces and conserves breeder seed and foundation seed. PNL is keenly aware of the importance of these activities, but it faces many severe obstacles. In the field, the lack of irrigation facilities, pesticides, and labor regularly results in high crop losses. There is some justification for selection in stress conditions that limit yield, but seed production under yield-limiting conditions results in unaffordably low return to seed, labor, and land inputs.

PNL's policy for seed increase recommends that the land used for seed multiplication be "representative" but also "fertile." Generally, this is a contradiction.

In fact, if the seed is increased too many generations before again being passed through a cycle or two on poor soil (to avoid subtle genetic shifts), that could cause loss of adaptation to soils of low fertility. It is best to multiply on the richest soil available. Seed multiplication should be given high priority for good soils because it has such wide benefits and may create such a bottleneck, especially for crops with low multiplication ratios (such as grain legumes).

Uniformity of the site is almost as important during multiplication of foundation seed as it is in selection experiments, because highly variable terrain in seed production fields contributes to phenotypic variation among plants and makes detection of off-types and contamination difficult. After harvest, the lack of proper cleaning and, especially, lack of storage facilities results in further high losses to moisture, insects, rodents, and physiological losses of viability.

PNL also has difficulty in defining a realistic price for the foundation seed it produces. Seed may be donated or sold to collaborators. The price is often defined "not according to costs of production or ability of farmers to pay, but according to the price of grain legumes sold for consumption on the market" (Elukessu, 1992).

PNL cooperates with SENASEM, the national organization that runs several seed farms. New varieties have come slowly and SENASEM's strict testing procedures for uniformity and superiority have not been a bottleneck. However, because of the cost of the trials, the limited budget available to agricultural development in Zaïre, and the very probable increased frequency of new releases of improved varieties, it seems likely that the requirement that new varieties be tested by SENASEM in two sets of trials before they are accepted for multiplication and distribution will eventually cause unacceptable delays. Since the trials duplicate PNL advanced trials, it should be possible to work out an agreement between PNL and SENASEM whereby SENASEM accepts certain types of PNL data in lieu of conducting its own tests.

5. Germplasm Conservation

The technical limitations to seed production, processing, and storage all apply to germplasm conservation as well as to breeder and foundation seed production. Moreover, PNL does not trust the reliability of IRAZ, the regional institution assigned a crop germplasm conservation role by the Economic Community of Great Lakes Countries (Zaïre, Rwanda, Burundi). PNL resents the diversion of resources to a regional organization for a function that it would prefer to control itself.

At present, SENASEM is the only other unit functioning in the Plan National Semencier. SENASEM faces the obstacle of enormous need for quality seed of superior varieties but, because of the low income of most of the farming sector and the difficulty of transport, effective economic demand is highly irregular to completely absent. This requires highly subsidized activities in the beginning, activities that are themselves an obstacle to the development of the desired competitive private sector. The need to price seed such that the seed production centers are self-supporting, yet

at a price that the chief user, the small farmers, can afford, is a critical problem. The commercial distribution and sales sector of the Plan National Semencier is almost nonexistent; this is currently the weakest link in the system. SENASEM recognizes this combination of circumstances--immense need, weak economic demand, and the absence of a commercial sector--as the most serious obstacle to be overcome (Anota, 1992; Conférence sur le lancement des variétés, 1989).

The Goma workshop on promotion of new varieties (November 1989) reached several important conclusions. One conclusion was that there is a need to decentralize the seed distribution centers. (One or two production centers per region are terribly inadequate in a country the size of Zaïre, even if road systems permitted their reaching an effective area of more than about 100 km radius.) The workshop also concluded that seed conservation facilities will be essential all along the seed distribution chain.

The Goma workshop also recommended the establishment of a National Seed Council to officially accept variety recommendations, standardize the concept of variety, and maintain and publicize a list of recommended varieties. It was not clear why the workshop concluded that another new organization is needed to perform these functions, but the clarification of variety recommendation and release processes is certainly needed. It is not clear from PNL documents what is meant by "recommended variety." Many varieties "recommended for distribution" (e.g., EMP 143 beans, UFV-1 beans, Muyaya cowpeas) are never mentioned as "recommended for release" (e.g., Afya, Aliya, Wambedi, Jamashi). It is unclear whether PNL intended to distinguish between the two groups of varieties.

Another issue on which PNL and SENASEM disagree is varietal purity. SENASEM is currently very strict that varieties of self-pollinated crops must be 100 percent pure, i.e., no discernable variation is permitted. PNL maintains that some low level of heterozygosity, occasionally resulting in phenotypic variation within a variety, is desirable to impart wide adaptation to a variety, which is necessary in a country like Zaïre. This dispute between seed certification agencies and plant breeders over the necessity of absolute varietal purity is not confined to Zaïre. This author (a plant breeder) believes that extreme purity is not necessary and may in fact be detrimental in Zaïre.

6. PNL Documentation, Planning, and Communication

For any research program, documentation is both internal and external. Internal documents that create institutional memory (such as reports, reviews, crossing records) and documents reporting external research (such as journal articles) are complementary aids to research planning. The availability of adequate documentation ensures the greatest benefit from current and future research by permitting research design that is technically correct; adds new knowledge where most appropriate; avoids duplication; and facilitates the choice of appropriate objectives, since these evolve from previous research.

a. External Documentation

In spite of years of USAID collaboration, grain legume germplasm development researchers in Zaïre remain critically in need of external documentation. Researchers make excellent use of all available materials, but these are very limited. Moreover, there is a chronic problem of distribution: Due to the shortcomings of the mail system, all publications are sent to Kinshasa SENARAV headquarters for distribution to the programs and stations. Far too often, the material never leaves Kinshasa. (Journals that USAID had subscribed to for the M'Vuazi station for several years, for example, were nowhere to be found.) There should be closer supervision to make sure that documentation actually goes to the intended users. The same applies to abstract services; the abstracts should be available to each researcher, not limited to a headquarters staffer who makes decisions regarding their distribution. This was the system during RAV I, and the reality was that not a single abstract or article ever reached Gandajika.

There is strong demand for additional materials--not only journals of research results, but also texts for self-study. Books on statistics, applied genetics, and crop monographs all would be profitably used. The staff who have not had long-term training in the United States or in Nigeria are frustrated by the predominance of English-language material and would make highly effective use of literature and texts if these materials were provided in French.

b. Internal Documentation

There are three major documentation and planning activities for grain legume germplasm development research: the annual PNL internal review in July followed by the scientific review in August of all three SENARAV programs; the annual report; and the annual rollover of the two-year work plan. In addition, five-year summary reports were prepared in 1990 for beans and soybeans. (A short summary was also prepared for cowpea research; this author is unaware of any summary of peanut research.)

The internal review is intended to provide collaborating PNL researchers from all stations with an opportunity to present and critique their results and plan the coming year's work together. The idea is excellent, but in the one year (1991) observed by this author, the review was disappointing. The last-minute announcement of the date, the impossibility of communication between researchers at different stations before the review, and a cumbersomely large audience of observers from other programs all contributed to poor quality of preparations and to inhibition of frank discussion and concrete planning. Consequently, the review was perfunctory, trying, and of little value.

The following suggestions are made for restoring the value of the internal review:

- Set the date for the review at least two months in advance.

- Designate the responsibility and authority for each phase of the preparations, for the development of the documents, and for the conduct, content, and form of the internal review and associated workshops before the end of Season A (no later than April).

- Finalize the concept, format, and requirements of each meeting, presentation, and document (annual report, work plan, others) accompanying the internal review and present this information to the researcher staff before the end of Season A (no later than April).

- Hold a week-long series of workshop sessions of all PNL researchers before, or in lieu of, the formal week of presentations of the internal review. At these sessions, researchers will present their research results and analysis and drafts of work plans for extensive review by colleagues. Attendance at the workshops should be strictly limited to the researchers directly involved in order to permit uninhibited, exhaustive, and unceremonial discussion and critique of results and work plans. Due to the cost and difficulty of travel within Zaïre, the workshop will usually be the only opportunity during the year for researchers from different stations to work together actively and informally.

- Follow the review by a second, shorter, series of workshops in order to incorporate suggestions of the review into revised reports and workplans.

The annual report of PNL is increasingly well written as the level of training and experience of the staff increases, but shortcomings remain. The reports are presently written without summaries or conclusions. The result is a document with far too much detail for administrators to dig through to find out what was actually accomplished; at the same time, there is not nearly enough detail for succeeding researchers to reconstruct what was done in order to evaluate or continue the research.

In order to correct this deficiency, in-service training should emphasize the fact that annual reports must serve the very different needs of several different groups. Busy administrators and donors, for example, need quick summaries of results obtained and resources used. Outreach groups need clear statements of the conclusions and recommendations that, when time permits, a year or two later, may be available in technical bulletins ("fiches techniques") but are likely to be available

first in reports. Other researchers need details of genetic materials, field plot technique, and statistical analyses, and sufficient data to be able to evaluate the report's conclusions and to design efficient follow-on research. Thus, the annual report should have several different sections: summary and conclusions for administrators and casual readers; and materials, methods, and results for researchers. Each section should cover the same activities but with a different presentation style and level of detail.

Another shortcoming of the PNL annual reports is that they are often written without any reference to the activities of previous years; continuity of the research is therefore difficult to establish. The research reported in one year should be discussed with explicit reference to that conducted in previous years (even when combined analyses are not possible).

Distribution of the report has been another problem. The annual report was generally not distributed to the research staff--who write it and should be its key users--probably due to high duplication costs. At the least, an active attempt should be made to circulate a copy around each station. This means that each station should have at least two copies: one for the archives (generally the director's office) and one for active use.

The PNL two-year work plan proved its value during the RAV I-RAV II transition period, when germplasm improvement research in progress continued remarkably smoothly in the hands of the junior staff in spite of the several-months absence of a plant breeder/advisor. The work plan is, however, an unusual document that must be taken with a grain of salt.

The work plan is used as, and is intended to be, less a guide to activity than a highly ambitious, largely unprioritized request for funds to the administration. The work plan is prepared on the theory that the program should offer to do essentially all the research that may contribute to increased on-farm grain legume production, and ask for a budget accordingly. The theory is, what is not requested is not received. It is so much a public-relations document that its usefulness is limited. For example, in the description of almost every individual germplasm development activity, the experimental objective is listed as "genetic improvement of grain legumes" (which is, in fact, a program goal), or some equally sweeping, self-evident statement. Definable, achievable objectives (such as "evaluate introduction nursery to identify lines adapted to drought") appear only several paragraphs later in the description--or not at all. A reader skimming the document comes away with the vague idea that PNL is ambitious but does not know how to define realistic research objectives (in reality, PNL is more sophisticated). An unsuspecting researcher, taking the document seriously as a work plan, would despair of where to begin or of accomplishing half of the plan presented.

Because the document known as the "work plan" neither takes account of the resources actually likely to be available, nor provides a practical guide to how those resources should be allocated to the highest priority research, there is no real work

plan for researchers at the stations to follow from month to month and from one season to the next. This type of pragmatic, prioritized work plan is urgently needed as a protection against loss of effectiveness due to overextension. If necessary, it could be a strictly internal contingency document used only by the director and the research staff.

Like the annual report, the PNL work plan was not available to the very researchers who needed to use it. At least one circulating copy, in addition to the director's archive copy, should be readily available at each station for researcher use.

c. Grain Legume Germplasm Documentation

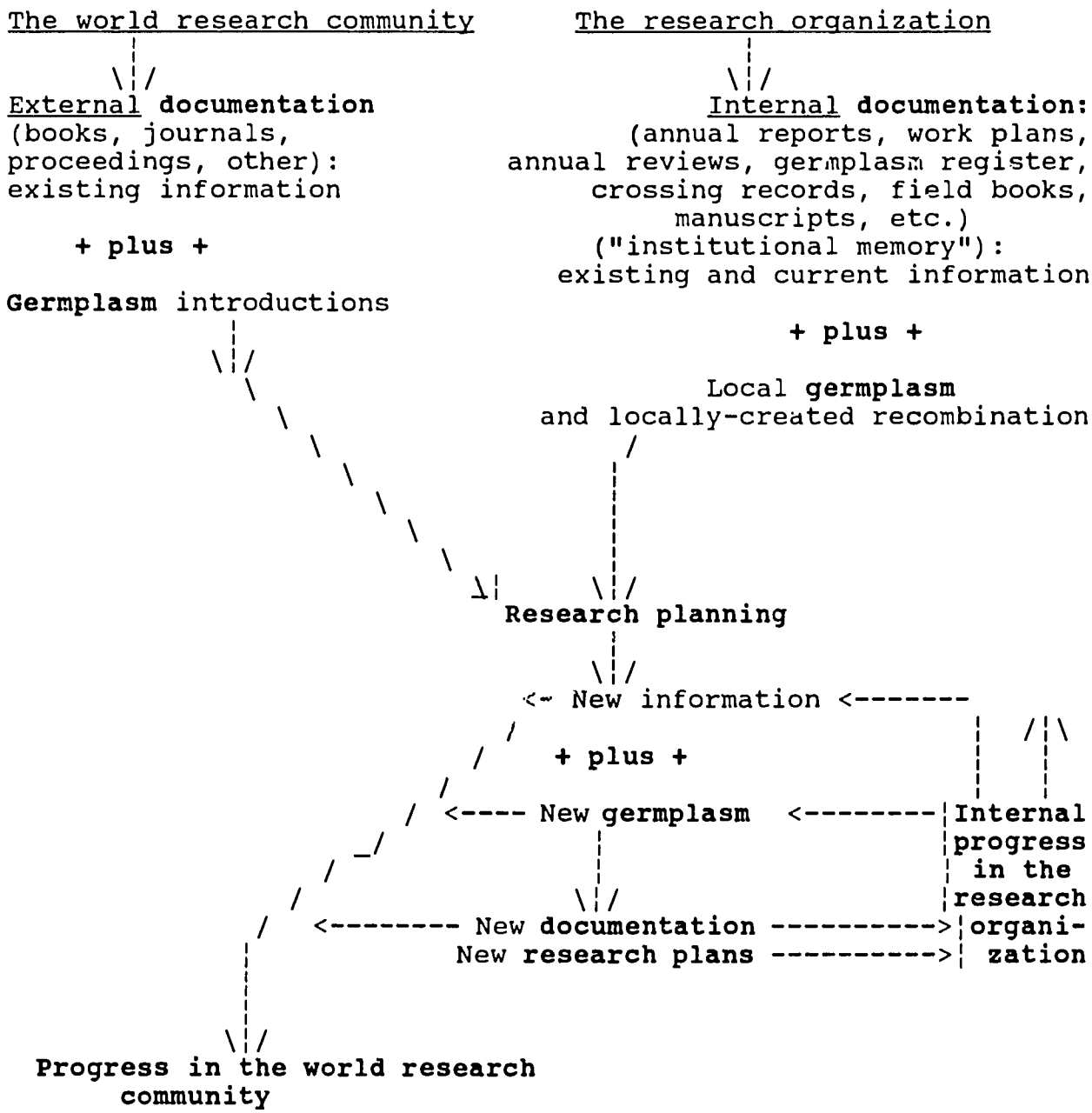
Germplasm descriptor data was kept in field notebooks, which were often stored in piles on shelves in outbuildings and sometimes (apparently at random) in file cabinets in the office. The notebooks used for this purpose were generally inexpensive and of poor quality. A computer file or even a card file would have been far more flexible and more easily consulted. The most serious limitation to this system was the rapid deterioration of the notebooks. This was a problem for all PNL data but was particularly serious for the germplasm data because only summaries of numbers of lines rejuvenated were included in annual reports: the extensive descriptor data remained buried in the notebooks.

In addition to documentation of research activities, a set of records is needed to permit the tracking of particular sets of germplasm or crosses through the program. These records include an inventory of the germplasm collection (identity of each accession and seed availability of each one) and a record of all crosses made, the purpose of the cross, the attributes for which each parent was chosen, and the history of the resulting hybrid populations and lines.

To date, PNL operations have been small enough that the need for such records has not been pressingly apparent. However, in 1991, the first group of long-term trainees was returning with no knowledge of research done in their absence, and staff who were on station during the last years of RAV I had left for training. The PNL Breeding and Selection Section found that much information (e.g., what material came from where, why a cross had been made, or what had happened to its progeny) was simply missing. Over time, clear and complete records will be critical to sustained progress.

An information flow diagram is included as Figure 3.3. Its purpose is to illustrate the dependence of successful research on the research planning process, on access to information from internal and external sources, and on return of information to internal and external channels in a continuing cycle. Information input and output is a cost but not a luxury.

Figure 3.3. Information Flow in Germplasm Development Research



Note: The reader is reminded that germplasm is information coded in the biological alphabet.

Communication difficulties between stations seriously hamper efforts to build a national grain legume germplasm development program. PNL researchers at different stations have no means of contact beyond letters sent with occasional travellers and an erratic radio system over which each word must be shouted two or three times before it is understood at the other end. The back-and-forth exchange of ideas is impossible. Confounding this, limited travel funds make interstation travel by PNL researchers except directors, an extremely rare event.

7. PNL Administration and Collaboration

SENARAV, and thus PNL, is essentially dependent on USAID financing augmented by collaboration with the international agricultural research centers (IARCs). PNL is, and for the foreseeable future will continue to be, dependent on the IARCs for germplasm, specialized training, collaboration in research planning and design, and technical information and documentation. The senior PNL staff fully understand the importance of networking and are masters at using IARC contacts and networks to strengthen their programs.

The younger staff, nationally trained researchers at the bachelor's degree level and newly returned M.S. degree-holders, who are isolated at interior stations, do not yet fully understand that they, as NARS (National Agricultural Research Systems) scientists, are partners with the IARCs, whose collaboration is essential in order for the on-farm pay-off of IARC research to be realized. Nor do they understand that this partnership gives them the freedom and responsibility to initiate contact with the IARC as needed. One of RAV II's goals was to develop in this young staff, self-confidence and an appreciation of their role in international agricultural research. The objective was to strengthen their initiative and effectiveness in networking.

a. IITA

The International Institute of Tropical Agriculture (IITA) has the longest history of collaboration with agricultural research institutions in Zaïre, but contacts with the grain legume program are not as strong as those with the cassava program. The IITA Grain Legume Improvement Program provides soybean and cowpea germplasm to PNL, which in turn provides data to IITA. PNL's contact with IITA is primarily through the PNL director, who is an agronomist and an important, longtime collaborator in IITA's alley-cropping research.

b. ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has the Consultative Group for International Agricultural Research (CGIAR) mandate for research on peanuts and conducts peanut research in India, Malawi, and Niger. PNL has received peanut germplasm from ICRISAT, and PNL personnel have attended workshops sponsored by SADCC and ICRISAT/Malawi; but contacts are neither strong nor recent. Strengthening contacts with ICRISAT should be a priority.

c. CIAT

Collaboration between PNL and the Centro Internacional de Agricultura Tropical (CIAT) is very strong. The CIAT Great Lakes Regional Bean Project provides four types of support to PNL/Mulungu and, before evacuation, was beginning to extend its support to other stations in Zaïre. This very valuable support includes (1) technical assistance in research planning and design (on-site at Mulungu), and technical documentation; (2) training at CIAT-Rwanda and at CIAT headquarters in Colombia, and in university degree programs; (3) germplasm developed especially for Africa by the basic/strategic/adaptive research of the bean program at CIAT headquarters, which gives PNL direct access to any useful material developed through biotechnology, microbiology, soil fertility, pathology, physiology, and entomology research; and (4) financial and material support.

PNL/Mulungu functions essentially as a CIAT outstation. The only operating funds that arrive regularly are funds contributed by CIAT, which amount to about one-third of the total operating budget; the only transport until the last month of RAV II was a CIAT motorcycle; CIAT's Rwanda offices can be contacted by telephone and reached in a half-day's drive on paved roads. Added to this, PNL salaries at Mulungu are paid by INERA rather than by SENARAV, since PNL researchers there are INERA staff who were trained during the INERA Support Project. Gandajika headquarters is a two- to three-day, $1,000 journey away, with only erratic radio communication. It is clear that Mulungu identifies more closely with CIAT than with SENARAV.

In addition to the CIAT "upstream" collaboration, PNL/Mulungu has "downstream" collaborators (see Table 3.28), including, but not limited to, the GTZ Kabare Agricultural Development Project. These outreach collaborators multiply seed of promising varieties and provide funding and technical support for extension agents in villages, thus greatly extending the spread of benefits from PNL research. These advantages to PNL/Mulungu create a situation of unequal fortunes within PNL. M'Vuazi also has some advantages, such as electricity and proximity to headquarters in Kinshasa; Kaniameshi has electricity. Gandajika, Kaniama, and Kiyaka share very difficult conditions of isolation, difficult communications, and lack of electricity, health care, and adequate roads.

Mulungu is the obvious first choice for PNL headquarters, but neither peanuts nor cowpeas (two of the four PNL crops) are grown in that cool, high-altitude location. Gandajika, representative of poor savannah soils, is an essential site for PNL if its research is to be relevant. M'Vuazi and Kaniameshi (Lubumbashi) are already headquarters for PRONAM and PNM, respectively, and it is desirable for logistical reasons to spread headquarters offices among as many stations as possible so that each headquarters station can provide certain administrative services to the staff members of other programs who are located at that station.

This author's recommendation is to move PNL's bean/soybean headquarters to Mulungu, to station the peanut/cowpea researchers at M'Vuazi, and to require all

researchers to spend two to four months at Gandajika, where the program would be conducted by staff with three- or five-year national university degrees. This author does not recommend abandoning the Gandajika station for facilities outside Mbuji Mayi because of a certain stability conferred on the program by the existence of the station, given present unsettled times; however, when agricultural research in Zaïre gains a sounder footing in the future, this may be advisable.

References

Anota, T. 1992. "La filière semences au Zaïre." In Actes de la conference sur le lancement des variétés, la production et la distribution des semences de haricot dans la Région des Grandes Lacs, Goma, Zaïre, November 2-4, 1989 (Brouillon/Draft). CIAT.

Beadle, G. W. 1939. J. Hered. 30:245-47.

Beck, B. D. A. 1982. "Historical Perspectives of Cassava Breeding in Africa." In Root Crops in Eastern Africa, 13-128. Proceedings of a workshop held in Kigali, Rwanda, 1980. Report no. IDRC-177e. Ottawa: International Development Research Centre.

Berti, F. 1985. "Synthèse de travaux realisés sur Phaseolus aux Zaïre, Rwanda et Burundi de 1945 à nos jours." CIAT.

Bock, K. R. 1989. "ICRISAT Regional Groundnut Pathology Program, 1985-87." In ICRISAT, Proceedings of the Third Regional Groundnut Workshop for Southern Africa, March 13-18, 1988, Lilongwe, Malawi. Patancheru AP 5-2-324, India.

Bokosi, J. M. 1991. "Bean Evaluation in Africa." In Crop Genetic Resources of Africa, edited by F. Attere, H. Zedan, N. Q. Ng, and P. Perrino, 197-204. IBPGR/UNEP/ IITA/CNR.

Brewbaker, J. L. 1985. In Breeding strategies for maize production improvement in the tropics, edited by A. Brandolini and F. Salamini. Rome: Food and Agricultural Organization.

Camacho, L. 1990. "National Grain Legumes Program: Final Report on Improvement of Grain Legumes, 1986-1990." USAID/IITA/SENARAV Zaïre Project.

Camacho, L., and Kilumba, N. 1990a. "Rapport synthèse 1985-1990 sur la selection et l'amélioration du haricot commun." Gandajika: PNL. Mimeograph.

------. 1990b. "Rapport synthèse 1985-1990 sur la selection et l'amélioration du soja (Glycine max)." Gandajika: PNL. Mimeograph.

Conférence sur le lancement des variétés, la production et la distribution des semences de haricot dans la Région des Grandes Lacs. 1989. Annexe II. "Recommandations." In Actes de la conference sur le lancement des variétés, la production et la distribution des semences de haricot dans la Region des Grandes Lacs, Goma, Zaïre, November 2-4, 1989 (Brouillon/Draft). CIAT.

Conn, E. E. 1973. "Cyanogenic Glycosides: Their Occurrence, Biosynthesis, and Function." In Chronic Cassava Toxicity: Proceedings of a Workshop, edited by B. Nestel and R. MacIntyre, 55-63. Report no. IDRC-010e. Ottawa: International Development Research Centre.

Dashiell, K. L., E. N. Jackai, G. L. Hartman, H. O. Ogundipe, and B. Asafo-Adjei. 1991. "Soybean germplasm diversity, uses, and prospects for crop improvement in Africa." In Crop Genetic Resources of Africa, edited by F. Attere, H. Zedan, N. Q. Ng, and P. Perrino, 203-212. IBPGR/UNEP/IITA/CNR.

Elukessu, Komba Lumba. 1992. "Perspectives sur la multiplication des semences de base de haricot (Phaseolus vulgaris) au Programme National Légumineuses à Mulungu." In Actes de la conference sur le lancement des variétés, la production et la distribution des semences de haricot dans la Région des Grandes Lacs, Goma, Zaïre, November 2-4, 1989 (Brouillon/Draft). CIAT.

Engelbeen, M. 1948. Le soja au Congo Belge. Brussels: Ministère des Colonies, Direction de l'Agriculture et de l'Elevage.

Food and Agricultural Organization (FAO). 1986. Role of Roots, Tubers and Plantains in Food Security in Sub-Saharan Africa. Report to the Committee on Food Security, 11th Session (April 9-16, 1986). Rome: FAO.

Frangoie, Ngoie, Ngeleka Kadima, and Ndayi Kilumba. 1991. "Kyakulwa, nouvelle variété d'haricot (Phaseolus vulgaris L.) sélectionnées au SENARAV par PNL." Technical Report (fiche technique).

Gatsinzi, Nahimana, Nlancu ne Nsaku. 1989. Catalogue du germoplasme de la communauté economique des pays des grands lacs (Burundi, Rwanda, et Zaïre). Collecte de 1985 à 1988. Gitega, Burundi: Institut de Recherche Agronomique et Zootechnique (IRAZ).

Goodman, M. M. 1988. CRN Critical Reviews in Plant Sciences 7:197-220.

Hahn, S. K. 1979. "Cassava Improvement in Africa." Field Crops Research 2:193-226.

------. 1982. "Research Priorities, Techniques, and Accomplishments in Cassava Breeding at IITA." In Root Crops in Eastern Africa, 19-22. Proceedings of a workshop held in Kigali, Rwanda, 1980. Report no. IDRC-177e. Ottawa: International Development Research Centre.

Hahn, S. K. and A. K. Howland. 1973. "Breeding for Resistance to Cassava Mosaic." In Proceedings of Cassava Mosaic Workshop. Proceedings of a workshop held in Ibadan, Nigeria, 1972. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Hallauer, A. R., and J. B. Miranda. 1988. Quantitative Genetics in Maize Breeding. Ames: Iowa State University Press.

Institut National pour l'Etude Agronomique du Congo Belge (INEAC). 1936. Peanut Bulletin.

Institut Régional d'Agronomie et Zootechnologie (IRAZ). 1986. Synthèse du point de la recherche agronomique et zootechnique dans les pays de la Communauté Economique des Pays des Grands Lacs (CEPGL). Gitega, Burundi: Institut de Recherche Agronomique et Zootechnique (IRAZ).

------. 1988. Catalogue.

Jackai, L. E. N., and S. R. Singh. 1991. "Evaluation of cowpea insect resistance." In Crop Genetic Resources of Africa, edited by F. Attere, H. Zedan, N. Q. Ng, and P. Perrino, 85-94. IBPGR/UNEP/IITA/CNR.

Jennings, D. L. 1957. "Further Studies in Breeding Cassava for Virus Resistance." East Afr. Agric. J. 22:213-29.

Jones. 1959. Manioc in Africa. Stanford: Stanford University Press.

Kadima, Ngeleka. 1986. "Résultats de la campagne 1985-1986. Soja et arachide." Gandajika: PNL.

Kawano, K., A. Amaya, P. Daza, and M. Rios. 1978. "Factors Affecting Efficiency of Hybridization and Selection in Cassava." Crop Sci. 18:373-76.

Kilumba, Ndayi. 1990. "Synthèse des activités scientifiques de la sélection de niébé durant la période de 1985 à mai 1990." Gandajika: PNL.

Kilumba, N., and M. Kubengu. "Vigna unguiculata (Nkunde): Son importance et ses contraintes de production autour de la station de Gandajika, Kasai-Oriental."

Leakey, C. L. A., and J. B. Willis. 1977. Food Crops of the Lowland Tropics. Oxford: Oxford University Press.

Lonquist, J. H. 1964. "A Modification of the Ear-to-Row Procedure for the Improvement of Maize Populations." Crop Sci. 4:227-228.

Lubanga, Lunze, and N. Mulangwa. 1991. "Adaptation du haricot aux sols acides." In Proceedings of the Sixth Regional Seminar on Bean Improvement in the Great Lakes Region. Draft. CIAT.

Magoon, M. L. 1967. "Recent Trends in Cassava Breeding in India." In Proceedings of the 1st International Symposium on Tropical Root Crops, 100-117. St. Augustine, Trinidad: University of the West Indies.

Magoon, M. L., R. Krishanan, and K. V. Bai. 1969. "Morphology of the Pachytene Chromosomes and Meiosis in **Manihot esculenta**." Cytologia 34:612-24.

Mangelsdorf, P. C., and R. G. Reeves. 1939. "The Origin of Indian Corn and Its Relatives." Texas Agric. Exp. Sta. Bull. 574 (May 1939).

Mbikayi, Nkonko. 1988. "Développement variétal et amélioration du haricot au Zaïre." In Proceedings of the Fourth Regional Seminar on Bean Improvement in the Great Lakes Region, Bukavu, Zaïre, November 21-25, 1989. (CIAT African Workshop Series No. 9.)

------. 1991. "Variétés améliorées de haricot type volubile 'Aliya' (G2333) et 'Cihembe' (G 2331)." Mulungu: PNL.

------. 1992. "Processus de mise au point des meilleures variétés de haricot commun (Phaseolus vulgaris L.) par le Programme National Légumineuses (PNL). Connexion entre la recherche et les réseaux de diffusion de semences au Zaïre." In Actes de la conference sur le lancement des variétés, la production et la distribution des semences de haricot dans la Region des Grandes Lacs, Goma, Zaïre, November 2-4, 1989 (Brouillon/Draft). CIAT.

Mbikayi, N., Lodi Lama, Frangoie Ngoie, and M. M. Kalombo. 1990. "Développement variétal et amélioration du haricot commun au Zaïre: esquisse de travaux de recherche, 1985-1990."

Mbikayi, N., and M. M. Pyndji. 1991. "Incorporation de gènes de resistance à la maladie des taches anguleuses aux cultivars locaux de haricot." In Proceedings of the Sixth Regional Seminar on Bean Improvement in the Great Lakes Region. Draft. CIAT.

Miracle, Marvin. 1966. Maize in Tropical Africa. Madison: University of Wisconsin Press.

------. 1967. Agriculture in the Congo Basin: Tradition and Change in African Rural Economics. Madison: University of Wisconsin Press.

Mputu, Monsheviale, and Maya Bock. 1992. "La strategie de diffusion des semences de haricot au Project Kabare." In Actes de la conference sur le lancement des variétés, la production et la distribution des semences de haricot dans la Région des Grandes Lacs, Goma, Zaïre, November 2-4, 1989 (Brouillon/Draft). CIAT.

Muimba-Kankolongo, A., G. Muyolo, N. M. Mahungu, and S. J. Pandey. 1985. "Strategies of Programme National Manioc (PRONAM) of Zaïre in Screening Cassava for Resistance to Major Diseases." In Tropical Root Crops: Root Crops and the African Food Crisis. Proceedings of the Third Triennial Symposium of the International Society for Tropical Root Crops, Africa Branch, held in Owerri, Nigeria, August 17-23, 1986.

------. 1987. "Tropical Root Crops." In Root Crops and the African Food Crisis, edited by E. R. Terry, M.O. Akomada, and D. B. Arene. Ottawa: International Development Research Centre.

M'Vita, M., and N. Kilumba. 1991. "Adaptation du haricot au bas-fond." M'Vuazi: PNL.

Ng, N. Q., and P. Palulosi. 1991. "Cowpea distribution and importance." In Crop genetic resources of Africa, edited by F. Attere, H. Zedan, N. Q. Ng, and P. Perrino, 161-74. IBPGR/UNEP/IITA/CNR.

Programme Nationale des Légumineuses (PNL). 1986. Rapport Annuel. Gandajika: PNL.

------. 1987. Rapport Annuel. Gandajika: PNL.

------. 1988. Rapport Annuel. Gandajika: PNL.

------. 1989a. Rapport Annuel desiccation 1989. Gandajika: PNL.

------. 1989b. Les points saillants de la recherche du rapport annuel. Gandajika: PNL.

------. 1989-1990. Rapport annuel. Document de travail presenté à la revue scientifique général du SENARAV à Kinshasa. Gandajika: PNL.

------. 1991. Résumé des points saillants en sélection et amélioration du haricot commun (Phaseolus vulgaris L.). Gandajika: PNL.

Shannon, Dennis A. 1986. "Grain legume research in Zaïre: A review of past research from 1979 to 1985 and suggestions for the future."

------. 1990. "Final Report, Agronomist, International Institute of Tropical Agriculture." USAID Project 660-0091. Applied Agronomic Research and Extension Project.

Singh, T. P. 1980. "Breeding cassava resistance to pests and diseases in Zaïre." In Tropical root crops: Research strategies for the 1980s, edited by E. R. Terry, K. A. Oduro, and F. Caveness, 37-39. Report no. IDRC-163e. Ottawa: International Development Research Centre.

Sperling, L., U. Scheidegger, B. Ntambovura, R. Musungayi, and M. Muhandikire. 1992. "Analysis of bean seed channels in South Kivu, Zaïre, and Butare and Gikongoro Prefectures, Rwanda." CIAT Great Lakes Regional Bean Improvement Project.

Sprague, E. W., D. L. Winkelmann, T. G. Hart, T. Z. Pandosi, Salumu Shabani, and Mbuki Mwamufiya. 1979. Maize Strategy for the National Maize Program of Zaïre. Mexico City: CIMMYT.

Steiner, Herbert H. 1979. "Zaïre Ups Food Imports to Offset Declining Domestic Production." Foreign Agriculture 17 (February 1979):8.

Terry, E. R. 1978. "Productivity under CMD stress." In IITA Annual Report, 1978. 50-53. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Wedeman, M. G., E. F. Tollens, J. C. Denis, and G. E. Neill. 1988. "Threshold decision evaluation, Applied Agricultural Research and Outreach Project 660-0091." Kinshasa, Zaïre: USAID/Kinshasa and Chemonics International Consulting Division.

CHAPTER 4

PLANT PROTECTION

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I. Importance of Insect Pests and Diseases

Insect pests and diseases are major biological constraints to crop production. Insects not only cause damage by feeding on plant tissue; some insects are also vectors of many devastating viral diseases. All portions of the plant, from root to flower/fruit, are threatened by diseases and/or insects; all growth stages of plants, from seedlings to the mature plant, are vulnerable. Even after harvest, stored grain may also be attacked.

Worldwide crop loss due to insects and diseases is estimated at approximately 35 percent. In most cases, losses in tropical countries exceed the world average: The combined effect of insect attacks and plant diseases may result in a loss of 35 to 50 percent of the potential yield of crops in tropical areas. About 20 percent of total crop loss is due to insect attack during cultivation.

Pest attack may cause an additional 20 percent loss during post-harvest storage. These losses are often greater in countries that can least afford them. Insect damage to commodities in storage results in (a) actual weight losses, (b) loss in quality and so causing an additional loss in the commodity's market value, (c) promotion of mold development, (d) reduced nutritional value, and (e) reduced germination and thus reduced availability of seeds for planting in the subsequent cropping season.

II. Insect Pests and Diseases of Cassava

A. Introduction

Zaïre is the largest cassava-producing country in Africa, and cassava is the most important staple food in the country. The average yield of cassava in Zaïre is approximately 7 ton/ha, which is low compared to other cassava-producing countries. This low yield is due to lack of improved varieties, poor management practices, and pest and disease problems.

The most devastating disease in Zaïre is the cassava bacterial blight (CBB), which is capable of causing root yield losses of up to 90 percent. In addition, CBB causes serious reduction in leaf production.

The important arthropod pests of cassava in Zaïre are cassava mealybugs and cassava green mites. Both are introduced pests and with severe infestations may cause yield losses of up to 100 percent to both tuberous roots and leaves.

In 1968-69 a serious cassava disease appeared in the Bandundu region of Zaïre and soon spread in epidemic form to the Bas-Zaïre and Kasai regions. In 1973, the Government of Zaïre asked the International Institute of Tropical Agriculture (IITA) in Ibadan, Nigeria, to send experts to identify the disease and provide suggestions for its control. The IITA visiting team identified the disease as cassava bacterial blight. It was then that the Government of Zaïre realized the importance of research on cassava and requested IITA to assist in establishing a national cassava program.

The Programme National du Manioc (PRONAM) of Zaïre was established in 1974. IITA provided technical assistance and administered training programs with funds provided by the Zaïrian Government. USAID assistance to support the cassava program began in 1980. The main objective of the program was to develop high-yielding cassava varieties resistant to major diseases and insect pests.

B. Research Strategies and Control Status

In general, cassava in Zaïre did not suffer from many insect pests or diseases until 1969. The situation changed when serious outbreaks of cassava bacterial blight and cassava mealybugs appeared in different regions during the 1970s. Among the arthropod pests of cassava in Zaïre, the cassava mealybug, **Phenacoccus manihoti**, and the cassava green mite, **Mononychellus tanagoa**, are the most important (see Table 4.1). Yield losses due to these pests may approach 100 percent with severe infestations. The most important cassava diseases in Zaïre are bacterial blight, mosaic virus, anthracnose, and stem-tip dieback (see Table 4.2).

The PRONAM entomology section was established in 1976 primarily as a response to the threat posed by the cassava mealybug. Four approaches were taken to control cassava mealybugs and green mites: (a) breeding for resistance, (b) biological control, (c) cultural control, and (d) chemical control. Breeding for resistance and cultural control were the focus of disease control strategies.

In the beginning, PRONAM entomologists and pathologists concentrated their efforts on epidemiological/bioecological studies of major diseases, crop loss assessments, surveys of insect pests and diseases, and development of simple methodologies and techniques for varietal screening.

Population dynamics studies of cassava mealybugs showed that mealybug populations increase during the dry season and decrease in the rainy season. The distribution of mealybugs in Zaïre, mode of spread, and biology were studied. The pattern of field infestations of mealybugs depends on crawlers (immature stage of mealybug), wind speed, and wind direction. Long distance spread is facilitated by the movement of infested leaves and planted materials. Yield losses due to mealybug infestations range from 54 to 84 percent depending upon the severity of infestation and age of the plant at the time of attack. Techniques have been developed for varietal screening for mealybugs and green mites. Several local predators and parasites of mealybugs have been recorded (see Table 4.3).

Table 4.1. Arthropod Pests of Cassava in Zaïre

Order and Family	Common Name	Scientific Name
HOMOPTERA		
Pseudococcidae	Mealybug	**Phenacoccus manihoti** M.-F.
Aleyrodidae	Whitefly	**Bemisia tabaci** (Gennadius)
Diaspidae	Cassava scale	**Aonidomytilus albus** (Ckll.)
HEMIPTERA		
Coreidae	Coreid bug	**Pseudothraptus devastans** D.
ORTHOPTERA		
Pyrgomorphidae	Grasshopper	**Zonocerus variagatus** (L.)
ISOPTERA		
Termitidae	Termite	no confirmed identification
ARACHNIDA		
ACARIFORM	Green mite	**Mononychellus tanajoa** Bondar **Mononychellus progresivus**
	Red mite	**Olygonychus gossypii**

Source: Programme National du Manioc (1976 to 1982); Singh and Lutaladio (1980); IITA (1985); and Nsiama She et al. (1990).

Cassava anthracnose, previously believed to be caused only by the fungus **Colletotrichum gloeosporioides** f. sp. **manihotis**, also involves a sap-feeding coreid bug, **Pseudotheraptus devastans**. Feeding by the insect is apparently necessary for fungal colonization and canker development. The fungus can be carried in the insect's body. The cassava plant debris left in the field after harvest can be an important source of inoculum of fungal pathogen.

Infection of the same cassava plant by both bacterial blight and anthracnose is frequently observed under field conditions. PRONAM studies have shown that inoculation with the bacterium (causal agent of bacterial blight) followed by inoculation with the fungus (causal agent of anthracnose) causes more severe leaf wilting dieback and long stem lesions than does inoculation with either pathogen alone. Results also showed that causal agent of anthracnose, **Colletotrichum gloeosporioides** f. sp. **manihotis**, is a weak pathogen alone; however, in the presence

Table 4.2. Major Diseases of Cassava in Zaïre

Common Name	Causal Organism
Bacterial blight	**Xanthomonas campestris** pathovar. **Manihotis**
Anthracnose	**Colletotrichum gloeosporioides** f. sp.**manihotis**
Cassava mosaic virus	Virus
Stem tip dieback	no confirmed identification
Leaf spot	**Cercospora** sp.

Source: Muimba et al. (1987); Programme National du Manioc (1976); IITA (1985).

of **Xanthomonas campestris** (causal agent of bacterial blight), severe crop losses can occur. Yield losses of leaves, an important constituent of the diets of many Zaïrians, due to cassava bacterial blight were studied; the results showed that inoculation of a bacterial blight susceptible clone resulted in loss of more than 60 percent of edible leaves.

PRONAM pathologists also developed methods for scoring diseases and techniques for varietal screening (see Chapter 3 for details). Cassava "tip detopping" proved very effective for resistance screening to mosaic virus.

C. Host Plant Resistance

One of the most practical methods of control for cassava diseases and insect pests is host plant resistance. Accordingly, for the last 15 years, PRONAM has assigned high priority to breeding for resistance to major cassava diseases (bacterial blight, mosaic and anthracnose), and insects (mealybugs) and mites (green mites). Breeders, pathologists, and entomologists work together as a multidisciplinary team to develop high-yielding cassava varieties resistant to diseases and insect pests. The breeding program has been designed accordingly. Starting from seedling nurseries, screening for resistance to diseases and insect pests is performed. Materials are evaluated to determine target diseases and insect pests either by artificial inoculation/infestation or by natural infection/infestation. Final evaluations of selected varieties are done through multilocational trials.

Table 4.3. Local Predators and Parasites Associated with Cassava Mealybug (Phenacoccus manihoti) in Zaïre

Order and Family	Species
	Predators
ARANEAE	
Theridiidae	Argyrodes sp.
HOMOPTERA	
Anthocoridae	Cardiastethus exiguus Poppius
Reduviidae	Rhynocoris segmentarius (Germar)
COLEOPTERA	
Anthicidae	Formicomus ?niveopilosus F.
Coccinellidae	Cheilomenes lunata (F.)
	C. propinqua (Mulsant)
	C. sulphurea (Olivier)
	Chilocorus angolensis Crotch
	Clitostethus neuenschwanderi Fursch
	Declivitata uncifera Fursch
	Diomus hennesseyi Fursch
	Exochomus flavipes (Thunberg)
	E. ventralis Gerstaecker
	Hyperaspis aestimabilis Mader
	H. senegalensis Mulsant
	Isora circularis Mader
	Micraspis striata (F.)
	Nephus flavomaculatus (Fursch)
	N. phenacoccophagus Fursch
	N. reunioni (Fursch)
	Platynaspis capicola Crotch
	P. vittigera Weise
	Scymnus kibonotensis Weise
	S. levaillanti Mulsant
	S. viduus Weise
Corylophidae	Aposericoderus sp.
	Arthrolips sp.
Lathridiidae	Corticarina sp.

Table 4.3, continued

Order and Family	Species
LEPIDOPTERA	
Cosmopterigidae	**Pyroderces hemizopha** (Meyrick)
Lycaenidae	**Spalgis lemolea** Druce
Tortricidae	**Archips occidentalis** (Walsingham)
DIPTERA	
Cecidomyiidae	**Coccodiplosis citri** Barnes **Diadiplosis** sp. nr. **hirticornis** Felt **Dicrodiplosis manihoti** Harris
Syrphidae	**Allobaccha** sp. **Melanostoma annulipes** (Macquart)
	Parasites
HYMENOPTERA	
Aphelinidae	**Coccophagus** sp.
Encyrtidae	**Aenasius** sp.nr.**bugandaensis Compere** **Anagyrus sp.**

Source: Neuenschwander et al. (1987).

Note: Question marks here appear in the original data.

At the beginning of the project, locally cultivated varieties were evaluated on their disease resistance, and all proved to be susceptible to cassava bacterial blight, cassava mosaic disease, and anthracnose. As a result, large numbers of cassava seeds (100,000) were introduced from IITA to increase genetic variability and were evaluated for resistance to major diseases. The evaluation results showed considerable differences in their reaction to diseases. A total of 109 clones showed multiple disease resistance to bacterial blight, mosaic, and anthracnose. This procedure led to the identification of two varieties resistant to cassava bacterial blight, cassava mosaic virus, and anthracnose. Also, a resistant donor to cassava mealybug (TMS 70453) has been identified, but it has poor agronomic characteristics, especially low yield. The population development rate of mealybug on clone 70453 was almost 14 times less than the susceptible clone 02864 (see Table 4.4). As far as we are able

Table 4.4. Population Build-up of Cassava Mealybug on Resistant and Susceptible Clones

Clone	Immature CM	Pre-ovipositing CM	Ovipositing Adults	Total
70453 (Res.)	16.3**	0.5**	1.00**	17.8**
02864 (Sus.)	195.1	29.8	17.00	241.9

Source: IITA (1982).

Note: Each shoot of clone 70453 and of clone 02864 was infested with three adult cassava mealybugs, and observations were recorded one month after infestation.

** = highly significant at 1% level

to discern, PRONAM clone 70453 is, at the moment, the only cassava clone in the world with a proven good level of resistance to mealybugs. The clone 70453 shows two interesting characteristics: (1) ability to retard development of mealybug population and (2) tolerance to mealybug attack, which suggests low level of antibiosis (tolerance may be the mechanism of resistance). PRONAM breeders have been using this clone as a donor in their breeding program, and many other promising lines are also in the pipeline. A hybridization program is currently underway to develop varieties resistant or moderately resistant to the cassava mealybug.

The team efforts of plant pathologists, breeders, and extension specialists of PRONAM led to the identification of many sources of resistance to major cassava diseases in Zaïre. Some of the selected clones are 30085/28, F 100, 4(2)0426/1, 30572/149, 02864, 30010/10, 61665/4, and 41784/9. The reactions of the best PRONAM selections to major cassava diseases in Zaïre are shown in Table 4.5.

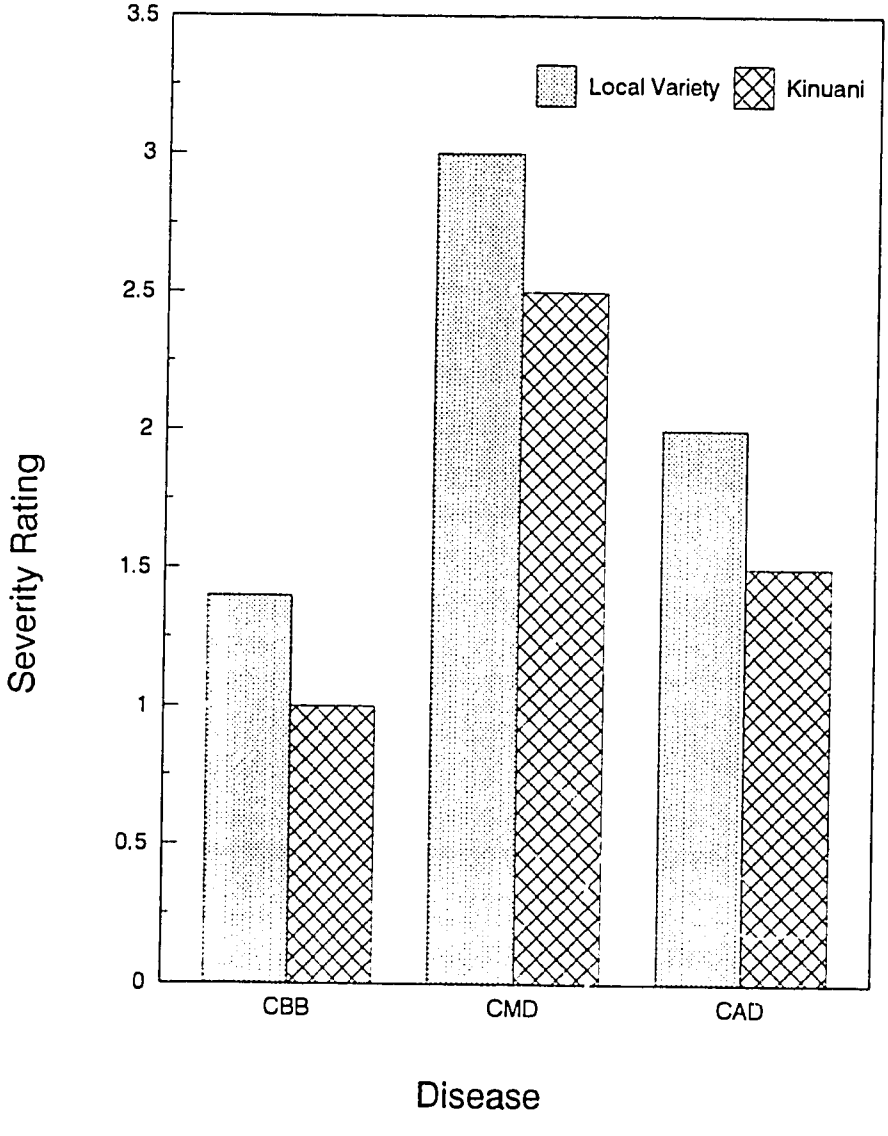
The first improved variety from PRONAM was Kinuani, released in 1983. Kinuani, which means "fighter" in the local language of Bas-Zaïre, possesses good resistance to bacterial blight, mosaic virus, and anthracnose (see Figure 4.1). Kinuani is also moderately resistant to green mites. The reactions to major diseases and insect pests of two PRONAM-released varieties and a clone are shown in Table 4.6.

Table 4.5. Reactions of the Best PRONAM Selections to Major Cassava Diseases

Selection	Disease Severity		
	CMV	CBB	CAD
M'Vuazi			
Kinuani	2.3	2.0	2.6
02864	2.7	2.0	3.5
30344/6/2	1.9	3.6	3.5
61665/4	1.7	2.4	2.0
50467/12	2.1	2.5	3.0
41784/9	2.0	3.0	3.0
40230/3	2.0	2.8	3.5
A 56	2.6	4.5	2.8
Mpelolongi(Ch)	2.3	4.0	3.5
Kiyaka			
F 100	2.0	2.6	3.0
F 150	2.7	3.0	3.0
F 156	3.0	2.6	2.5
F 113	2.6	4.0	3.0
F 162	3.7	3.5	4.0
Gandajika			
5220-5217/7	1.9	3.5	3.0
A 56/1	3.6	3.5	2.5
G 11/5	3.7	3.5	2.5
MWP/7	3.0	2.5	2.0
30085/28/10	3.0	2.5	2.0
30085/28/4	2.6	3.0	2.5
33787/6	2.9	3.0	2.0
Bitter cassava (six months)	3.6	4.0	3.0
4(2)0426/1	2.8	2.5	3.0
60882/10	2.8	2.5	2.0
60441/8	3.9	3.5	2.5
30093/6	3.8	3.5	3.0
Kazebe	4.0	4.0	3.0

Source: Muimba et al. (1987).
Notes: Disease severity ranges from 1 to 5; 1 = no symptoms and 5 = severe infection. CMV = cassava mosaic virus; CBB = cassava bacterial blight; CAD = cassava anthracnose disease.

Figure 4.1 Reactions of Kinuani and a Local Variety to Three Cassava Diseases



Note: CBB = Cassava Bacterial Blight; CMD = Cassava Mosaic Disease; CAD = Cassava Anthracnose Disease.

Source: IITA (1985).

Table 4.6. Reactions of PRONAM-Released Cassava Varieties/Clones to Major Diseases and Arthropod Pests

Pest	Variety/Clone		
	Kinuani (300085/28)	F 100	70453
Mealybug	HS	HS	R
Green mite	MR	HS	HS
Bacterial blight	R	MR	MR
Anthracnose	MR	MR	S
Mosaic virus	MR	MR	S

Source: Based on Nsiama She et al. (1990), as modified by Alam (1990).

Note: R = resistant; MR = moderately resistant; S = susceptible; HS = highly susceptible.

D. Cultural Control

PRONAM pathologists and entomologists selected cultural control as one of their approaches to combat major cassava diseases and insect pests. Results of studies on cultural control conducted since 1980 showed that the severity of cassava bacterial blight and mosaic virus was reduced when cassava was intercropped with maize rather than grown as a monoculture. Intercropping with groundnut did not affect disease severity. It seems that maize may provide a physical barrier for the dispersion of inoculum.

In 1980, stem-tip dieback, a previously unknown disease, was observed in Bas-Zaïre. It results in the death of tertiary branches during the dry season and the decay of tuberous roots. Various studies on cultural control of this disease during the period 1980-1985 indicated that (a) cassava planted late in the rainy season was less affected than cassava planted early, (b) mulching reduced the incidence of disease, and (c) dieback incidence and decay of tuberous roots were reduced as the application of potassium fertilizer increased to 150 kg K_2O/ha.

Selection of planting materials for ensuing cropping seasons has a positive effect on the incidence and severity of cassava mosaic disease. It was found that, as the level of severity of cassava mosaic virus in planting material increased, the incidence and severity of the disease in the resulting crop rose significantly. Thus, growth, yield and disease development depend not only on the presence or absence of viral infection in the planting material, but also on the severity of the infection.

Mulching and land preparation have also been shown to reduce the incidence and severity of cassava mealybugs.

E. Chemical Control

The use of insecticides/fungicides as foliar sprays is discouraged since cassava leaves are a major part of the daily diet in Zaïre. Moreover, cassava is a subsistence crop that is intercropped in small holdings where insecticides are relatively expensive and dangerous in application.

A preliminary trial of dipping cuttings of cassava stem in dimethoate (Rogor) solution 500 g a.i. at the rate of 5 ml/l of water for five minutes and sun drying for five hours before planting gave satisfactory control of cassava mealybug infestation up to eight weeks. This practice cannot be used as a sole control method of mealybugs, but it may be used as a component of an integrated pest management program. This practice may also limit the spread of mealybugs from one location to another by the use of clean planting materials, as crawlers often hide inside the sprouting buds of cassava stem cuttings.

F. Biological Control

The International Workshop on the Cassava Mealybug held at M'Vuazi, Bas-Zaïre, in June 1977 recommended that "control strategies should place emphasis on breeding for host plant resistance and biological control. However ... for short-term results, both cultural and chemical approaches are encouraged and should be incorporated within the framework of an integrated pest management program ...." Based on this recommendation, an expatriate entomologist was recruited in 1981 to work on biological control of cassava mealybug for PRONAM when USAID began supporting the project.

Biological control of cassava mealybug in Zaïre was actually initiated in 1978; USAID began its support for PRONAM in 1980. This and the support of the Biological Control Program (BCP) of IITA/Ibadan, Nigeria, strengthened the control program considerably. As a result, effective biological control of cassava mealybug in Zaïre started in 1982 with the release of several species of natural enemies.

By this time another exotic arthropod pest, the green mite, had also become a serious problem affecting cassava production in Zaïre. Biological control was considered to be an appropriate approach to combat this pest. Nine species of natural

Table 4.7. **Natural Enemies of Cassava Pests Released in Zaïre**

Species	Family	Common Name	Target Species	Trophic Level
Allotropa sp.	Platygasteridae	none	CM	Parasite
Diomus sp.	Coccinellidae	Ladybird beetle	CM	Predator
Epidinocarsis lopezi	Encyrtidae	none	CM	Parasite
Hyperaspis jucunda	Coccinellidae	Ladybird beetle	CM	Predator
Hyperaspis notata	Coccinellidae	Ladybird beetle	CM	Predator
Sympherobius maculipennis	Sympherobiidae	Brown lacewing	CM	Predator
Neoseilulus anonymus	Phytoseiidae	none	GM	Predator
Neoseiulus idaeus	Phytoseiidae	none	GM	Predator
Galendromus annectens	Phytoseiidae	none	GM	Predator

Note: CM = cassava mealybug; GM = green mite.

enemies have been imported from South America by IITA for biological control of cassava pests in Zaïre, six to combat mealybugs and three to combat green mites (see Table 4.7). Additional releases were also made, and the effectiveness of released natural enemies was evaluated over a large area. Follow-up surveys and monitoring results revealed that the parasite, **Epidinocarsis lopezi** (de Santis) had become established and widespread. A predator, **Diomus** sp., was also established only in the Kinshasa area. As a result of the establishment of **E. lopezi**, the mealybug population has been reduced in many areas in Zaïre. Nevertheless, a few sites of infestation still

persist, and some new mealybug-infested areas are constantly appearing in the country. Therefore, the mealybug problem is only partially solved and will require further releases in the newly infested areas.

The biological control method was also utilized for the control of green mites in Zaïre. Eggs and active stages of three phytoseiid predator mite species, **Neoseiulus idaeus, N.anonymus** and **Galendromus annectens**, were released on several occasions in green mite-infested areas in Zaïre. So far, releases to control the green mite have been unsuccessful.

G. Integrated Pest Management

The International Workshop on the Cassava Mealybug in 1977 suggested that cultural and chemical control be incorporated into the framework of an integrated pest management (IPM) program in Zaïre.

Knowledge of a pest's basic biology and ecology is essential to gain insight into the interaction of the pest with the component of the ecosystem in which it thrives. Lack of accurate biological information can have serious consequences for the development of an IPM program. During the period 1980-1990, PRONAM conducted a considerable number of studies on the bioecology/epidemiology of major pests and diseases. There was also some success with individual pest control methods such as host plant resistance, biological control, and cultural control, as discussed earlier. There is now a need to integrate these components in a way that will provide cost-effective control of cassava diseases and pest complexes in each agroecosystem.

During the second phase of RAV II, emphasis was to have been placed on the integration of these results into feasible IPM strategies to effectively control the major pests and diseases of cassava in Zaïre.

III. Insect Pests and Diseases of Maize

A. Introduction

Maize is a staple food in Zaïre, second only to cassava. Its importance in Zaïre is increasing due to population growth and shift in food preferences. Most of the maize production and consumption occurs in the southeastern quadrant of Zaïre (the Kasai Oriental, Kasai Occidental, and Shaba regions). Maize is also grown elsewhere in Zaïre, but other crops are more staple in those regions.

Most of the maize in Zaïre is grown as a subsistence crop. Average yield per hectare is less than one ton. The major limiting factor is the low level of management starting from seed selection through field preparation, time of planting, and use of

fertilizers. Only 15 percent of total maize area is planted using improved open-pollinated varieties.

Disease and insect pests are also major constraints to maize production in Zaïre. All parts of the plant are attacked by a number of diseases and insect pests, which reduces yield quality and quantity. The extent of damage varies from year to year.

Zaïre's Programme National du Maïs (PNM) began in 1972 through USAID support to CIMMYT (International Maize and Wheat Improvement Center, Mexico) for development of a strong program of maize research and training. Prior to the creation of PNM, the Institut National pour l'Etude et la Recherche Agronomique (INERA) was responsible for maize research in Zaïre. The CIMMYT team left Zaïre in 1981, and the program was continued, with difficulties, by local scientists. USAID renewed support to the maize program in 1985 under the Zaïre Applied Agricultural Research and Outreach Project (RAV I). Two other programs (cassava and grain legumes) were also supported. The International Institute of Tropical Agriculture (IITA) provided technical assistance for RAV I under cooperative agreement. RAV I ended September 30, 1990, and RAV II began on October 1, 1990. The South-East Consortium for International Development (SECID) was the prime contractor. Project activities were suspended in September 1991 due to civil unrest and political disturbance in the country.

B. Research Strategies and Control Status

Although insects did not pose a serious threat to maize production in Zaïre in the early 1970s, all varieties were found to be susceptible to maize streak virus and downy mildew disease. With the shift from traditional practices to new technologies and the increase in the area under maize production, insects and diseases now are one of the major constraints to maize production in Zaïre. A severe outbreak of a particular disease or insect may cause almost complete loss of a maize crop. Maize yield loss attributable to insects and diseases in Zaïre is estimated at 20 percent.

The objectives of the Programme National du Mais (PNM) are similar to those of the Programme National du Manioc: to develop varieties of high-yielding maize resistant to the prevailing economically important diseases and insect pests and to improve other agronomically desirable traits.

When PNM got underway in 1972, the nation had only a few trained scientists, and little was known about the severity of damage to maize caused by diseases and insect pests. Therefore, during the period of CIMMYT involvement (1972-1981), PNM's entomologists and plant pathologists performed regional surveys to assess the incidence and severity of various diseases and insect pests. Work was also begun on breeding for resistance and on cultural and chemical control of major insect pests and diseases.

Screening cultivars for resistance was based on field evaluation of natural infestation/infection. Efforts were concentrated mainly on evaluation of introduced cultivars from CIMMYT, IITA, Thailand, Kenya and other countries. Results of these surveys revealed that there were six species of insects and seven diseases affecting maize in Zaïre. Among them, the most destructive diseases of maize in Zaïre were found to be the maize streak virus (MSV) and downy mildew. The maize streak is caused by a virus-like agent and is restricted to Africa and its surrounding islands. Downy mildew is caused by a fungus. Severe infection of MSV was first observed during the 1972-73 cropping season, and late-planting materials were 100 percent infected. They also noticed that while two foliar diseases, caused by **Helminthosporium maydis** and **H. turcicum**, showed a high incidence in many introduced varieties, incidence in local varieties was insignificant. In the case of insects, they found that cutworms (**Agrotis ipsilon**), which attack late-planted maize in the Shaba region, and root worms were the most destructive. Stored maize was often heavily damaged by insect pests.

CIMMYT efforts during the period 1972-1981 resulted in six varieties: Shaba safi, Shaba-1, PNM-1, Kasai-1, Salongo-1, and Salongo-II. But these varieties lacked adequate resistance to disease, especially to MSV and downy mildew, and to major insect pests.

Maize research declined after CIMMYT's withdrawal in 1981. USAID's renewed support to PNM in 1985 was accompanied by the return of some trained personnel and the arrival of technical assistance team members. Maize research activities were revived and strengthened. The major objective of PNM during RAV I was to develop high-yielding varieties of maize resistant to major diseases and insect pests, especially maize streak virus. Pest control strategies focused on breeding for resistance and on cultural control. In addition, the plant protection specialists placed emphasis on regional surveys to assess disease and insect pests and crop loss, on bioecological studies, and on development of simple, reliable methodologies for varietal screening for resistance.

PNM conducted disease surveys during RAV I in four major agroecological zones for three years to determine the incidence and severity of maize diseases in Zaïre (Table 4.8). Table 4.9 summarizes the relative occurrence of maize diseases in different maize-growing areas in Zaïre. Maize streak virus and downy mildew, **Helminthosporium turcicum, H. maydis,** are the most important. Stalk and ear rot, **Diplodia**, brown spot, **Physoderma**, leaf spot, rust, bacterial stalk rot, and parasitic weed (Striga) also showed increased levels of infection in several places.

Maize streak virus, transmitted by leafhoppers of the genus **Cicadulina**, is one of the most economically damaging diseases in Zaïre. It was found that yield losses due to MSV and stem borer are very dependent on planting date. Losses to MSV began at 0 percent in early-planted fields but increased rapidly, reaching 50 percent in late-planted fields.

Table 4.8. Agroecological Description of Maize Diseases and Insect Pests Study Sites

Parameter	Site				
	Kaniameshi (S. Shaba)	Kaniama (N. Shaba)	Gandajika (K. Oriental)	Kiyaka (Bandundu)	M'Vuazi (Bas-Zaïre)
Longitude	28E	24E	24E	19E	15E
Latitude	12S	8E	7S	6S	5S
Altitude (m)	1,200	950	780	735	470
Ecology	Savannah	Valley	Savannah	Savannah/ Valley	Valley
Rain Period	Oct-May	Aug-May	Aug-June	Aug-June	Sept-June
Annual Rainfall (mm)	1,150	1,500	1,450	1,600	1,900
Temperature Range (°C)	2-34	14-33	14-34	15-33	16-32
Mean Temperature (°C)	18	23	24	24	24
Maize Planting Season	Dec-May	Sept-Feb Jan-May	Sept-Feb Feb-June	Sept-Feb Feb-June	Oct-March Feb-June

Source: Johnson (1990b), as modified by Alam (1990).

Surveys during RAV I revealed that 34 species of insects and 14 diseases were associated with maize in Zaïre (Tables 4.10 and 4.11). Among the insect pests are stem borer (**Busseola fusca**), storage weevil (**Sitophilus** spp.), grain moth (**Sitotroga cerealella**), and termites and leafhoppers (**Cicadulina** spp-vector of maize streak virus). In the Gandajika area, root mealybug (locally known as shimbu), **Crypticera** sp. (**Vrydagha lepesmei,**) is also considered an important pest of maize.

Table 4.9. Relative Occurrence of Maize Diseases in Maize-Growing Areas of Zaïre

Kaniameshi (S. Shaba)	Kaniama (N. Shaba)	Gandajika (Kasai Oriental)	Kiyaka (Bandundu)	M'Vuazi (Bas-Zaïre)
Streak	Downy mildew	Downy mildew	P. polysora	Diplodia
H. turcicum	H. turcicum	Striga	H. maydis	Curvalaria
Physoderma	Streak	Phyllosticta	Streak	Erwinia
P.sorghi	P.sorghi	Streak	P. sorghi	Cercospora
Curvalaria	Striga	H. maydis	Curvalaria	P. polysora
Diplodia	Physoderma	P. sorghi		Phyllosticta
H. maydis	Phyllosticta	H. turcicum		H. maydis
Cercospora	H. maydis	Curvalaria		Streak
	Diplodia			H. turcicum

Source: Johnson (1990b), as modified by Alam (1990).

Note: Diseases are listed in order of importance.

Cicadulina mbila, the predominant species of the vector of maize streak virus, was also studied during RAV I. Basic biology, species composition, host suitability for mass-rearing, alternate hosts, natural enemies and percentage of viruliferous insects in the native population were studied. For stem borer, **Busseola fusca**, "hot spot" for screening for resistance under natural infestation and optimum time of planting of varietal screening were determined.

Methodologies and techniques for evaluating maize varieties/lines with resistance to major diseases and insect pests have been developed, but there is still much progress to be made.

Table 4.10. Maize Insect Pests in Zaïre

Order and Family	Common Name	Scientific Name
	Field Insects	
LEPIDOPTERA		
Noctuidae	Stalk borer	**Busseola fusca** (Full.)
	Pink borer	**Sesamia calamistis** (Hamps)
	Cut worm	**Agrotis ipsilon** H.
	Army worm	**Spodoptera exiqua**
	Boll worm	**Heliothis armigera**
Pyralidae	Sugarcane borer	**Eldana saccharina** Walk.
COLEOPTERA		
Curculionidae	(no common name)	**Apion** sp.
Coccinelidae	Lady bird beetle	**Chnootribia similis** (Thunb)
Meloidae	Blister beetle	**Mylabris** sp.
Nitidulidae	(no common name)	**Brachypeplus** sp.
HOMOPTERA		
Cicadellidae	Leafhopper	**Cicadulina mbila** (Naude) **Cicadulina ghauri** D.
Aphididae	Aphid	**Rhopalosiohum** sp.
Cercopidae	Spittle bug	**Locris arithmetica** Walk. **Locris auripennis** Distant
Delphacidae	Planthopper	**Peregrinus madis**
Margarodidae	Root mealybug	**Crypticera** sp. (=**Vrydagha lepesmei**)

Table 4.10, continued

Order and Family	Common Name	Scientific Name
HEMIPTERA		
Coreidae	(no common name) (no common name) Bug	**Antestica cincticollis** S. **Borerias fumigata** (Distant) **Aspavia** sp.
Pyrrhocoreidae	Cotton bug	**Dysdercus** sp.
ORTHOPTERA		
Acrididae	Grasshopper	**Spathosternum** sp. **Zonocerus** sp.
ISOPTERA		
Termitidae	Termite	Macrotermis Microtermis
	<u>Storage insects</u>	
LEPIDOPTERA		
Gelicidae	Grain moth	**Sitotroga cerealella** Oliv.
Pyralidae	Indian meal moth	**Plodia interpunctella** (H.)
COLEOPTERA		
Curculionidae	Maize weevil	**Sitophilus oryzae** (L.) **Sitophilus zeamais** (M.)
Tenebrionidae	Flour beetle	**Tribolium castaneum** H.
Silvanidae/ Dermestidae	(no common name)	**Trogoderma granarium** E.
	Saw-toothed beetle	**Oryzaephilus** sp.

<u>Source</u>: Programme National du Maïs (1974); Hennessey (1989); Alam (1990).

Table 4.11. Maize Diseases in Zaïre

Common Name	Causal Organism
Upland blight	**Helminthosporium turcicum**
Leaf blight	**Helminthosporium maydis**
Downy mildew	**Perenosclerospora** sp.
Brown spot	**Physoderma maydis**
Southern rust	**Puccina polysora**
Common rust	**Puccinia sorghi**
Leaf spot	**Curvalaria** sp.
Ear and stalk rot	**Diplodia** sp.
Cercospora leaf spot	**Cercospora** sp.
Yellow leaf blight	**Phyllosticta maydis**
Bacterial stalk rot	**Erwinia** sp.
Charcoal rot	**Macrophomina** sp.
Maize streak	Virus
Striga	**Striga asiatica** **Striga forbesii**

Source: Programme National du Maïs (1973, 1974, and 1975); Johnson (1990b).

C. Host Plant Resistance

During RAV I, PNM placed the highest emphasis on resistance breeding as a strategy for disease and insect control. The primary strategy of disease resistance development was the back-cross improvement technique using sources of resistance from IITA. This was first initiated in the PNM existing varieties, Kasai-I, Solongo-II, and Shaba-I. Because maize streak virus and downy mildew are the most important diseases in the Kasai and North Shaba regions, Kasai-I and Salongo-II were improved to increase resistance to these diseases. A similar approach was initiated to improve Shaba-I's resistance to maize streak and **Helminthosporium turcicum**, the most prevalent and important diseases in South Shaba, where this variety is recommended. The improvement of Kasai-I, Salongo-II, and Shaba-I for resistance to major diseases may prove to be one of the important accomplishments of RAV I.

Several varieties/lines were identified as resistant to maize streak virus, bacterial blight, and downy mildew through international variety trials conducted during RAV I (Tables 4.12, 4.13, and 4.14). Two of these varieties, Babungo (3) 83 TZMSR-W and IK 83 TZSRY-1, were identified for release in the country. Both varieties, which originally came from IITA, have high levels of resistance to maize streak virus and to bacterial blight and have high yield potentials. The variety Babungo (3) 83 TZMSR-W was given the name Babungo 3 and proposed for release for country's most important maize production area in South Shaba. The variety IK 83 TZSRY-1 was also proposed for release in the Bandundu region. Table 4.15 illustrates the reaction of PNM-improved varieties to major diseases and insect pests.

The success of any program with the objective of breeding for resistance to diseases and/or insect pests depends largely on the development of suitable and reliable screening techniques. Such techniques must be simple and inexpensive. Field screening under natural infestation/infection is often unsuccessful because the incidence of pests is erratic. To overcome this problem and to minimize the chance of "escapes" in screening, it is necessary to infest/infect a large number of plants artificially every season. For that purpose, mass production of target pests is essential. Realizing the importance of maize streak virus and storage weevil in Zaïre, PNM entomologists developed low-cost techniques for mass-rearing Cicadulina leafhoppers and storage weevil at Lubumbashi and were able to infest approximately 25,000 plants with approximately 50,000 leafhoppers in two years. Mass-rearing of **Cicadulina** leafhoppers in Lubumbashi is very difficult due to low temperatures during the winter months (June through August). At a minimum, facilities for mass-rearing of leafhoppers at Lubumbashi requires a greenhouse with heating units to maintain proper temperature. Two such greenhouses were procured in 1989 but could not be erected due to lack of a permanent site of PNM headquarters. It is expected that with the installation of two greenhouses, mass-rearing of **Cicadulina** leafhoppers at Lubumbashi will be increased to a level that will fully support a MSV resistance breeding program of PNM.

Table 4.12. Varieties/Lines Showing Resistant Reaction to MSV in Response to Natural Infection

Location	Source	1987-88 Season	1988-89 Season
Lubumbashi	IITA	Bab(3)83 TZMSR-W Jos(1)83 TZMSR-W Jos 85 TZMSR-W Acr 83 TZMSR-W MM(2) 83 TZMSR-W IK 83 TZSR-W TZB Gus SR EV 8443 SR Gwebi 84 Pool 16 Ik 84 Pool 16 8321-21 8537-18 8534-7	Jos(1) 83 TZM Foun(1) 85 TZM
	PNM	--	Ik 83 x Bab.3F1 Ik 83 x TZB F1 Ik 83 x 8321-21 F1 Ik 83 x Pop 22 F1 HSA x IITA 502 F1 Bab.3 x SR 52 F1 Shaba 1 x SR 52
Gandajika	IITA	MM(1)85 TZMSR-W MM(2)85 TZMSR-W Acr 83 TZMSR-W Kan(2) 83 TZUT-W DMR-LSR-W EV 8444 SR 8321-21	IK 83 TZMSR-W-1 8505-3 8321-21 Fut 86 TZUTW-SR Sam. 84 TZESR-W DMR-ESR-W Acr 86 TZESR-W
	CIMMYT	ACR 8443	--
	PNM	--	EV 8443 SR x Bab.F2
Kiyaka	IITA	Eko 83 TZSR-Y ACR 85 TZSR-Y	TZSRY- 1 Sam 83 TZSRY-1 FarBa 85 TZSRY-1 ACR 81 TZSRY-1 ACR 85 TZSRY-1 DMR-LSR-Y
	CIMMYT	ACR 8363 QPM ACR 7940 QPM	

Table 4.13. Varieties/Lines Showing Resistant Reaction to Leaf Blight Diseases in Response to Natural Infection

Location	Source	Disease	Variety/Line
Lubumbashi	IITA	Helminthosporium turcicum	Jos(1)83 TZMSR-W Jos 85 TZMSR-W Ik 84 Pool 16
	CIMMYT	Helminthosporium turcicum	Pirs 8425 ACR 8329
	PNM	Helminthosporium turcicum	Shaba
	Private	Helminthosporium turcicum	SR 52
Gandajika	CIMMYT	H. maydis	Ferk(1) 8521 PR 8521
Kiyaka	IITA	H. maydis	ACR 83 TZSR-Y IK 85 TZSR-Y DMR-ESR-Y EV 8428 SR 8329-15
	PNM	H. maydis	Bandundu

Source: Johnson (1988b).

Note: Only varieties/lines deviating two or more standard deviations from the mean, in trials showing significant disease response differences, are included.

In Zaïre, the storage weevil, **Sitophilus** spp., and angoumois grain moth, **Sitotroga cerealella**, are important pests of stored maize. The development of varieties that are resistant to pests is one possible means of dealing with the storage

Table 4.14. Varieties/Lines Showing Resistant Reaction to Downy Mildew in Response to Natural Infection

Location	Source	Variety/Line
Gandajika	IITA	DMR-ESR-W
		DMR-LSR-W
		TZSR-W
		8644-31
	CIMMYT	Guay.Arag 8422
	PNM	Kas 1 x DMR-ESR-W
		Sal.II x DMR-ESR-W
Kiyaka	IITA	DMR-ESR-W
		DMR-LSR-W
		EV 8443 SR
		EV 8444 SR
		8505-3
		8321-18
		8321-21
	CIMMYT	Sawan 8222
		Gwebi 8422
		Ib(1) 8443
		Syn 62 QPM
	PNM	Sal II x DMR-ESR-W2
		Kas 1 x DMR-ESR-W3
		Sal 11 x DMR-ESR-W3
		Sal 11 x EV 8443 SR F1
		LB(1) 8232 x Bab 3 F2
		LB(1) 8232 X Ev 8429 SR F2
		EV 8443 SR x Bab 3 F2

Source: Johnson (1990b).

Note: Only varieties/lines deviating two or more standard deviations from the mean, in trials showing significant downy mildew response differences, are included.

Table 4.15. **Reactions of PNM-Improved Maize Varieties to Major Diseases and Insect Pests**

Variety	Reaction					
	MSV	H.turcicum	H.maydis	DM	SB	SW
Babungo 3	R	R	--	--	S	S
IK 83 TZSRY-1	R	--	R	--	S	MR
Shaba-1	MR*	--	--	--	--	S
Kasai-1	MR*	--	--	MR*	--	MS
Salongo-II	MR*	--	--	MR*	--	S

Source: Johnson (1990b).

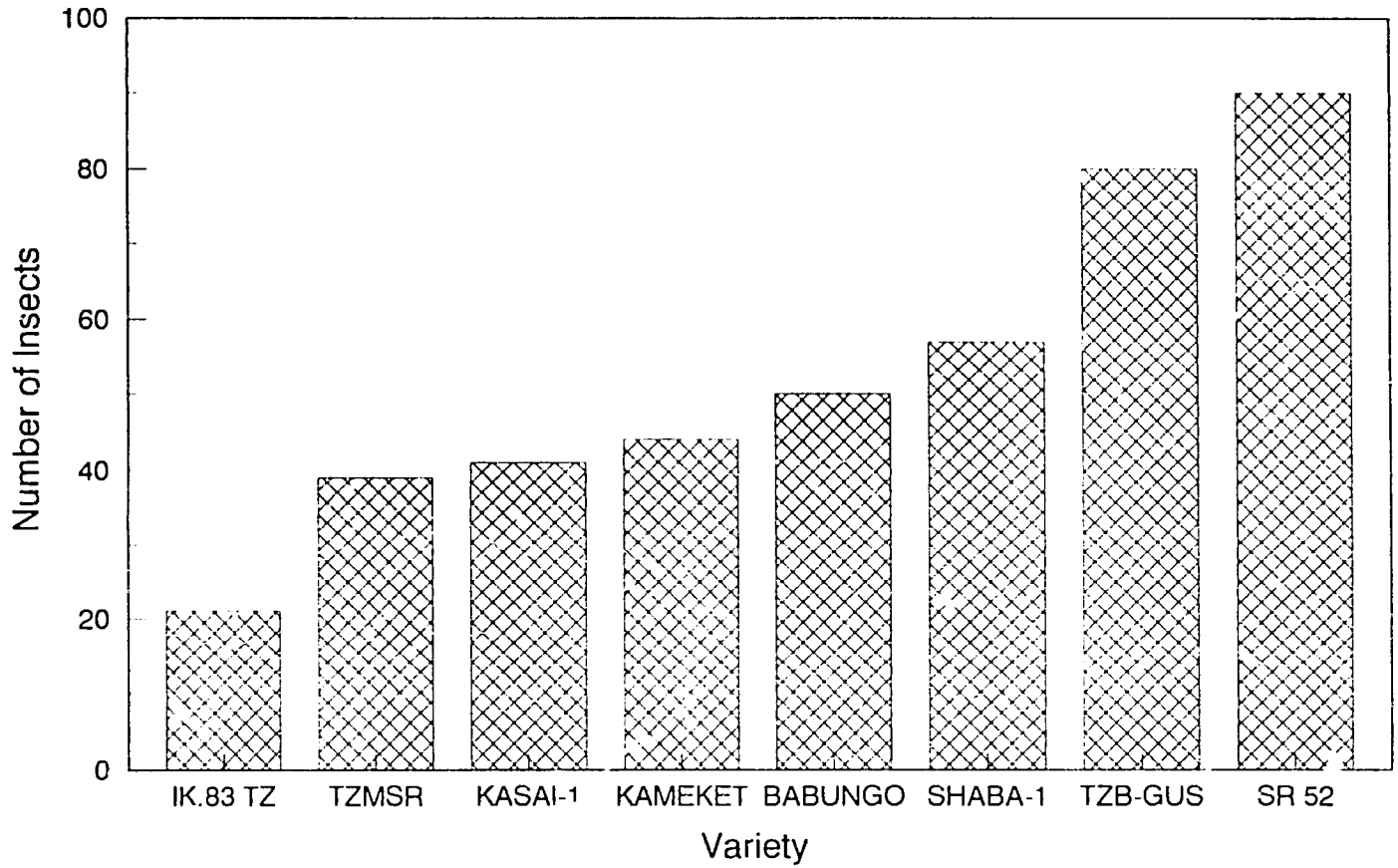
Note: MSV = maize streak virus; DM = downy mildew; SB = stem borer; SW = storage weevil. * = improved by back-crossing from the existing varieties. -- = no information available/no improvement on the disease/pest.

grain insect problem. Work by PNM during RAV I to evaluate the relative susceptibility of elite maize genotypes to storage weevil showed significant differences among genotypes in population build-up of the weevil (see Figure 4.2). In the 1990 test, the lowest number of weevils was recorded in IK 83 TZSRY-1, the variety proposed for release in the Bandundu region; the highest number was recorded in SR 52 (almost five times more than in IK 83 TZSRY-1).

The stem borer, **Busseola fusca**, is recognized as a major pest of maize in Zaïre. Due to its feeding habits (the larvae feeds inside the stem), the borer is difficult to control--even with systemic insecticides. Some potential for cultural and biological control of stem borer does exist, but resistant varieties should be a key component in integrated pest management of stem borer in Zaïre. Unfortunately, high levels of resistance to stem borer are very difficult to achieve. Therefore, negative selection should be considered in the breeding program whereby highly susceptible materials are discarded.

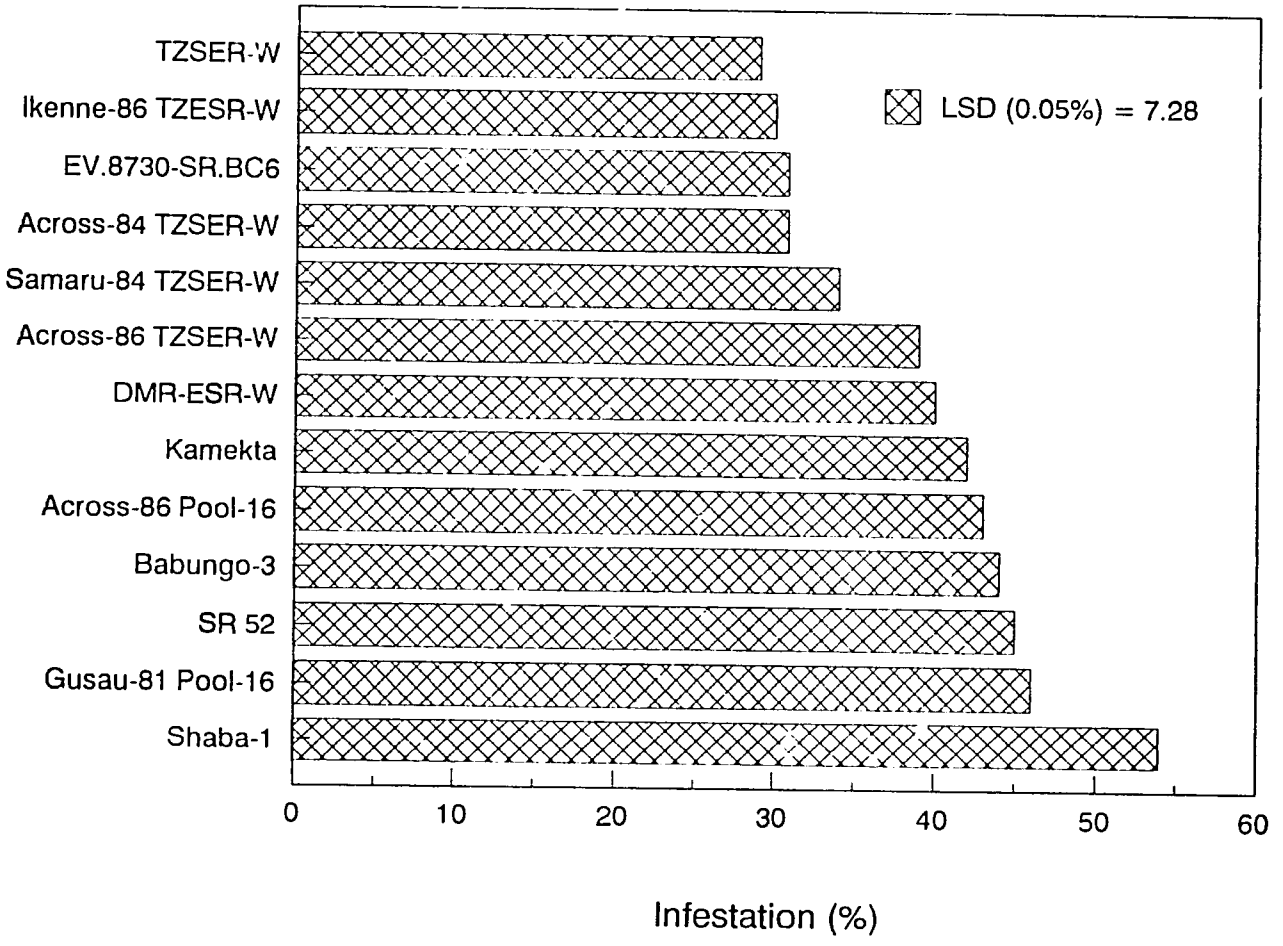
During 1989-90, varietal evaluation to **Busseola fusca** was initiated. In 1989, highly significant differences were found among the entries. The least infestation (29.15%) was found in TZESR-W; the highest was found in Shaba-1 (Figure 4.3).

Figure 4.2 Relative Susceptibility of Eight Maize Genotypes to Maize Weevils, Sitophilus sp. (Kaniameshi, 1989-90)



Source: Alam (1990).

Figure 4.3 Infestation of Thirteen Maize Varieties by Stem Borer, Busseola fusca (Kaniameshi, 1989)



Source: Alam (1990)

The following year, 21 multiple borer-resistant lines were received from IITA for evaluation against **Busseola fusca**; all lines showed promising evidence of resistance.

D. Cultural Control

It was observed during the CIMMYT days that the incidence of disease and insect pests is lower when maize is planted in the beginning of the season (first three to four weeks after commencement of the first rains); late-planted crops showed severe incidence of maize streak virus and downy mildew.

During RAV I, observations on-station and on-farm in southern Shaba clearly showed an increase in the incidence of maize streak virus with delayed planting and a consistently lower incidence in Babungo-3 than in the PNM variety Shaba-1; the widely grown, imported hybrid SR 52; and the local variety Kameketa. The severity of maize streak virus is also much less in Babungo-3 than in the other three varieties (Figure 4.4). There were also dramatic differences in stem borer infestation with planting date (Figure 4.5), as with downy mildew and **Helminthosporium**. Planting maize in the beginning of the cropping season minimizes the incidence of maize streak virus and the stem borer.

Although it is reported in some countries that mixed cropping, or intercropping (a common practice of small farmers in Zaïre), can reduce the incidence of pests and diseases, PNM has not yet conducted sufficient trials to confirm this finding in Zaïre. Preliminary observations in Lubumbashi indicated that the incidence of maize streak virus is lower when maize is grown as a mixed crop with **Crotalaria** sp. Alley cropping could be another interesting area to investigate as a cultural control method (not a sole method) of maize pests and diseases in Zaïre.

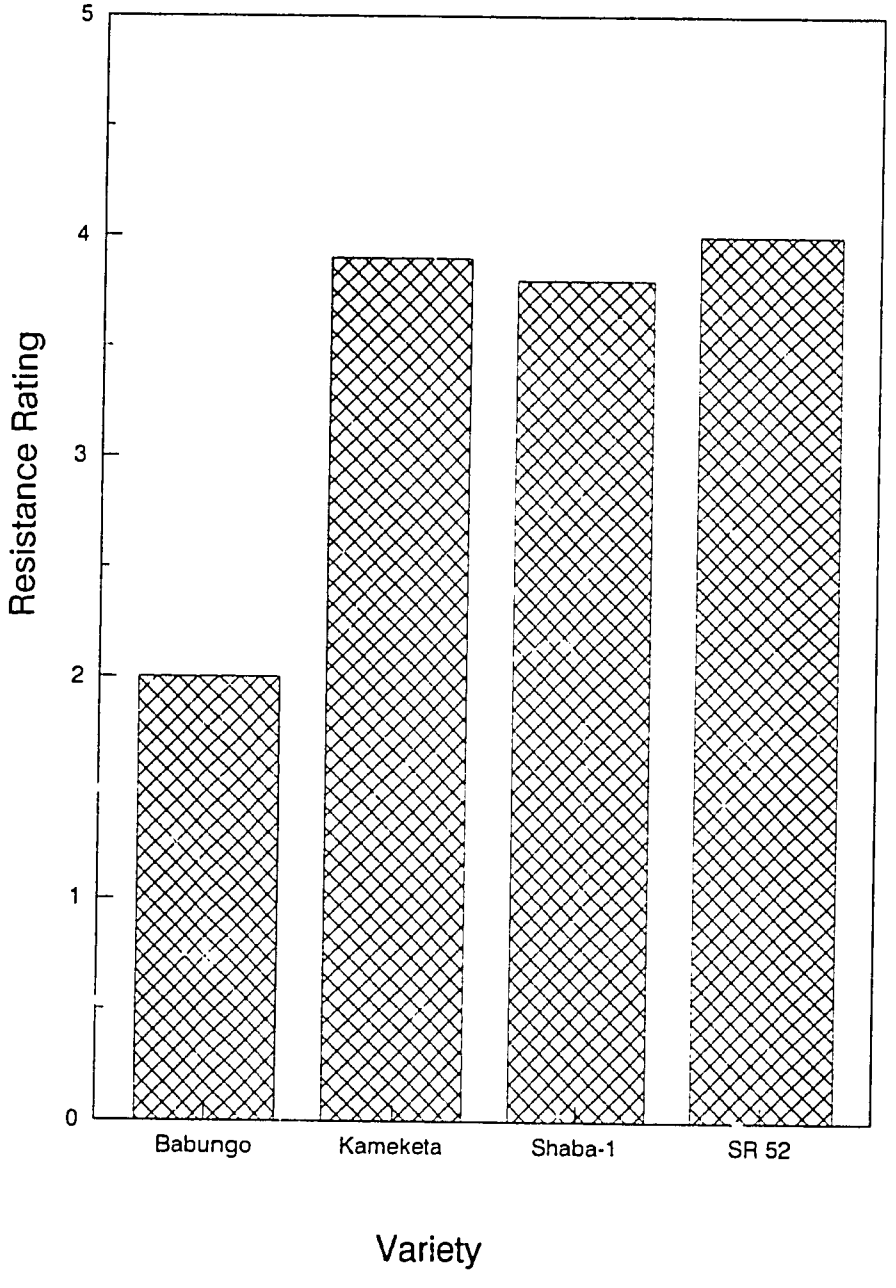
E. Chemical Control

The National Maize Program did not put much emphasis on chemical control of diseases and insect pests because insecticides/fungicides are too expensive and dangerous to be utilized by the peasant farmer and are not readily available on the market. Therefore, chemical control may not be a practical solution for the subsistence farmer in Zaïre. In the beginning of the program (1973-1974), only a few insecticidal trials were conducted to control stem borers and cut worms (a sporadic insect pest). Results showed that Thimet and Dieldrin at a rate of 2 Kg a.i./ha provided better control of cutworms. Diazion, Cytrolane, Thimet and Sevin at the rate of 500 g to 1 Kg a.i./ha also showed promising results to reduce stem borer damage with whorl application. Diazinon and Cytrolane provided better control of stem borer even at 500 g a.i./ha than Sevin and Thimet.

F. Biological Control

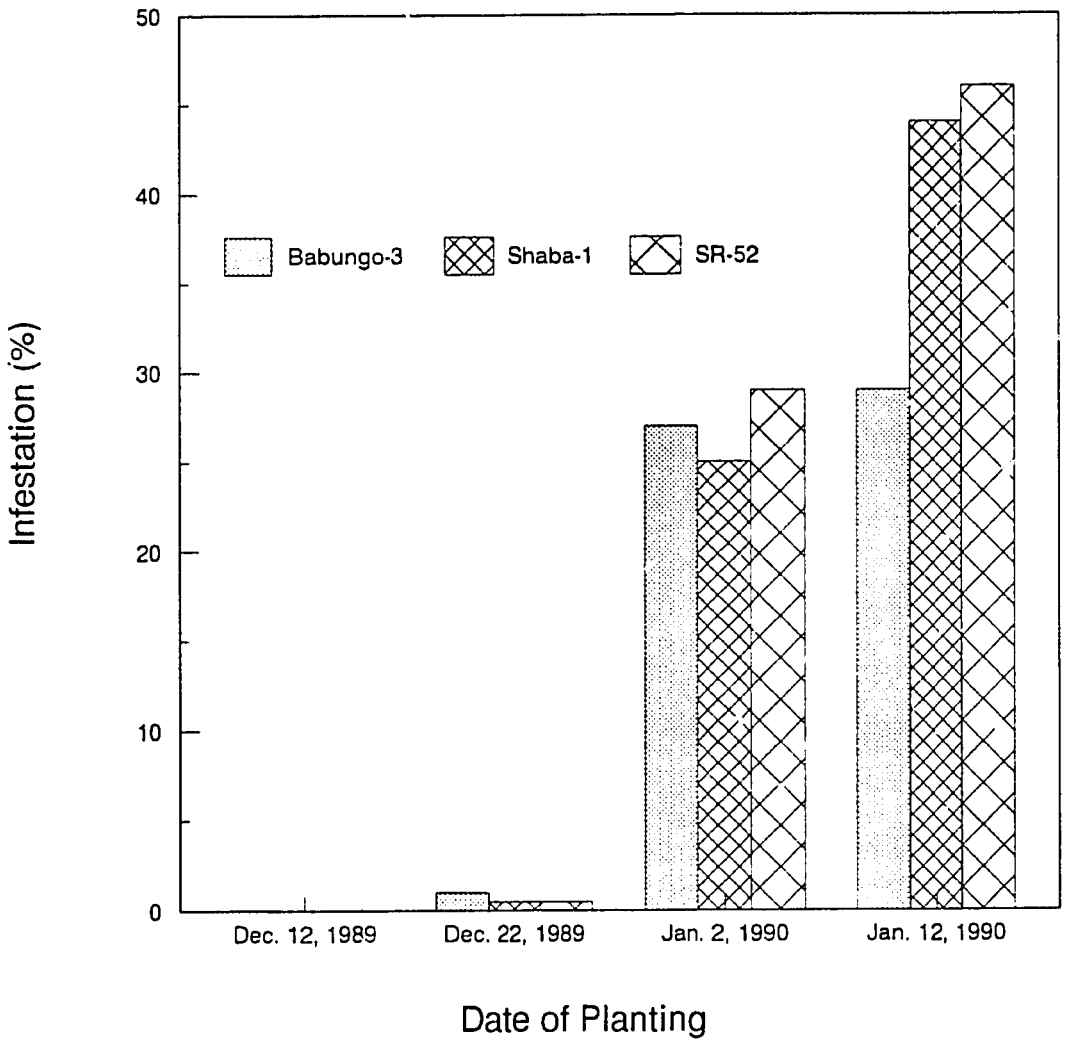
In the beginning of the program, PNM did not consider biological control as a viable approach to control maize pests and diseases because pests were not a serious

Figure 4.4 Resistance of Four Maize Varieties to Maize Streak Virus



Source: Alam (1990).

Figure 4.5 Effect of Planting Date on Stem Borer Infestation of Three Maize Varieties



Source: Alam (1990).

Table 4.16. Parasitoids of Maize Insect Pests in Zaïre

Order and Family	Scientific Name	Host
DIPTERA		
Pipunculidae	Tomosvaryella basalis H.	Cicadulina mbila nymph and adult
Tachinidae	Gonia bimaculata W.	Agrotis ipsilon larva
	Nemoraea rubellana V.	Agrotis ipsilon larva
	Siphona maurina (M.)	Busseola fusca larva
HYMENOPTERA		
Pteromalidae	Anisopteromalus calendre (Howard)	Beetles of stored maize
Dryinidae	Gonatopus incognitus O.	Cicadulina mbila nymph and adult
Braconidae	Apanteles sp.	Busseola fusca larva

Source: Alam (1990); Hennessey (1989).

threat to maize production in Zaïre. This is no longer true. Stem borers could be a possible candidate for biological control. During RAV I, surveys on the parasites and predators of maize insect pests were initiated. Nine parasites and two predators were collected, but only seven of them were identified (Table 4.16).

G. Integrated Pest Management

As stated earlier, PNM's strategy for pest control focused on host plant resistance and cultural control. Considerable work has been done to develop varieties resistant to major diseases. Cultural practice (e.g., date of planting) clearly demonstrated some promise to reduce the incidence of major insect pests and diseases (e.g., stem borer and maize streak virus).

Potential exists for PNM to develop an integrated pest management (IPM) strategy for pest control with the use of resistant varieties, biological control and cultural practices. Such work should be initiated.

IV. Insect Pests and Diseases of Grain Legumes

A. Introduction

Grain legumes provide a major source of protein in the daily diet of Zaïrians. Green pods and dry seeds are the source of high-quality protein for rural people, whose per capita consumption of animal protein is very low. In addition to their nutritional importance, grain legumes also have advantages in subsistence and mixed farming because they notonly grow on poor soil but also supplement nitrogen to the soil. The major grain legumes in Zaïre are groundnut, common beans, soybeans and cowpeas.

In Zaïre, compared with cassava and maize, grain legumes have received limited attention from crop improvement specialists, and their yields have remained relatively low. Insects and diseases cause enormous losses to grain legume crops every year in Zaïre. The percentage of damage, which varies from year to year and location to location, is estimated at 20 to 25 percent.

Insects are the most serious constraint to cowpea production. A wide range of insect pests attack cowpeas throughout their life cycle. The occurrence and severity of insect pests depend on the location and the age of the plant. Average yield losses in cowpeas due to insect pests and diseases range from 50 to 80 percent; under severe infestation, the losses can be total.

Insects do not cause very serious destruction to common beans, soybeans and groundnuts in Zaïre, but this situation may change with the introduction of improved varieties, changes in the cultivation practices, and an increase in areas of production.

Diseases are the main limiting factor of bean (**Phaseolus vulgaris**) production in Zaïre. Their severity varies according to environment and agroecosystems.

B. Research Strategies and Control Status

In 1979, USAID began to support grain legume research and extension work in Zaïre through the Institut National pour l'Etude et la Recherche Agronomique (INERA) at the Mulungu station. That project was terminated in 1984.

The Programme National des Légumineuses (PNL) was established in September 1985 within the framework of RAV I, with USAID providing financial support and IITA

providing technical assistance and administering the training program. The program had the mandate to conduct research on common beans, cowpeas, groundnuts and soybeans.

Because it has a mandate for research on four food crops, PNL has more responsibilities than the cassava and maize programs. With severely limited resources, PNL set up research priorities for each of the four mandated crops. Soybeans were given highest short-term priority in crop improvement, while beans and groundnuts received highest long-term priority. Cowpeas were given lower priority than soybeans, common beans and groundnuts because the most important constraint of cowpeas in Zaïre is insect pest susceptibility, a problem that cannot be solved by varietal improvement due to the limited resources of PNL.

When PNL was established in 1985, little information was available on insect pests and diseases of grain legumes in Zaïre. Effective control requires knowledge of damage, distribution and peak period of pest activity. In the beginning of the program, crop protection researchers focused their research activities on surveys of pests and diseases of the four grain legumes. Studies were also carried out on seasonal abundance and species composition of some insect pests to determine the pest status. Yield losses due to insect pests of cowpeas and soybeans were also studied.

Surveys during 1984-90 revealed that 47 species of insects and 30 diseases are associated with cowpeas, common beans, groundnut and soybeans in Zaïre (Tables 4.17 and 4.18). Approximately 12 insects and 12 diseases are most prevalent.

The important insect pests and diseases of cowpeas in Zaïre are thrips, maruca pod borers, three species of pod bugs (**Mirperus jaculus, Riptortus dentipes** and **Clavigralla shadabi**) and bruchids (**Callosobruchus maculatus**). Scab (**Sphaceloma scab**), cercospora leaf spot (**Cercospora cruenta** and **C. canescens**), web blight (**Rhizoctonia solani**), cowpea aphid borne mosaic virus, and a parasitic weed (**Alectra vogelii**) are commonly observed diseases of cowpeas in Zaïre.

The important diseases of beans are angular leaf spot (**Phaeoisariopsis griseola**), ascochyta leaf blight (**Ascochyta phaseolus**), bacterial blight (**Xanthomonas campestris**), anthracnose (**Colletotrichum lindemuthianum**), rust (**Uromyces appendiculatus**), halo blight (**Pseudomonas phaseolicola**), web blight (**Thanatephorus cucumeris**), and bean common mosaic virus. Among insect pests, the bean fly (**Ophomyia phaseoli**), leaf beetle (**Ootheca** sp.), and bruchids (**Acanthoscelides obtectus**) are predominant.

Only three diseases--early and late leaf spot, caused by **Cercospora arachidicola** and **C. personatum**, respectively, and rosette virus--are very common in groundnut. Insects do little direct damage to groundnuts in Zaïre. A lepidopterous insect, **Diacrisia** sp., can sometimes cause considerable leaf-feeding damage.

Soybeans are also relatively free of diseases and insect pests in Zaïre. Although leaf spot (**Pyrenochaeta glycine**) and bacterial pustule (**Xanthomonas campestris**) occur

Table 4.17. Insect Pests of Grain Legumes in Zaïre

Order and Family	Common Name	Scientific Name
	Cowpeas	
LEPIDOPTERA		
Pyralidae	Pod borer	**Maruca testulalis** (Geyer)
Olethreuthidae	Seed moth	**Cydia ptychora** (Meyrick)
THYSANOPTERA		
Thripidae	Thrips	**Megalurothrips sjostedti** (T.)
HOMOPTERA		
Aphididae	Aphid	**Aphis craccivora** Koch
Aleyrodidae	White fly	**Bemisia tabaci** (Gennadius)
Margarodidae	Root mealybug (Shimbu)	**Crypticera** sp.
Cicadellidae	Leafhopper	**Empoasca** sp.
HEMIPTERA		
Coreidae	Pod bug	**Riptortus dentipes** (F.) **Clavigralla tomentosicollis** S. **C. shadabi** Dolling **Mirperus jaculus** **Anoplocnemis curvipes** (F.)
Pentatomidae	Pod bug Sting bug Pod bug Pod bug	**Aspavia armigera** (Fabricius) **Nezara viridula** Linnaeus **Piezodorus** sp. **Acrosternum** sp.
COLEOPTERA		
Chrysomelidae	Leaf beetle	**Ootheca bennigseni** Weise
Meloidae	Blister beetle	**Mylabris** sp.
Curculionidae	Apion	**Piezotrachelus varius** W.

Table 4.17, continued

Order and Family	Common Name	Scientific Name
COLEOPTERA, continued		
Bruchidae	Bruchid	Callosobruchus maculatus (F.) Callosobruchus sp.
	Common Beans	
DIPTERA		
Agromyzidae	Bean fly	Ophiomyia phaseoli (Tryon)
HOMOPTERA		
Aphididae	Aphid	Aphis fabae Scopoli
LEPIDOPTERA		
Pyralidae	Pod borer	Maruca testulalis (G.)
COLEOPTERA		
Chrysomelidae	Leaf beetle	Ootheca bennigseni W.
Meloidae	Blister beetle	Mylabris sp.
Bruchidae	Bruchid	Acanthoscelides obtectus (S.)
HEMIPTERA		
Coreidae	Pod bug	Anoplocnemis curvipes F. Alcidodoes dentipes
Pentatomidae	Sting bug	Nezara viridula Linnaeus
THYSANOPTERA		
Thripidae	Thrips	Megalurothrips sjostedti (T.)
	Soybeans	
HEMIPTERA		
Coreidae	Pod bug	Riptortus dentipes (F.) Clavigralla shadabi D. Mirperus jaculus Anoplocnemis curvipes (F.)

Table 4.17, continued

Order and Family	Common Name	Scientific Name
HEMIPTERA, continued		
Pentatomidae	Sting bug	**Nezara viridula** Linnaeus
	Pod bug	**Aspavia armigera** (F.)
	Pod bug	**Piezodorus** sp.
HOMOPTERA		
Margarodidae	Root mealybug (Shimbu)	**Crypticera** sp.
COLEOPTERA		
Curculionidae	Apion	**Piezotrachelus varius** W.
	<u>Groundnuts</u>	
HOMOPTERA		
Aphididae	Aphid	**Aphis craccivora**
Margarodidae	Root mealybug	**Crypticera** sp.
COLEOPTERA		
Meloidae	Blister beetle	**Mylabris** sp. **Cylindrothorax** sp.
ORTHOPTERA		
Pyrgomorphidae	Grasshopper	**Zonocerus variagatus** (L.)
THYSANOPTERA		
Thripidae	Thrips	**Taeniothrips sjostedti** **Ennoeothrips flavens**
LEPIDOPTERA		
Arctiidae	Defoliator	**Diacrisia maculosa**

<u>Source</u>: Mathys (1985); Shannon (1986); Zantoko et al. (1989); PNL (1989); Alam (1990).

Table 4.18 Diseases of Grain Legumes in Zaïre

Common Name	Causal Organism
Cowpeas	
Scab	Sphaceloma scab (Elisinoe phaseoli)
Cercospora leaf spot	Cercospora cruenta Cercospora canescens
Web blight	Rhizoctonia solani
Leaf spot	Aristastoma sp.
Anthracnose	Colletotrichum sp.
Rust	Phakopsora parhyrhizi
Powdery mildew	--
Cowpea aphid-borne mosaic virus	Virus
Parasitic weed	Alectra vogelii
Common Beans	
Angular leaf spot	Phaeoisariopsis griseola
Ascochyta leaf spot	Ascochyta phaseolus
Anthracnose	Colletotrichum lindemuthianum
Rust	Uromyces apendiculatus
Halo blight	Pseudomonas phaseolicola
Bacterial blight	Xanthomonas campestris
Web blight	Thanatephorus cucumeris Cercospora canescens
Bean common mosaic virus	Virus

Table 4.18, continued

Common Name	Causal Organism
	Soybeans
Leaf spot	**Pyrenochaeta glycines**
Bacterial pustule	**Xanthomonas campestris**
Soybean mosaic virus	Virus
Web blight	--
Pod rot	--
	Groundnuts
Leaf spot	**Cercospora arachidicola**
Late leaf spot	**Cercosporidium personatum**
Rust	**Puccinia arachidis**
Leaf spot	**Botrytis** sp.
Wilt	**Verticilium** sp.
Groundnut rosette	Virus

Source: Maraite (1984); Mathys (1985); Camacho (1990); IITA (1990); Shannon (1986); Pyndji (1988b).

at higher elevations and lower elevations, respectively, they do not cause serious yield losses in soybeans. Among the insects, pod sucking bugs (**Riptortus dentipes**, **Nezara viridula** and **Clavigralla shadabi**) are important.

During RAV I, although the entomology section of PNL suffered due to insufficient staff and limited facilities, some basic research on the bioecology of some grain legumes insect pests was nonetheless conducted. Cowpea insect pests are

generally more prevalent in Season B (February-June) than in Season A (September January). Three species of pod-sucking bugs (**Mirperus jaculus, Riptortus dentipes** and **Clavigralla shadabi**) are predominant. Observations from farmers' fields and station trials showed that thrips, maruca pod borer and pod-sucking bugs are the most important insect pests of cowpeas in Zaïre. Bruchids are also important in storage.

An experiment was conducted at Gandajika using insecticides to control the insects at different stages of cowpea growth in order to assess the relative importance of insect attack at each stage. Results indicated that the effects of insects are most consequential through the flower bud, pod and seed development stages. Bioecological studies of leaf beetle, **Ootheca bennigseni**, a defoliator and an important pest of common beans, were conducted in Lubumbashi during RAV I. Only fields planted in the first two months of the rainy season were severely affected by the **Ootheca** beetle.

PNL has made considerable progress on bean pathology research. PNL found that yield losses in the bean crop due to disease range from 20.7 to 43.9 percent for susceptible varieties. Loss is generally higher in the rainy season than in the dry season. Epidemiology of angular leaf spot (**Phaseoisariopsis griseola**) showed pathogenic variation. At least two pathotypes exist in Zaïre (Table 4.19). This finding furnished valuable information to breeders for determining the strategy for resistance breeding to angular leaf spot.

C. Host Plant Resistance

PNL gave highest priority to resistance breeding as a strategy for disease control. During the first phase of the project, resistant sources of angular leaf spot (**Phaseoisariopsis griseola**), an important disease of common beans, were identified (Table 4.20) and a hybridization program was initiated. Table 4.21 provides a list of donors and recurrent parents used in the hybridization program to develop varieties resistant to angular leaf spot.

During RAV I, PNL proposed the release of several improved varieties of cowpeas, groundnuts, and beans that were either resistant or tolerant to various diseases. The variety J 24 introduced from ICRISAT was identified as high-yielding, early maturity, and tolerant to **Cercospora** leaf spot. Several varieties resistant to common bacterial blight of beans were identified, including MCD 201, a CIAT line proposed for release in the southern Kasai and northern Shaba regions under the name Wambedi. Two cowpea varieties, H 36 and H 204, which were selected from the INERA collection, were also proposed for release. The variety H 36 is tolerant to scab (**Elisinoe phaseoli**), and H 204 is resistant to the parasitic weed, **Alectra vogelii**.

Little work was done on breeding for resistance to grain legume insect pests. Attempts were made to evaluate some advanced breeding materials of cowpeas for resistance to bruchids in the laboratory, but results were inconclusive due to procedural problems and lack of controlled environmental conditions.

Table 4.19. Reactions of Differential Varieties to Three Isolates of Angular Leaf Spot (Phaseoisariopsis griseola)

Differential Variety	Field Reaction[1]	Greenhouse Reaction[1]		
		Zmt[2]	Zmm[2]	Rrw[2]
BAT 76	R	I	I	I
Calima	I	I	S	S
Montcalm	I	I	I	S
A 62	I	I	R	R
BAT 332	I	I	I	R
G 5686	I	I	I	I
Caraota 260	R	I	R	R
Seafarer	I	S	I	S
Alabama No.1	I	S	I	I
Jalo EEP558(G 9603)	R	I	R	R
BAT 1647	R	R	R	R
A 21	I	S	R	I
Pompador Checa	I	I	I	S
A 235	R	I	I	I
G 1805	I	I	R	R
A 212	R	I	R	I
Amendoin	I	I	S	S
G 2858	S	S	R	I
A 301	I	S	R	R
A 339	R	R	R	R
Cornell 49242	I	I	I	S
A 285	R	--	R	R

Source: Pyndji (1991).

[1]R = resistant (rating 1-3); I = intermediate (rating 4-6); S = susceptible (rating 7-9).

[2]Zmt = isolate Zaïre Mulungu-Tshirumbi; Zmm = isolate Zaïre Mulungu-Molehe; Rrw = isolate Rwanda Rwerere.

Table 4.20. **Resistant Sources to Angular Leaf Spot (Phaseoisariopsis griseola)**

Variety/Line	Type	Grain	
		Color	Size
A 75	II	Cream	Small
A 140	III	Cream	Small
A 163	II	Cream	Small
A 212	II	Black	Small
A 216	III	Cream	Small
A 221	II	Black	Small
A 240	II	Cream	Small
A 285	III	Striped	Small
A 300	II	Cream	Small
A 339	II	Cream	Medium
A 345	II	Cream	Small
A 384	II	Brown	Small
A 387	II	Yellow	Small
BAT 67	II	Black	Small
BAT 76	II	Black	Small
BAT 434	II	Black	Small
BAT 1432	II	Black	Small
EMP 81	III	Cream	Small
G 2676	II	Black	Medium
G 2959	I	Black	Small
G 4169	III	Black	Small
G 4459	I	White	Small
G 5473	II	White	Small
XAN 37	II	Purple	Small
XAN 68	II	Cream	Small

Source: Pyndji (1988a).

During RAV II, a systematic breeding program was initiated to develop cowpea varieties resistant to parasitic weed, **Alectra vogelii.**

D. Cultural Control

As regards control of insect pests of cowpeas in Zaïre, one should keep in mind that cowpeas and the most damaging insect pests of cowpeas in Zaïre are indigenous to Africa. One must also recognize that Zaïrian farmers are acting to reduce pest damage (e.g., mixed cropping, using wood ashes for storing seeds of grain legumes).

Table 4.21. Donors and Recurrent Parents Used in the Improvement of Common Bean Resistance to Angular Leaf Spot (Phaseoisariopsis griseola)

Variety/Line	Type	Grain	
		Color	Size
Donor Parents			
A 140	III	Cream	Small
A 345	II	Cream	Small
A 300	II	Cream	Small
XAN 68	II	Cream	Small
A 285	II	Cream	Small
Recurrent Parents			
D 6	I	Spotted	Large
Rubona 5	I	Spotted	Medium
Munyu	I	Brown	Medium

Source: Mbikayi and Pyndji (1991).

In a preliminary trial at Gandajika, it was observed that the populations of some major insect pests of cowpeas were lower when cowpeas were intercropped with maize. Mixing palm oil with cowpea seeds also showed promising results to reduce bruchid infestation in stored seeds. For small farmers who produce limited amounts of cowpea seeds, this storage practice will be more practical and effective to control bruchids.

Root mealybug, **Crypticera** sp. (locally known as Shimbu), is considered an important pest of cowpeas, soybeans, and maize in Gandajika. The economic importance of this insect is yet to be determined. Field observations seem to indicate that land preparation has an effect on shimbu infestation.

Date of planting has an effect on **Octheca** (leaf beetle) infestation. Beans planted in the beginning of the season suffered more damage than late-planted crops. The effect of planting dates and mixed cropping for the control of pests of grain legumes, especially cowpeas and beans, should be investigated.

The effect of varietal mixtures (resistant and susceptible local) of beans at different ratios was studied at Mulungu in 1988. It was observed that mixing a resistant variety with a local susceptible variety was efficient in reducing the severity

of the disease (angular spot) and improving grain yields (Table 4.22). These findings will provide a very practical method of controlling diseases with pathogenic variations.

E. Chemical Control

At PNL, insecticides are used for the control of cowpea insect pests. Breeding materials with insecticide protection are evaluated, which hinders the objective of the program: to develop disease-resistant varieties. Due to the continuous use of the same insecticide at the Gandajika station, the pest population has increased enormously.

F. Biological Control

A number of parasites and predators of legume insects have been reported by various workers in some African countries, but not much work has been done at PNL on this aspect because of limited resources. During RAV I, some natural enemies to insects and mites of common beans were recorded. Field observations indicated the presence of parasites of the maruca pod borer, aphids, bean fly and pod-sucking bugs. Some coccinellid beetles act as predators of aphids.

Table 4.22. **Effect of Varietal Mixtures on Grain Yield of Common Beans**

Proportion of Resistant/Susceptible	Grain Yield (kg/ha)		Yearly Average Yield (kg/ha)
	Season A	Season B	
0/100	1,387b	677b	1,032b
25/75	1,858a	861a	1,360a
50/50	1,840a	897a	1,369a
75/25	1,874a	847a	1,361a
100/0	1,735a	826a	1,281a
CV (%)	9.85	6.49	8.17

Source: Pyndji (1988b).

Note: Means within columns followed by the same letters are not significantly different (PPDS, p = 0.5).

The actual role of these biological control agents in suppressing the pest populations of legume insect pests in Zaïre is unexplored. During the initial stage of RAV II, emphasis was placed on collecting and identifying parasites, predators, and fungal diseases of insect pests of grain legumes and studying their role in suppressing the pest population below damaging levels.

G. Integrated Pest Management

To combat insect pests, control measures to minimize the economic impact of their damage must be devised. During RAV I, work was initiated on some of the components of integrated pest management (e.g., cultural control, chemical control, and host plant resistance). Initial efforts were made during RAV II to formulate an IPM package for cowpea insect pests. A model was proposed for testing in farmers' fields during the last cropping season (September 1991-January 1992), but the work was halted due to civil unrest and political disturbances.

V. Priorities for Future Research

The project papers for both RAV I and RAV II call for the development and implementation of integrated pest management systems for all SENARAV mandated crops. Future plant protection research on cassava, maize, and grain legumes should therefore emphasize integrated pest management. Because of limited resources, research focus should be limited to key insect pests and diseases.

Integrated pest management systems for cassava, maize, and grain legumes grown by subsistence farmers in Zaïre must differ markedly from those in advanced countries. In Zaïre, these food crops are mostly cultivated as mixed crops, and farmers rarely use chemicals. Therefore, there is a need to develop a sound, sustainable pest management strategy that will minimize or eliminate pesticide application.

Researchers working to develop integrated pest management programs for cassava, maize, and grain legumes in Zaïre are still hindered by the lack of adequate information on occurrence, behavior, and peak activity of pests. Further, they have little information on the effect of mixed cropping. It is recommended that an economist work in collaboration with crop production researchers to assess crop losses due to field and storage pests.

In some developed countries, cassava, maize, and grain legumes are grown on a large scale. Researchers focused their attention on IPM at least partly because the use of pesticides had become extensive. Due to the lack of effective extension services at the village level and the lack of fixed market prices of crops in Zaïre, the scouting and establishment of economic injury levels, which are prerequisite for IPM, is difficult. Therefore, the applicability of these methods in Zaïre is minimal at present.

Emphasis for IPM must be on other control measures in the field: pest-resistant varieties, biological control, and cultural practices. Breeding for suitable varieties is also important. The indeterminate cowpea plant has the capacity to grow and produce over a longer period than most determinate varieties; hence, it will probably be a more desirable plant type for subsistence farmers in Zaïre. The longer period of growth enables the indeterminate type to compensate for damage to reproductive and vegetative parts.

All components of IPM should aim to identify the best combination of practices to develop a program that is effective, inexpensive, and easily adopted by subsistence farmers in Zaïre. Farmers' practices for controlling pests and diseases in the field and in storage should be investigated. Insecticides should be used judiciously for the control of cowpea insect pests in order to help to conserve or augment natural enemies (parasites and predators). The potential for using local botanicals as a substitute for insecticides should be explored.

References

Alam, M. S. 1990. Final Report: USAID/IITA/Zaïre Applied Agricultural Research andOutreach Project. Lubumbashi: USAID.

Camacho, L. H. 1990. Report on Improvement of Grain Legumes 1986-1990, National Grain Legumes Program. USAID/IITA/SENARAV Zaïre Project.

Hahn, S. K., and R. J. Williams. 1973. "Investigations on Cassava in the Republic of Zaïre." Ibadan, Nigeria: International Institute of Tropical Agriculture. Mimeograph.

Hennessey, R. D. 1989. Final Report: RAV Project, 091.

------. 1991. "Insect and Mite Natural Enemies of Insects Associated with Intercropped Maize and Phaseolus Bean near Lubumbashi, Zaïre." Manuscript submitted to Tropical Pest Management.

Herren, H. R., P. Neuenschwander, R. D. Hennessey, and W. N. O. Hammond. 1987. "Introduction and Dispersal of **Epidinocarcis lcpezi** (Hym., Encyrtidae), an Exotic Parasitoid of the Cassava Mealybug, **Phenacoccus manihoti** (Hom. Pseudococcidae), in Africa." Ecosystems and Environment 19:131-44.

International Institute of Tropical Agriculture (IITA). 1982. Annual Report for 1981. Ibadan, Nigeria: IITA.

------. 1985. Final Report: Cassava Outreach Project, USAID Project, No. 660-0077. Ibadan, Nigeria: IITA.

------. 1990. Final Report: IITA/USAID/Zaïre Applied Agricultural Research and Outreach Project (660-0091). Ibadan, Nigeria: IITA.

Johnson, K. M. 1987. "1985-86 Annual Report of PNM Pathology Program in the National Maize Program of Zaïre." Mimeograph.

------. 1988a. "1987 Annual Report of Testing, Breeding and Pathology Activities in the National Maize Program of Zaïre." Mimeograph.

------. 1988b. "1988 Annual Report of Testing, Breeding and Pathology Research Activities in the National Maize Program of Zaïre." Mimeograph.

------. 1990a. "1989 Annual Report of Testing, Breeding and Pathology Research Activities in the National Maize Program of Zaïre." Mimeograph.

------. 1990b. "1990 Final Report of Maize Testing, Breeding and Pathology Research Activities in the National Maize Program of Zaïre." Mimeograph.

Kasu, T. 1985. "Development of a Fast and Appropriate Rating Scale for Cassava Green Mite Damage at M'Vuazi." International Society for Tropical Root Crops Newsletter 2 (December).

Maraite, H. M. 1984. "Phytosanitary Problems on Food Crops in Zaïre and Strategies for Control." Report submitted to USAID/Kinshasa.

Mathys, G. 1985. "Problèmes entomologiques rencontrés dans les cultures de riz et de légumineuses du Zaïre et stratégies de lutte." Report submitted to USAID/Kinshasa.

Mbikayi, N. T., and M. M. Pyndji. 1991. "Incorporation de gènes de résistance à la maladie des taches anguleuses dans des cultivars locaux." Actes du Sixième Séminaire Régional sur l'Amélioration d'Haricot dans la Région de Grands Lacs. Kigali, Rwanda, January 21-25.

Muimba, K., and K. Phuti. 1987. "Relationship of Cassava Mosaic Severity in Planting Material to Mosaic Development, Growth and Yield of Cassava in Zaïre." Expl. Agric. 23:221-25.

Muimba, K., L. Simba, T. P. Singh, and G. Muyolo. 1989. "Outbreak of an Unusual Stem Tip Dieback of Cassava (**Manihot esculenta** Crantz) in Western Zaïre." Agriculture, Ecosystems and Environment 25:151-64.

Muimba, K. A., G. Muyolo, N. M. Mahungu, and S. J. Pandey. 1987. "The Strategies of Programme National du Manioc (PRONAM) of Zaïre in Screening Cassava for Resistance to Major Diseases." In Tropical Root Crops: Root Crops and African Food Crisis, edited by E. R. Terry, M. O. Akoroda, and D. Arene, 109-12.

Mulamba, N. N., and M. Y. Asanzi. 1985. "Maize Research and Production in Zaïre." In To Feed Ourselves. Proceedings of the First Eastern, Central and Southern Africa Regional Maize Workshop, Lukasa, Zambia, sponsored by CIMMYT, Mexico.

Neuenschwander, P., R. D. Hennessey, and H. R. Herren. 1987. "Food Web of Insects Associated with the Cassava Mealybug, **Phenacoccus manihoti** Matile-Ferreo (Hemiptera: Pseudococcidae) and its Introduced Parasitoides, **Epidinocarsis lopezi** (de Santis) (Hymenoptera: Encyrtidae) in Africa," Bull. Ent. Res. 77:177-89.

Nsiama She, H. D. 1991. "Prospective Trends in Integrated Management of Cassava Mealybug and Green Mites in Zaïre." In Integrated Pest Management in Root and Tuber Crops, edited by P. Neuenschwander, H. R. Herren, and A. Wodageneh, 80-91. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Nsiama She, H. D., N. B. Lutaladio, and N. M. Mahungu. 1990. "Integrated Management of Cassava Pests in Zaïre: Status and Prospects." In Integrated Pest Management for Tropical Root and Tuber Crops, edited by S. K. Hahn and F. E. Caveness, 196-200. Ibadan, Nigeria: International Institute of Tropical Agriculture.

Nwanze, K. F. and K. Leuschner, eds. 1978. Proceedings of the International Workshop on the Cassava Mealybug, **Phenacoccus manihoti** Mat.-Ferr. (Pseudococcidae). Workshop held at INERA, M'Vuazi, Bas-Zaïre, Zaïre, June 26-29, 1977.

Programme National des Légumineuses (PNL). 1989. Les points saillants de la recherche du rapport annuel 1989.

Programme National du Maïs (PNM). 1973. Rapport Annuel 1972-73. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1974. Deuxième Rapport Annuel 1974. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1975. Troisième Rapport Annuel 1975. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1976. Quatrième Rapport Annuel 1976. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1979. Sixième Rapport Annuel 1979. Kinshasa: Département de l'Agriculture, République du Zaïre.

Programme National du Manioc (PRONAM). 1976. Rapport Annuel 1976. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1977. Rapport Annuel 1977. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1978. Rapport Annuel 1978. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1979. Rapport Annuel 1979. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1980. Rapport Annuel 1980. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1981. Rapport Annuel 1981. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1982. Rapport Annuel 1982. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1983. Rapport Annuel 1983. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1984. Rapport Annuel 1984. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1985. Rapport Annuel 1985. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1986. Rapport Annuel 1986. Kinshasa: Département de l'Agriculture, République du Zaïre.

Pyndji, M. M. 1988a. "Taches anguleuses du haricot commun dans le Kivu Montagneux." Paper presented at Actes du Quatrième Séminaire Régional sur l'Amélioration du Haricot dans la Région des Grands Lacs, Bukavu, Zaïre, November 21-25, 1988.

Pyndji, M. M. 1988b. "Progrès de recherche sur la maladie de taches anguleuses du Haricot Commun dans la Région des Grands Lacs." Paper presented at Actes du Quatrième Séminaire Régional sur l'Amélioration du Haricot dans la Région des Grands Lacs, Bukavu, Zaïre, November 21-25, 1988.

Pyndji, M. M. 1991. "Variabilité pathogénique des **Phaseoisariopsis griseola** dans la Région des Grands Lacs. Paper presented at Actes du Sixième Séminaire Régional sur l'Amélioration du Haricot dans la Région des Grands Lacs, Kigali, Rwanda, January 21-25, 1991.

Shannon, D. A. 1986. "Grain Legume Research in Zaïre: A Review of Past Research from 1979 to 1985 and Suggestions for the Future." Report submitted to USAID/Kinshasa.

------. 1990. "Final Report: USAID Project 660-0091, Applied Agronomic and Extension Project."

Singh, T. P., and N. B. Lutaladio. 1980. "Zaïre: Country Report." Presented at a workshop in Kigali, Rwanda, November 23-27, 1980.

Vogel, W. O. 1990. "Final Report: USAID Project 660-009 , Applied Agronomic and Extension Project."

Vogel, W. O., R. D. Hennessey, T. Berhe, and K. M. Matungulu. 1991. "Yield Losses to Maize Streak Disease and **Busseola fusca** (Lepidoptera: Noctuidae), and Economic Benefits of Streak-Resistant Maize to Small Farmers in Zaïre." Mimeograph.

Zantoko, L., K. Bukasa, and D. A. Shannon. 1989. "Entomology Research in the National Legume Program of Zaïre." Annual Report of Grain Legume Program 1987, 155-58. Ibadan, Nigeria: IITA.

CHAPTER 5

NATURAL RESOURCE MANAGEMENT: SOILS AND AGROFORESTRY

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I. Historical Rationale for Soil and Agroforestry Research

Like most other African countries, Zaïre has experienced a steady decrease in per capita food production since independence. Among the factors that have caused this decline is the degradation of the country's most productive soils. Rural to urban migration and the rural to urban transfer of soil-borne plant nutrients to meet the demands of urban food markets have resulted in agricultural extensification characterized by shorter fallow periods, clearing of generally less productive land, and greater reliance on food crops that are capable of growing on poorer soils and are consequently of lower nutritional value.

Soil degradation due to the utilization of traditional soil management practices in a new, non-traditional market economy has been recognized as a major constraint to increased domestic food production and rural development in Zaïre (USAID/Zaïre, 1990). USAID has attempted to address this problem through several agricultural research projects. This chapter discusses those projects and project components that specifically addressed the soil degradation issue through a research emphasis in soil and water management.

Available information describing the objectives and results of research in soil management is scarce. Only one project, the INERA Support Project (1979 to 1984), included soils research as a major component. Although project evaluation reports were made available to this author by the USAID Document Center during the information-collection operation that preceded the drafting of this compendium, the center did not provide the annual reports and technical reports known to exist in Zaïre.

Each of SENARAV's three commodity programs (PNL, PNM, and PRONAM) conducted agronomic research in intercropping, fertilizer response, and related soil-management practices. Most of their annual reports are available, as are the RAV I evaluation and end-of-tour reports of the technical advisors who assisted in developing the research programs in agronomy and agroforestry. SENARAV, through the International Institute of Tropical Agriculture, participated in the AFNETA (Alley Farming Network for Africa) Alley-cropping Network, and one of its annual reports (for 1990) is also available.

The discussion of the soil and water management research presented in this chapter is organized by project or project component activities. This approach is taken because each project or component developed its own research agenda, and there appears to have been little cross-utilization of research results from previous or concurrent research programs. This was due to the fact that the work was primarily adaptive research; known technologies were applied to local biophysical and socioeconomic conditions. In addition, the information network both within and between research projects was poorly developed.

II. Research Objectives and Results

A. INERA Support Project (1979-1984)

The INERA Support Project was conceived as a means of focusing agricultural research on the chronic malnutrition becoming more prevalent in the southern band from Bandundu across the Kasais into the northern Shaba province and eastern Kivu (USAID, 1977). These regions possess much of Zaïre's most agriculturally productive soils and support the highest rural population densities. The increasing rural population and the nearby growing urban and mining population were creating demand for both marketable and locally consumable food--a demand that subsistence farmers were unable to meet with an equivalent increase in production utilizing their traditional farming practices. Their participation in the rural and rural to urban food markets was decreasing farm-family food consumption and increasing the degradation of the soil resource.

The INERA Support Project was created to arrest this downward spiral of human nutrition and soil fertility. The project's goal was to increase the level, availability, and nutritional quality of food production for the low-income majority in Zaïre. The INERA Support Project was designed to assist with the development of INERA's institutional capability to:

- create production packages for food legumes through applied and adaptive research using a participatory research approach;
- provide soil fertility investigations, consulting, and recommendation services to those interested in advancing food crops production and, while developing this capability, to deliver those services to the ongoing food production projects;
- provide reliable estimates of the production potentials and limitations of soils in support of regional development programs; and
- devote its resources in an optimal manner within budgetary restraints to research priorities.

At the project programming and implementation level, these objectives translated into: (1) a research program to introduce adapted edible legumes into the farming systems and diet of the rural population; (2) a soil testing facility that could conduct routine chemical analysis of soils and interpret these into management recommendations; and (3) a soil classification capacity that could conduct soil survey studies and develop a national land use capability system. The project goals and

implementation objectives were extremely ambitious, and to some degree misguided, considering the political and rural development reality of the country.

The project called for 288 months of long-term technical assistance with the following breakdown for specialty and duration: Soil Scientist, 48 months; Land Classifier, 48 months; Lab Technician, 48 months; Research Agronomist, 48 months; Rural Sociologist, 48 months; Agricultural Research Management Planner, 24 months; and Business Management Consultant, 24 months. Another 40 months of short-term technical assistance in the plant and food sciences was also scheduled. Eleven Zaïrians were to be trained to the M.S. level in soil science (3), agronomy (2), land classification (4), plant pathology (1), and entomology (1).

Implementation of the project was a fiasco from the very start. Political unrest delayed project start-up and the arrival of the technical assistance team by a year, to November 1979. The project, based at the INERA Mulungu station, experienced severe logistical, infrastructure, technical assistance, and inter-institutional problems.

An evaluation conducted by USAID/Zaïre and USAID/REDSO/ESA personnel in May 1981 found the project in a dismal state (USAID, 1981). Vehicles were inappropriate to the conditions where gasoline and spare parts were not available. Laboratory equipment arrived late and incomplete. Housing did not meet the standards of some technical assistance team members. All but one of the team spoke little or no French; one team member spoke little English. The training courses conducted by the team were considered "totally incomprehensible" by the Zaïrian trainees. Some members of the team did not meet even minimal technical qualifications for their positions. Project management and the research program lacked direction. Recommendations emanating from this evaluation dealt primarily with management issues; the evaluation team assumed the resolution of management issues would allow development of the essentially dormant research agenda.

Another evaluation was conducted in November 1982 to assess the sustainability of project activities following the project agreement completion date (USAID, 1982). This evaluation found the project in better shape than the previous evaluation had, but serious management deficiencies were again noted. The evaluation team cited several constraints to realizing end-of-project outputs: (1) lack of planning and management of the program, materials, and equipment; (2) lack of collaboration and communication; and (3) lack of planning and follow-up of off-station trials.

Several of the technical objectives of the project were deleted due to lack of technical assistance and Zaïrian expertise. The soil classification program was terminated due to lack of expertise and analytical capacity. The soil fertility program, which was also hampered by lack of expertise, was not developing soil fertility correlations relating soil test results to yield data. While the soils lab was functioning, it was slowing down to conserve chemicals due to the lack of a stock management plan and budget line item for the reorder of supplies.

The legume program suffered from constant communication and management problems. The expatriate technical assistant and his Zaïrian counterpart developed and analyzed experiments in isolation of one another. Many experiments were poorly conceived and even more were poorly implemented, due to the lack of cooperation, oversight, and transportation.

It is a sad commentary when the "lessons learned" sections of two successive evaluations are dominated by lessons learned from failures and poor management. The project was so poorly implemented and the evaluations were so preoccupied with addressing the management problems, that only one technical success was recognized: Soybeans out-yield the local varieties of common beans in Bukavu.

B. RAV I

The three national programs within SENARAV and funded by RAV I (PNL, PNM, and PRONAM) were discussed in previous chapters; their overall research goals will not be repeated here. Each program initiated some sort of agroforestry research either previous to or during the first year of the RAV I Project.

1. Programme National des Légumineuses (PNL)

PNL was created in 1983, with the mandate to provide research to support an increase in the prevalence of legumes in the diet of Zaïrians. The research agenda focused on six objectives:

- identify the factors limiting yields of groundnuts (**Arachis hypgaea**), common bean (**Phaseolous vulgaris**), cowpea (**Vigna unguiculata**), and soybean (**Glycine max**);
- screen varieties to find those best suited to low, medium, and high altitudes, tolerant to the principal insects and diseases, and accepted by the population;
- evaluate and adapt new varieties into agronomic practices with small farmers;
- develop varieties tolerant to low levels of nitrogen, phosphorus, and pH;
- develop high-yielding hybrid varieties tolerant to insects and diseases; and
- conduct research to adapt results to the conditions of small farmers and, to the extent possible, avoid outside inputs generally not available to the small farmer.

The soil management research conducted by PNL emanated from the third and sixth objectives. This research focused primarily on determining the effects of fertilizers on crop yields, the optimal intercrop densities of edible legumes with other non-leguminous crops, and the applicability of alley cropping.

The fertilizer research experiments were primarily "spread and measure" trials to determine the effects of several types of fertilizers on yields in an attempt to identify and assess the magnitude of nutrient deficiencies. This research program suffered from a lack of access to chemical analysis of soils and plant tissues. Although some soil samples were apparently sent to IITA in Nigeria for analysis, the researchers acknowledged on numerous occasions in the PNL annual reports that there was no access to soil analysis facilities. The soils lab established under the precursor INERA Support Project was essentially inoperative by 1985.

In 1985, PNL set up a fertilizer trial at M'Vuazi to determine if the prevalence of a high percentage of empty pods in groundnuts was due to low pH (i.e., high acidity) or a calcium deficiency. Hydrated lime at rates of 0, 100, 400, and 1,000 kg/ha were applied, assuming that 100 kg/ha would be insufficient to raise pH but adequate to overcome a calcium deficiency. All rates of lime reduced the percentage of empty pods from 30 percent for the untreated control to 14, 18, and 16 percent for the 100, 400, and 1,000 kg/ha lime rates, respectively. Analysis of variance was not presented; however, the researchers concluded that the problem was most probably a calcium deficiency.

Numerous experiments were conducted to determine optimal rates of plant densities, with various application rates of fertilizers. Such research provides an endless variety of treatments and is highly site specific; it therefore should be done directly on farmers' fields, because the results change from field to field. One finding, not surprising for low-fertility, acid tropical soils, was that diammonium phosphate increased soybean yields.

Alley cropping was developed as a cultural practice to replace slash-and-burn agriculture with a system that could support continuous cropping with little or no added chemical inputs. The general premise of alley cropping is that adequately pruned trees at sufficient planting density can develop root systems under field crops and thereby absorb the nutrients leaving the root zone of the crops; these nutrients are then transported to the trees' foliage. The leaves can be reapplied to the soil surface to again potentially feed the field crop. Utilization of nitrogen-fixing trees provides a continuous source of nitrogen to the overall system.

As a substitute for slash-and-burn agriculture, alley cropping should be analyzed over the long term. It is intended to extend the productive life of soil before fallowing. It generally does not show short-term benefits over non-alley-cropped systems, because the presence of the trees decreases the total amount of space available for crops per hectare. Consequently, the first years of an alley-cropped system may be less productive than the first years of a non-alley-cropped system.

PNL inherited alley-cropped plots that had been established in Gandajuka in 1981. These plots, composed of **Cassia floribunda** and **Leucaena leucocephala**, were intercropped in a wide array of food crop mixes to test the trees' effects on crop yields. But because most of the trials were of a short duration (one to two seasons), they demonstrated only the detrimental, not the beneficial, effects of alley cropping.

As part of a 1985 study, cotton was intercropped with **C. floribunda** and **L. leucocephala**, both with and without fertilizer (18-46 kg/ha diammonium phosphate). The text and the tables contradict one another as to the method regarding the inclusion of cowpeas in the design; however, the cotton yields were lower within both alley-cropped tree species than the yields in the non-alley-cropped control (PNL, 1986). Fertilizer showed no effects on cotton yields or tree biomass. Again, the trial was too short to demonstrate the nutrient-cycling potential of alley cropping.

In 1986, studies were performed to determine the effects of fertilizer on a **L. leucaena**/maize alley crop using the plots just described. Fertilizer was reduced to 30 kg/ha P_2O_5 , and 30 kg/ha K_2O as potassium sulphate. The non-fertilized **L. leucaena**/maize mix yielded slightly less grain than the maize grown as a mono-crop, probably due to competition for nutrients. However, when fertilized, the **L. leucaena**/maize mix yielded more than the mono-cropped maize. The fertilizer doubled yields both in **L. leucaena** and the mono-cropped maize. This result is most likely due to the phosphorus, because in previous experiments with fertilizer and plant densities, maize and soybeans showed little or no response to potassium but a good response to relatively small amounts (20 to 50 kg/ha) of P_2O_5.

Several years of experiments were conducted to determine which tree species provided the best characteristics for alley cropping under the multiple usage demands the trees have on-farm. In addition to their ability to recycle sub-soil nutrients, trees are also used for fuelwood, fencing, fruits, and construction material. The selection criteria the PNL used for these experiments centered on (1) ability to fix atmospheric nitrogen, (2) amount of biomass production, and (3) ease of seedling establishment.

In 1986, several studies were initiated to screen tree species according to these selection criteria. Trials measuring total biomass production over a four-month period showed **Cassia siamea**, **L. leucocephala**, and **C. floribunda** yielding 8.6, 4.1, and 1.8 Mg/ha, respectively. **L. leucaena** intercropped with cassava, soybean, and maize, and cut at the end of September, November, January, March, and May, yielded on average 1.1, 1.4, 3.1, 4.0, and 2.4 Mg/ha, respectively. The only significant interaction was with **L. Leucaena** biomass yield in September, which in cassava was 2.0 Mg/ha but only about 0.6 Mg/ha in soybeans and maize. No explanation was given.

In February 1988, PNL initiated some on-farm alley-cropping trials at the Gandajuka station. The design was with and without **L. leucaena** and with and without fertilizer (18 and 46 kg/ha of nitrogen and P_2O_5 as diammonium phosphate). The presence of **L. leucaena** had no significant effect on the companion crop of groundnuts. This result was attributed to the poor establishment of the **L. leucaena**

due to insufficient weeding. The height of the on-farm **L. leucaena** averaged 14 cm compared to 50 cm for the on-station **L. leucaena**. The follow-on crop of maize gave higher yields as a monocrop than as an alley crop with and without fertilizer, which was attributed to less frequent weeding of the alley-cropped fields.

By 1989, the long-term benefits of alley cropping had begun to show increased yields of the intercrop (PNL, 1989). The alley-cropped trials with and without fertilizer yielded more maize than the non-alley-cropped maize with and without fertilizer--a turnaround from previous results. This was attributed to both the better access to recycled nutrients given by the pruned tree foliage and the increased organic matter in the alley-cropped soils, which were better able to hold nutrients against leaching.

2. Programme National du Maïs (PNM)

USAID initiated support to PNM in 1972 through a grant to the GOZ in collaboration with CIMMYT. The objectives of the project were to:

- develop maize varieties appropriate to the conditions of rural Zaïre, especially for the regions of Shaba and East and West Kasai;
- develop post-harvest technologies to decrease grain storage losses to disease and pests;
- develop soil management technologies; and
- utilize on-farm testing to assess technologies and their appropriateness to rural farmers' conditions.

It should be noted that at this time farming systems research was just coming into vogue in the agricultural development methodology after having been championed by CIMMYT and CIAT in Latin America. This methodology--which conceptually viewed small-farm enterprises as economic units bounded by the demands of a household--was implemented in this project with initial rural appraisal studies, economic feasibility studies, and on-farm trial studies of technologies before they were recommended for extension.

The PNM program worked to improve maize yields by developing improved varieties, designing mixed cropping systems with legumes, and determining fertilizer application rates that provided positive economic returns over non-fertilized methods. Unfortunately, this period in history coincided with the skyrocketing of oil prices starting in 1973. The subsequent 400 percent increase in world fertilizer prices, combined with the high cost of transportation in Zaïre, made fertilizer use uneconomical at any application rate.

The fertilizer research program initially established trials to determine the response and maximum yields for various combinations of nitrogen and phosphorus.

Although nitrogen and phosphorus are not the only essential nutrients, it was assumed that since deficiencies of these nutrients are usually the first to limit crop yields, nitrogen and phosphorus would be the most likely nutrients to promote a response in fertilizer trials. Not surprisingly, in trials in Shaba and the Kasais, maize responded to nitrogen fertilizer at all locations and to phosphorus at most locations (PNM, 1974).

The research findings from these trials could be questioned as far as the results using phosphorus are concerned. The researchers were aware that some of their on-station trials might be on land that had an undocumented history of phosphorus applications ranging from zero to hundreds of kilograms per hectare. (Unlike nitrogen, which readily leaches from soil, phosphorus remains in the soil for years.) Because soil testing facilities were unavailable, researchers could not control for this possibility.

Knowing the economic limitations of fertilizer usage, the research agenda also included several crop rotation experiments composed of treatments involving fertilizer, lime, green manuring with **Crotalaria caricea** and **Pennisetum purpureum**, and intercropping maize with cowpeas (**Vigna unquiculata**) and soybean (**Glycine max**) (PNL, 1975). These experiments, over a six-year period, resulted in two major findings:

- **C. caricea** planted as an intercrop depressed maize yields in both fertilized and unfertilized intercrops during the first year but greatly increased maize yields in subsequent seasons without fertilizer. **C. caricea** showed only a slightly positive but insignificant ($P = 0.05$) effect on maize yields in fertilized plots after the first year. The fertilizer treatment was an uneconomical 180 and 120 kg/ha of nitrogen and P_2O_5, respectively, applied annually as urea and triple superphosphate.

- Maize grown on the previous year's maize fodder placed beneath the row and intercropped with **C. caricea** or **V. unquiculata** out-yielded the grain legume trials by 300 percent and the no-legume intercrop trial by 200 percent. Clearly, an intercrop mix with a forage legume or grain legume increased maize yields.

This study was conducted to test a "new technology," i.e., to show that intercropping with an efficient nitrogen-fixing legume could enhance maize yields over the long term. This experiment actually showed that a mix of new and old technologies was most effective--especially under a no-fertilizer program used by most farmers. Non-fertilized intercropping of a legume in the furrow and maize on a ridge underlain with the previous year's fodder (consisting of both maize and legume) yielded more maize than did either intercropping using no fodder or intercropping using only maize fodder. Intercropping with a grain legume (cowpeas) produced smaller maize yields the following year than did intercropping with forage legumes, because in harvesting and removal of the grain, the grain nutrients were lost from the

ecosystem. However, an advantage of intercropping with a grain legume was tha it allowed the farmer to diversify the cropping system.

Several other three- and four-year studies are worthy of note. Liming trial were begun in 1977 to demonstrate the effects of lime on maize response t phosphorus applications. The results were very site specific. For instance, the maiz variety Kasai I grown at Kasese showed no response to lime rates of 0, 2, and kg/ha, nor to fertilizer rates of 0, 60, and 120 kg/ha P_2O_5 or to 90 and 180 kg/h nitrogen (PNM, 1977). At Kisanga, lime applications at 1,000 kg/ha improved yield about 300 percent in fertilized and non-fertilized maize/legume plots compared t similarly fertilized non-limed plots (PNM, 1976). The material and methods descriptio of the 1977 trials at Kasese does not mention previous use of that land or the fac that maize showed no response to the lime or fertilizer treatments and yet yielde relatively well (6,500 to 7,000 kg/ha). This result is inconsistent with all othe fertilizer trial data. Unfortunately, the trial was discontinued and not conducte elsewhere.

Sulfur-coated urea was compared to non-coated urea to test the hypothesis that the sulfur coating delayed nitrogen leaching to improve its uptake by maize. The four-year study was able to demonstrate only a small (10 percent) significant ($P = 0.05$) yield increase when using regular urea when applications are split, and no significant differences if all urea is applied at planting. These results also indicated that a sulfur deficiency was probably not limiting maize yields.

PNM did not produce annual reports after 1981. While it is known that PNM initiated agroforestry trials in the mid-1980s, much of this work is undocumented.

3. Programme National du Manioc (PRONAM)

The PRONAM agronomic research program established the following soil fertility research priorities:

- study the effects of liming soil on the productivity of cassava-based cropping systems in Bas-Zaïre;
- study in greater detail the profitability of fertilizer application to cassava; and
- study the practicability of introducing alley cropping into the existing systems (PRONAM, 1990).

Cassava is well suited to the acid soils prevalent throughout Zaïre. However, many companion crops in the farming systems of Zaïre, such as maize, groundnut, and other legumes, are adversely affected by the conditions common to soils with pH values in the 4.0 to 5.0 range. Maize is susceptible to aluminum toxicity, and many of the legumes suffer from deficiencies of phosphorus, calcium, and magnesium.

Like PNL and PNM, PRONAM suffered from the lack of an analytical soils laboratory to permit the diagnosis of soil nutrient deficiencies and toxicity symptoms. In the absence of such analytical capacity, these national programs used field plot techniques to investigate soil problems. For lack of a laboratory and a very simple and inexpensive analysis, trials were conducted in 1985 to determine if cassava would respond to lime and phosphorus fertilization. Not surprisingly (since cassava does very well on acid (pH 4) soils and at very low levels of phosphorus), neither lime nor phosphate additions had any significant effect on cassava root yield.

However, to test the performance of an intercrop farmers would use, trials were conducted to evaluate the effects of lime on a cassava/maize and a cassava/groundnut mix. Again, cassava showed no response to lime; however, both the maize and peanut showed a strong linear response to lime. Maize yield increases of 70 percent were recorded with 2 Mg/ha of lime compared to the non-limed control. Groundnut yields increased over fourfold with lime applications of 800 kg/ha compared to the unlimed plots at the M'Vuazi station. In addition, the percentage of empty pods decreased from 14 percent with no lime to 2 percent with only 200 kg/ha. The 200 kg/ha lime did not affect pH or reduce aluminum toxicity. However, it apparently increased soil calcium levels to non-deficiency levels. In fact, an additional study performed by PRONAM on mono-cropped groundnuts found that as little as 50 kg/ha of lime increased yields from 603 kg/ha to 1,328 kg/ha, and 800 kg/ha lime produced 2,700 kg/ha. This effect of small application rates of lime on peanut yields was similarly seen in PNL research investigating the same problem. The diagnosis of a high percentage of empty pods as a calcium deficiency is not new.

Studies on alley cropping started at M'Vuazi in 1982, with the following objectives:

- to test **Leucaena leucocephala** as a means of maintaining soil fertility under intensive land-use employing an alley-cropping system; and

- to evaluate other leguminous trees species for their adaptation to acid soils and suitability for alley cropping in Bas-Zaïre.

Initial studies to determine the effects of **L. leucocephala** alleys on maize showed no significant differences in yields between maize in and out of an alley system. This was attributed to the low biomass yield of the **L. leucocephala**, due to its poor establishment on the acid (pH 4) soils and consequent poor nitrogen fixation and nutrient cycling capacity. Lime applied at 1 Mg/ha, which on similar soils raised the pH from 4.5 to 4.7, had no effect on **L. leucocephala** biomass. A 50-50-50, N-P-K application did not affect **L. leucocephala** biomass either, but it did increase intercropped maize yields by about 80 percent.

Following the discovery of the rather insignificant effect of **L. leucocephala** on maize in alley-cropped systems, new trials were set up to test five local tree varieties

and five imported varieties that had been used elsewhere in the world. All of the species out-yielded **L. leucocephala**, with the highest yields produced by **Albizia stipulata**, followed by **Cassia siamea**, followed by **Cassia spectabilis**. Results of trials with these newly selected varieties were not reported.

III. Lessons Learned

A. Institutional Organization and Structure

The institutional organization of SENARAV along commodity lines does not, in and of itself, hamper the research agenda. Alternative models, such as by discipline (e.g., entomology, soils, breeders), are probably less advantageous; organization by program (e.g., agroecological zone) also has its disadvantages when dealing with Zaïre's range of food crops, which are grown in almost all environments.

All three national programs recognized the need to include other food crops in their agronomic trials evaluating technological packages. Although the breeding programs were frequently mono-cropped, the agronomy trials used mixed systems and evaluated their advantages and disadvantages. There were occasional instances of similar research being repeated due to an apparent lack of coordination of research plans.

One of the major constraints to the agronomy and soil management research was the lack of soils and plant tissue analysis laboratories; it is hard to overestimate the extent to which this constraint hampered the research agenda. Many large-scale field trials were established to gain the knowledge that a few soil or leaf analyses could have provided. Field trials are expensive due to the requirements for labor, equipment, and analysis; soil analysis is relatively inexpensive. The agricultural research institutions in Zaïre need a laboratory that can perform routine chemical analysis of soils and plant tissues.

B. Research Strategy and Implementation

The research goals for each national program were well documented, but the implementation strategy was haphazard. First, there did not appear to be a logical link between scientific and technological research. As problems are identified, an assessment of what needs to be known should be made before the technology development process is started. For example, the cause of the high percentage of empty peanut pods on the very acid soils was suspected to be a calcium deficiency. A large field trial with four rates of lime and three rates of phosphorous was conducted instead of (1) performing a soil analysis to measure calcium concentrations, and (2) conducting a simple "pot study" under controlled conditions to determine if peanuts responded to small application rates of calcium. The field trial confirmed that

there was a calcium deficiency--but at a high relative cost for only a single piece of information. Because the experiment conducted was not technological in nature, another field trial was subsequently conducted to start the process of turning the new knowledge into a farmer-usable technology.

Field trials in fact were frequently used to provide information that simple, inexpensive greenhouse "pot studies" could deliver. While pot studies certainly have their limitations, they also have their strengths. Better judgment should therefore be brought to bear on decisions regarding field trials.

C. Institutional Memory and Follow Through

SENARAV should be commended for continuing to publish annual reports of research findings even under difficult budget constraints. However, the SENARAV annual reports usually provided inadequate descriptions of the materials and methods, and the statistical analysis was frequently incomplete. Since this type of research is not easily publishable in international journals, SENARAV should take extra care to fully document and explain each experiment. With the prevalence of computers and statistical software in SENARAV, these deficiencies in presentation can be easily overcome.

References

Programme National des Légumineuses (PNL). 1975. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1986. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1989. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

Programme National du Maïs (PNM). 1974. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1976. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

------. 1977. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

Programme National du Manioc (PRONAM). 1990. Rapport Annuel. Kinshasa: Département de l'Agriculture, République du Zaïre.

United States Agency for International Development (USAID). 1977. INERA Support Project Paper (Project 660-0064). Washington, D.C.: USAID.

------. 1981. INERA Support Preliminary Evaluation (Project 660-0064). Washington, D.C.: USAID.

------. 1982. Midterm Evaluation: INERA Support (Project 660-0064). Washington, D.C.: USAID.

------. 1990. RAV II Project Paper (Project 660-0124). Washington, D.C.: USAID.

CHAPTER 6

PRIORITIES AND RECOMMENDATIONS FOR THE FUTURE

All Team Members

I. Germplasm Development

A. Cassava

The Programme National du Manioc (PRONAM) was initiated in 1974 by the Government of Zaïre with technical assistance from the International Institute of Tropical Agriculture (IITA). At that time, cassava bacterial disease threatened the entire cassava crop. PRONAM has designed an efficient and effective breeding program of introduction, hybridization, and selection. The varieties developed have the combined characteristics of the local varieties, are resistant to major diseases and insect pests, and have high root yield and desirable pondu. Since the inception of PRONAM, the selection cycle was shortened from eight to five years.

In the early years of the program, seed varieties of high-yield cassava were introduced, which gave high root yield. However, little attention was placed on the quality of the vegetative part of the plant, an important consideration since the leaves are consumed on a large scale in Zaïre and provide sources of nutrients during the growing season.

The cassava breeding program is technically sound and functional. The program is almost identical to the IITA Root and Tuber Crops Program, which is a proven breeding program. All of the breeders at PRONAM have received some IITA training.

A number of recommendations are made here in order to improve the already high-quality germplasm development effort at PRONAM. First, it is recommended that the cassava breeding program utilize various ploidy levels to investigate the possibility of developing sources of resistance to diseases and insect pests. Other closely related species may possess some of the desirable characteristics that can be useful to the breeding program. Second, additional attention should be given to the quality evaluation of local varieties in the development of new varieties. The collection of local varieties should be expanded to include all areas of the country. Third, the laboratory should be equipped so as to fully support the high-quality breeding program. Finally, more attention should be devoted to the nutritional quality of the leaves, which, along with the tubers, are a staple of the Zaïrian diet.

B. Maize

The Programme National du Maïs (PNM) was established in 1974 with the technical assistance of CIMMYT-Mexico. Six improved, high-yield varieties were developed: Shaba Safi, Shaba I, and PNM I (South Shaba); Kasai I (North Shaba); and Salongo and Salongo II (Kasai Oriental). Downy mildew and streak virus are the two major diseases that pose the greatest problem for the corn-growing areas of

Zaïre. PNM was successful in developing streak resistance in the six new PNM varieties using the back-crossing breeding method.

It is strongly recommended that an inbred line development program be reestablished as a breeding tool. The breeding program devotes considerable time and resources to breeding disease-resistant varieties. However, the disease evaluation pressures have relied primarily on the natural infestation levels. It would be helpful to develop uniform exposure methodologies. In trials elsewhere, maximum expression of leaf blight has been induced by applying three separate isolates of **Helminthosporium turicum** at noon for three successive days, three weeks after emergence.

Finally, it is recommended that a collection of local germplasm from the major corn-growing regions of Zaïre be utilized as a source of germplasm for background material for the breeding program in the future.

C. Grain Legumes

PNL and its Breeding and Selection Section function effectively and productively, as attested to by the release of several varieties of each of the four principal grain legumes. The reasoning behind USAID's original support to PNL is sound. Support to PNL should be a priority if U.S. development aid to Zaïre is resumed.

1. Choice of Crops

The present priority order for resource use is sound: Beans and, increasingly, peanuts should have first priority as the most important grain legumes in Zaïre. Soybeans, a new crop in which there is considerable interest, should be assigned a second priority. Cowpeas are important in Zaïre, but little progress is possible until insect-resistant lines are available from IITA, the major international program. Cowpea research should be conducted only in close cooperation with IPM research.

2. Design of the Breeding and Selection Program

At its present level of sophistication, the PNL Breeding and Selection Section's most pressing technical assistance need is in-service training for researchers. Such training would permit researchers to streamline the crossing program and to select breeding and selection objectives and methods not only according to anticipated on-farm benefits (as in RAV I), but also according to the probability of achieving the desired outcome given the available resources. For staff members who have had this training at the master's level in graduate school, in-service technical support will help them develop the confidence and experience to be able to apply their training to their actual work situations.

3. Advanced Training

Long-term training in plant breeding and associated disciplines has been USAID's most effective and lasting contribution to food crop germplasm development in Zaïre. No Ph.D.-level plant breeders were trained for the PNL; had RAV II technical assistance continued for the anticipated full three years to give the Master's degree-level staff the hands-on experience in applying theory to research, none might have been needed. Without technical assistance, however, some national staff must be trained to the Ph.D. level.

4. Research Planning and Documentation

The annual PNL internal review, designed for reporting the year's research and planning the next year's research, is ineffective in its present form. The review is too ceremonial and allows far too little time for small-group researcher meetings. Much more opportunity is needed for face-to-face interaction among PNL staff researchers. This is critical in Zaïre, since long-distance communication is nonexistent.

Reports on grain legume research should be written with the needs of different user groups in mind. Summaries should be written for administrators, and complete experimental methods and results written for researchers. Data should be presented for each season. The common practice of presenting only yearly averages over Season A and Season B contributes to the loss of much valuable information.

The present workplan format more closely resembles a grant proposal than a practical plan for actual research activities. A tightly prioritized document that provides guidance at each decision point when resources available fall short of those requested or expected is needed. A serious effort should be made to ensure distribution of reports and workplans to the front-line users of these documents, the PNL research staff.

5. Location of Research Activities

PNL is overextended given its present resources. It is recommended that the number of crops per station be reduced, even though some important research will be omitted, until a later time when transport, communications, and funding are improved.

Crop recommendations for each of the six currently operating stations are as follows: Gandajika, peanuts, cowpeas, and soybeans; Kaniama, beans and peanuts, or, close this station; M'vuazi, beans, peanuts, and soybeans; Mulungu, beans and soybeans; Kiyaka, peanuts; and Kaniameshi, beans, peanuts, and soybeans, if Kaniama is closed, or, if Kaniama is retained, only two of the three.

As long as USAID's resources for support to Zaïre food crops research are limited and as long as the CIAT Great Lakes Regional Bean Improvement Program is active, USAID should not invest heavily in technical assistance for bean germplasm

development in the Kivu area--despite the temptation to work in an area where the need is well known and where quick and visible impact is most likely. The CIAT program is effective, and a major USAID investment in high-altitude bean research would result in duplication of effort and possibly counterproductive competition between the two groups for donor funding.

6. Location of Headquarters

Gandajika is the logical grain legume research headquarters site for reasons of agroecology and for purposes of distribution of SENARAV and technical assistance resources across stations. But Gandajika is too isolated to be a good choice for a headquarters location. Other factors that mitigate against Gandajika are high costs of operation; staff travel time; and the lack of communication, transportation, utilities, schools, and health services, which contributes to poor staff retention. Staff retention is a particularly important consideration because of the scarcity and value of trained staff in Zaïre and USAID's investment in training the present cadre.

Although all arrangements alternative to Gandajika also leave much to be desired, it is recommended that the PNL headquarters be moved to M'vuazi or Kaniameshi. Mulungu is not a good choice because it is too distant (a three-day trip) from all other sites and already disproportionately favored with other technical assistance.

7. Seed Multiplication and Storage/Conservation

Seed availability is the most critical bottleneck impacting grain legume germplasm development research. Lack of seed of recommended varieties because of low production and post-harvest losses was a chronic problem in the PNL's collaborative work with outreach organizations. Seed drying and storage facilities are also inadequate for proper maintenance of the working germplasm collection that is the raw material of genetic progress. At present, because of the very short shelf life provided by the available storage conditions, any line to be retained must be sown, harvested, dried, and threshed twice each year, a process that is an immense drain on resources.

The need for investment in seed production, processing, and storage equipment and facilities, and in personnel trained in these areas, has long been discussed but not addressed. Because of its critical importance, seed production should be the responsibility of a separate support section. Seed production should not be the responsibility of the Breeding and Selection Section because it is not "research" and will therefore suffer neglect when research staff time and resources are limited (as they always are).

II. Plant Protection

In the future, plant protection research on cassava, maize, and grain legumes should emphasize integrated pest management (IPM). Because of limited resources, the research focus should be limited to key insect pests and diseases.

Integrated pest management systems for maize, cassava, and grain legumes grown by subsistence farmers in Zaïre must differ markedly from those in advanced countries. In Zaïre, these food crops are mostly cultivated as mixed crops, and farmers rarely use chemicals. Therefore, there is a need to develop a sound, sustainable pest management strategy that minimizes or eliminates pesticide application.

Researchers working to develop integrated pest management programs for cassava, maize, and grain legumes in Zaïre are hindered by the lack of adequate information on occurrence, behavior, and peak activity of pests. They also have little information on the effect of mixed cropping. It is recommended that an economist work in collaboration with crop production researchers to assess crop losses due to field and storage pests.

Due to the lack of effective extension services at the village level and the lack of fixed market prices of crops in Zaïre, it is difficult to establish economic injury levels, which are a prerequisite for IPM. Therefore, the applicability of these methods in Zaïre is minimal at present. The emphasis of IPM must be on other control measures in the field. Potential exists for use of pest-resistant varieties, biological control, and cultural practices. Breeding for suitable varieties is also important. The indeterminate cowpea plant, for example, has the capacity to grow and produce over a longer period than most determinate varieties and hence will probably be a more desirable plant type for subsistence farmers in Zaïre. The longer period of growth enables the indeterminate type to compensate for damage to reproductive and vegetative parts.

All components of IPM should be directed toward identifying the best combination of practices in order to develop a program that is effective, inexpensive, and capable of easy adoption by subsistence farmers in Zaïre. Farmers' practices for controlling pests and diseases in the field and in storage should be investigated. Insecticides should be used judiciously for the control of cowpea insect pests in order to conserve or augment natural enemies (parasites and predators). Local botanicals should be explored as substitutes for insecticides. Breeding materials with full protection of pesticides should not be evaluated.

III. Natural Resource Management

Analysis of a technology's impact on the natural resources of an agroecosystem is as important as analysis of its economic impact. Both socioeconomic and biophysical evaluations of a technology are prerequisites of acceptable and sustainable agricultural development. Access to the tools of biophysical analysis is therefore a necessity.

Zaïre currently lacks the tools to effectively assess the agroecological soundness of technologies. Much of the analytical process is an assessment of the input and removal of biophysical resources. Although long-term field studies (six to eight years) can be used for assessment of the long-term sustainability of a technology, the assessment process can be much shorter if the field studies are performed in conjunction with chemical analysis of the soil and plant tissues involved in the field studies. In fact, many of the more costly field trials can be avoided with several simple and routine analyses of soils and plant tissues. That Zaïre, a country of 35 million people, has no capacity to perform these types of analyses is an indication of its exceptionally poor state of development. Most other countries in Africa have these capabilities to support their agricultural research and quality-control needs (e.g., water quality).

It is strongly recommended that if and when USAID reinitiates its support to agricultural research in Zaïre, it establish as a priority the development of a soil and plant tissue analysis laboratory, in Kinshasa, not Mulungu. Kinshasa has more reliable power, which will be required by the scientific equipment employed; is a port city and center of commerce for equipment and chemical suppliers, who will be needed to keep the lab operational; is the hub of the domestic airline industry, which will be used to transport samples from the many experiment stations; has the most reliable communication facilities, needed to radio/FAX results back to stations; and has social amenities, which are conducive to retaining highly trained Zaïrian personnel.

APPENDIX A:

Personnel Lists

Table A.1 PNM Staff Positions in April 1992

Name	Designation	Degree
Mukendi, K.	Director and Breeder	M.S.
Asanzi, M.Y.	Entomologist	Ph.D.
Musubao, M.L.	Breeder	Ing. Agronome
Kasongo, Ngindu	Plant Pathologist	M.S.*
Nsitu, Mbungu	Entomologist	M.S.*
Bakelana, Ba-K	Agronomist	Ph.D.*
Matengulu	Soil Scientist	Ph.D.*
Kembe, M.	Breeder/Pathologist	Ing. Agronome
Kalenga	Extension Specialist	Ing. Agronome
Kabongo	Head, PNM-M'Vuazi	Ing. Agronome
Major	Head, PNM-Kiyaka	Ing. Agronome
(vacant)	Head, PNM-Gandajika	Ing. Agronome
(vacant)	Head, PNM-Kaniama	Ing. Agronome

*currently enrolled

Table A.2 PRONAM Staff Positions in April 1992

Name	Designation	Degree
Muimba Kankalongo	Acting Director Pathologist	Ph.D.
Nsiama-She Hatalman	Director (on sabbatical at IITA/Benin) Entomologist	Ph.D.
Kasu Tombo	Entomologist	Ph.D.
Kiala Kilusi	Breeder	Ph.D.*
Ndombo Delo	Breeder/Pathologist	M.S.
Landu Kalemba	Agronomist	M.S.
Bidiaka Mpansu	Breeder	M.S.
Tata Hangy	Entomologist	M.S.
Kasele Idumbo	Agronomist	Ph.D.
Lukombo Singi M.	Food Scientist	M.S.

*currently enrolled

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Table A.3. National Program Staff at Level of Ingenieur Technicien and Above Conducting Grain Legume Research During the Years of USAID/GOZ Collaboration

Name	Training Level or Grade	Dates of Service	Activity (Highest Rank/Station)
Kilumba, Ndayi	M.S.	1985-present	Agronomy/farming systems (Director, PNL)
Kalombo, N'Goma	M.S.	1985-90	Variety testing, germplasm
Kalombo, Mwimbila	M.S.	1985-present	Plant breeding
Kadima, Ngaleka	M.S.	1985 (?)-present	Plant breeding (Head, PNL Breeding Section, Gandajika)
Ngoyi, Mwabilu	M.S.	1985-90	Soil fertility/agronomy
M'Vubi, Kabangie	A0	1985-90	Agricultural economics
Bukasa, Kalembue	A1	1985-present	Entomology (Gandajika; Chef d'Antenne, PNL-Kivaka)
Pyndji, Mukishi	M.S.	1979-present	Plant pathology (INERA; Chef du PNL-Mulungu)
Aliya (deceased)	M.S.	pre-1985	Extension
Mafolo, Tamahoto	M.S.	1985-present	Plant breeding
Nkonko, Mbikayi	M.S.	1979-present	Bean breeding (INERA/PNL-Mulungu)
Mbukapindo, Mopati		1985	
Mpiana, Kashalo		1985-92	
M'Vita, Mbambi	M.S.	1985-present	Plant breeding (Chef d' Antenne, PNL-M'Vuazi)

Table A.3, continued

Name	Training Level or Grade	Dates of Service	Activity (Highest Rank/Station)
Kabaluapa, Kapinga	A0	1985-present	Soil fertility
Mpoy, Mudiamvita C.	A0	1985-91	Rural sociology (Gandajika)
Likoko, Bambele	M.S.	1985-90	Soil classif. (Gandajika)
Mbahikira, Kireru	A0	1985-89	Plant breeding, beans
Wangata	M.S.	1985-present	Plant breeding, peanuts
Milambo	M.S.	1979-present	Plant pathology
Kubengu, Mudilamika	G3	1979-present	Farming systems agronomics
Tshibangu, Munianji	A1	1985-present	Cowpea breeding; outreach (Gandajika)
Kanonge		?-present	Soybean breeding; outreach (Gandajika)
Tchunza		?-present	Foundation seed; outreach (Gandajika)
Frangoie, Ngoie	A0	1989-91	Bean and cowpea breeding (Gandajika)
Matand Kanyand	M.S.	1885-present	Peanut breeding (Gandajika)
Dibwa	A	1985-present	Asst. Chef d'Antenne, PNL-M'Vuazi
Lunze, Lubanga	M.S.	1979-present	Soil fertility (INERA/PNL-Mulungu)

Table A.3, continued

Name	Training Level or Grade	Dates of Service	Activity (Highest Rank/Station)
Elukessu, Komba	M.S.	1979-present	Agronomy (INERA/PNL-Mulungu)
Tshitebwa, Musungayi	M.S.	1979-present	Agronomy, outreach (INERA/PNL, Mulungu)
Kanyenga, Lubobo	A	1985-90	
Kasu, Tombo	Ph.D.	1985-92	Entomology
Lodi, Lama	A1	1985-present	Plant breeding, M'Vuazi
Muyumba		1985-89	Foundation seed, Gandajika
Mbahikya, Kireru		1987	Breeding section, Gandajika
Muamba, Kalala	M.S.	1985-present	On-farm agronomy
Zantoko, Lubaki		1987	Entomology

Note: Omissions in this table reflect gaps in available information sources. Dates of service are approximate.

Table A.4. Key Collaborators with Grain Legume Research in Zaïre During the Years of USAID/GOZ Collaboration

Name	Organization	Dates of Involvement	Specialty
Buruchara, Robin	CIAT Great Lakes Pgm.	1990-present	Pathologist
Camacho, Luis	CIAT Great Lakes Pgm.	1990-present	Bean breeder
Davis, Jeremy	CIAT Great Lakes Pgm.	1987-89	Bean breeder
Dessert, J. M.	CIAT Great Lakes Pgm.	1987	
Dessert, K.	CIAT Great Lakes Pgm.		
Graf, Willi	CIAT Great Lakes Pgm.	1991	Agronomist
Scheidegger, Urs	CIAT Great Lakes Pgm.	1989-present	Agronomist
Sperling, Louise	CIAT Great Lakes Pgm.	1988-present	Anthropologist
Trutmann, Peter	CIAT Great Lakes Pgm.	1988	Pathologist
Voss, Joachim	CIAT Great Lakes Pgm.	1987	Cropping systems specialist
Bock, Marya	GTZ Projet Kabare		
Mputu	GTZ Projet Kabare		Extension
Melchior, Nahimana	IRAZ		

Note: Due to the custom of referring to organizations rather than individuals, many names are unavailable. In addition, omissions in this table reflect gaps in the available information sources. See Table 3.28 for a list of organizations that cooperate in outreach activities.

Table A.5. USAID-Contracted Technical Advisors to Grain Legume Research in Zaïre During the Years of USAID/GOZ Collaboration

Name	Training Level or Grade	Dates of Service and Contractor	Activity and Project/ Station
Nguyen	Ph.D.	1979-85 MASI	INERA Support Project Pre-RAV I/Mulungu
Shannon, D.	Ph.D.	1985-89 IITA	Agronomist, RAV I/ Gandajika
Camacho, L.	Ph.D.	1986-90 IITA	Plant Breeder, RAV I/ Gandajika
Thro, A. M.	Ph.D.	1991-92 SECID	Plant Breeder, RAV II/ Gandajika

APPENDIX B:

Summary of Grain Legume Germplasm Characteristics and Release Recommendations

Table B.1. Important Bean Lines in Zaïre

A. Bean Varieties Recommended by PNL for Release Through 1991

Year First Recommended and Variety Name	Experimental Number	Source	First Test Year in Zaïre	Region of Adaptation
1990				
ALIYA	G 2333	CIAT	1979	Kivu
Climbing, small, shiny, red seed, white flowers; high yield requires good soil fertility and climbing support to express yield potential; tolerant to angular leaf spot and anthracnose; resistant to floury leaf spot, ascochyta blight, and rust; line originally from Mexico; named in honor of a PNL extension scientist killed in a road accident while working.				
WAMBEDI	MCD 201	CIAT	1983	S. Kasai, N. Shaba
Semi-climbing, small, red seed; relatively high yield on poor soils (± 400 kg/ha), average yield (± 1,000 kg/ha) in favorable environments; moderately resistant to bacterial blight and web blight; name is Tshiluba for "The First," to commemorate the first bean variety from Gandajika.				
1991				
CIHEMBE	G 2331	CIAT	1980	Kivu
Climbing; medium-size, shiny, yellow seed; white flowers; high on-farm yield; tolerant to angular leaf spot; resistant to ascochyta blight, anthracnose, floury leaf spot, halo blight, and rust; line originally from Mexico; name refers to a special method of preparation that permitted its local acceptance.				
KYAKULWA	BAT 1449	CIAT	1985	N. Shaba
Semi-climbing; outstanding (± 1,400 kg/ha) yield in favorable environments in the Kaniama area over six seasons; poor yielder (± 300 kg/ha) in poor environments; resistant to angular leaf spot; name is Kiluba language for "something constantly noticed and admired."				

Table B.1, continued

B. Check Entries and Local Bean Lines in PNL Trials Through 1991

Experimental Number or Name	Source	First Test Year in Zaïre	Region of Adaptation
A 21			Kasai Oriental, Shaba

Bush; red seeds; recommended by INERA for distribution (pre-1985); check at Gandajika, Kaniama, Kaniameshi, 1988-89; average yields in favorable environments and low yields in poor environments; tolerant to bacterial blight and web blight.

CUARENTINO 0817			Kivu, Bas-Zaïre

Climbing; white seeds; recommended by INEAC for M'Vuazi, pre-1960, and by INERA for distribution as best white-seeded line for Bas-Zaïre (pre-1985); check at Mulungu, 1987-89.

D 6			Kivu, Shaba

Bush; large red-rose, spotted seed; responds to high soil fertility; check at Kaniameshi in 1990; seed increased in 1991 by a GTZ program (German) in Kivu for distribution in villages.

KIRUNDO	Burundi	1985	Kivu

Bush bean; recommended by PNL in 1987-88 for distribution in high-altitude regions.

MUHINGA	Zaïre		

Bush; high yields in favorable environments in Bas-Zaïre; poor yields in poor environments; recommended by INERA for distribution (pre-1985); check at Mulungu, 1986; susceptible (S) to angular leaf spot.

NAKAJA	Kivu	1986	Kivu

Bush; check entry for Mulungu trials, 1985-91; in S. Shaba, very high yield (± 1,600 kg/ha) in favorable environments and poor yield in unfavorable environments; recommended by PNL in 1987-88 for distribution in high-altitude environments.

Table B.1, continued

B. Check Entries and Local Bean Lines in PNL Trials Through 1991, continued

Experimental Number or Name	Source	First Test Year in Zaïre	Region of Adaptation
NAIN DE KIYONDO	Kivu	pre-79	Kivu
Bush; highest recorded bush bean yields at Mulungu, 1979-85; recommended by INEAC pre-1060 and by INERA for distribution pre-1985; recommended by PNL in 1987-88 for distribution in high-altitude environments; check at Mulungu, 1988; highly stable yield (low to moderate in favorable environments; relatively high yield in unfavorable environments) Mulungu, 1986-89; moderately resistant to bacterial blight.			
NTENDEZI			Bas-Zaïre Shaba
Bush; large, white seeds; recommended for Bas-Zaïre by INERA, pre-1985; check at M'Vuazi, 1987-90, and Kaniameshi, 1988.			
PVO 14/2	INERA		Bas-Zaïre
Bush; "best INERA bean line"; check at M'Vuazi, 1990; very high yields in poor environments in Bas-Zaïre; poor yields in good environments (requires confirmation).			

C. Candidates for Future Release Recommendation: Elite Bean Lines in PNL Advanced Trials, 1989-91

A 445	CIAT	1987	Kaniama
Semi-climber; outstanding (± 1,400 kg/ha) in favorable environments in the Kaniama area over six seasons; poor yielder (± 300 kg/ha) in poor environments.			
ASC 42		1989	Kivu
Climbing; outstanding yields in association with maize.			
ACV 83031		1989	Kivu
Climbing; outstanding yields in association with maize and in monoculture.			

Table B.1, continued

C. Candidates for Future Release Recommendation: Elite Bean Lines in PNL Advanced Trials, 1989-91, continued

Experimental Number or Name	Source	First Test Year in Zaïre	Region of Adaptation
AND 112 Climbing		1989	Kivu
AND 428 Climbing			
AND 622 Bush		1989	Kivu
AND 663 Bush		1989	
AND 668 Bush		1988	
AND 687 Bush		1989	
CARIOCA Bush; relatively high yield (± 600 kg/ha) in unfavorable environments in Kaniama area, with average yield (± 1,000 kg/ha) in favorable environments.		1987	N. Shaba
DOR 333 Bush	CIAT	1989	Kasai
DOR 335 Bush	CIAT	1987	Kasai
G 5173 Climbing; satisfactory yield in association with maize without depressing maize yield.	CIAT	1987	Kivu
G 5473 Relatively high yields in poor environments in Bas-Zaïre; low to average yields in good environments.	CIAT	1987	Bas-Zaïre

Table B.1, continued

C. Candidates for Future Release Recommendation: Elite Bean Lines in PNL Advanced Trials, 1989-91, continued

Experimental Number or Name	Source	First Test Year in Zaïre	Region of Adaptation
GUANAJUATO 10-A-5		1987	Kivu
Climbing; outstanding yields in association with maize.			
ICA LINEA 65	Colombia	1989	Kasai
Bush; moderately resistant to common bacterial blight and web blight.			
MELANGE 1	PNL from CIAT lines	1989	Kivu
Bush; mixture components: ICA Linea 68, AFR 315, M 167, and 622; developed for resistance to angular leaf spot in Kivu.			
NAKAJA	(See Section B of this table)		
NTENDEZI	(See Section B of this table)		
PAI 110		1989	S. Shaba
Bush; in S. Shaba, very high yield (± 1,600 kg/ha) in favorable environments and poor yield in unfavorable environments.			
PAN 72		1987	Kasai, N. Shaba
Bush; resistant to common bacterial blight; outstanding in favorable environments in Gandajika area over six seasons.			
RAB 267	CIAT	1988	Kasai, Shaba
Bush			
RAB 273	CIAT	1989	S. Shaba
RAB 416	CIAT	1987	Bas-Zaïre
Red grain; relatively high yields (± 600 kg/ha) in poor environments in Bas-Zaïre; low to average yields (± 900 kg/ha) in good environments.			
RAO 29	CIAT	1987	Kasai
Bush; outstanding in favorable environments in Gandajika area over six seasons.			

Table B.1, continued

C. Candidates for Future Release Recommendation: Elite Bean Lines in PNL Advanced Trials, 1989-91, continued

Experimental Number or Name	Source	First Test Year in Zaïre	Region of Adaptation
RUBONA 5	Colombia	1986	Kivu, S. Shaba
Bush; medium red-rose, spotted seed; highly stable, low to moderate yields over favorable and unfavorable environments, Mulungu, 1986-89, and Kaniameshi, 1988-90.			
XAN 192	CIAT	1988	Shaba

Table B.2. Important Soybean Lines in Zaïre

A. Soybean Varieties Recommended by PNL for Release Through 1991

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
1988-89			
MUNANGA	TGX 814-26D	IITA	Mid- and low altitudes
Mid-season maturity; non-shattering; good nodulation with indigenous Rhizobium; "Munanga" is Tshiluba language for "appreciated."			
AFYA	TGX 849-249D	IITA	Mid- and low altitudes
Medium to early maturity; non-shattering; good nodulation with indigenous Rhizobium; "Afya" is Tshiluba or Swahili for "good health."			
1991-92			
(To be det.)	IAC 73-5115	ISVEX	Bas-Zaïre, Bandundu
Check variety at M'Vuazi, 1989; medium maturity (110-120 days); good nodulation with indigenous Rhizobium; non-shattering; flowers mauve; pubescence tan; yellow seed; rapid loss of seed viability.			

B. Other Important Soybean Lines in PNL Trials

HERNON
Check variety Mulungu 1987, Lubumbashi (Kaniameshi) 1987; medium maturity.

JUPITER — Mid- to low altitudes
Check variety at Gandajika and Kaniama, 1987-88, and at Mulungu, 1988; late maturity. Significance of "Jupiter-R," "Jupiter-Gandajika," and other designations in PNL records is not clarified; it could mean seed lots of different origin with or without different characteristics, or the origin of single-line selections from Jupiter.

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Table B.2, continued

B. Other Important Soybean Lines in PNL Trials, continued

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
SJ 127		INERA (Gandajika?)	Mid- to low altitudes
Check variety Gandajika and Kaniama, 1986, 1987, 1988, and 1989, Lubumbashi (Kaniameshi), 1988, 1989; single-plant selection from Imperial; recommended pre-RAV I; desirable early to medium maturity; small seeds; susceptible to shattering.			
TGX 814-27D		IITA	Mid- to low altitudes
Medium to late maturity; shatter-resistant; "good in on-farm trials" (Shannon, 1990).			
TGX 814-49D		IITA	
"Good in on-farm trials" (Shannon, 1990).			
UFV 1		ISVEX/ Brazil	High, mid-, and low altitudes
Recommended by INERA; good yield potential at high as well as mid- and low altitudes; medium maturity.			

Table B.3. Important Peanut Lines in Zaïre

A. Peanut Varieties Recommended by PNL for Release Through 1991

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
1989			
BUBANJI	JL 24	ICRISAT	Mid- and low altitudes

Early; Spanish; medium size, pink seed; adapted to both short and normal rainy seasons; recommended based on a mean yield of 1,428 kg/ha vs. mean yield of checks of 698 kg/ha in 23 test environments; yield advantage for Bubanji over checks: 104%. (In Gandajika, Kaniama, and locality, checks were G 17 and A 65; in M'Vuazi, Kiyaka, and locality: G 17 and P 43); used as parent, PNL 1989, 1990, 1991 peanut crosses; intermediate susceptibility to cercospora leaf spots and rosette; "Bubanji" is Tshiluba for "fortune."

B. Important Peanut Lines in PNL Trials Through 1991

A 1052		INERA	Bandundu
Used as check at Kiyaka, 1989-90.			
A1208/2		INERA	
Used as parent in PNL 1989 peanut crosses.			
A 33		INERA	Kasai
Used as parent in PNL 1990 peanut crosses.			
A 65		INERA	Kasai, N. Shaba

Described as "local cultivar" in PNL 1986 annual report; A 65 and P 43 are both from the INERA collection and are of unclarified origin (local land races collected by INERA or INEAC? introductions by INERA or INEAC?); used as the check entry, Gandajika and Kaniama, 1987, 1989; used as parent in PNL 1989, 1990, and 1991 peanut crosses; may be MR or R to rosette.

AE4/2			Bas-Zaïre
No other information.			

Table B.3, continued

B. Important Peanut Lines in PNL Trials Through 1991, continued

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
B24 Used as parent in PNL 1989 peanut crosses.			
BLANCHE DE KANIAMA Rated as a consistently high-yielding variety by RAV I; notably high yields in Gandajika.			Kasai, N. Shaba
E 285 Used as parent in PNL 1990 peanut crosses.			Bas-Zaïre
G 17 Used as the check entry at Gandajika and Kaniama, 1986, 1988, 1989, and at M'Vuazi and Kiyaka, 1988; used as parent in PNL 1989, 1990, 1991 peanut crosses; susceptible to rosette.			Mid- and low altitudes
HYQ(CG)S-10 "High yield and quality"; large seed; parent in PNL 1990 crosses.		ICRISAT	
ICG (FDRS)-4 "Foliar disease resistant selection"; parent in PNL 1990 crosses.		ICRISAT	
ICGS(E)-4 Rated as a consistently high-yielding variety by RAV I; used as parent in 1989 and 1991 PNL peanut crosses; early maturity.		ICRISAT	Kasai, N. Shaba
ICGS(E)-18 Rated as a consistently high-yielding variety by RAV I; used as parent in 1991 PNL peanut crosses; early maturity.		ICRISAT	Kasai, N. Shaba
JL 12 Rated as a consistently high-yielding variety by RAV I; used as parent in 1991 PNL peanut crosses.			

Table B.3, continued

B. Important Peanut Lines in PNL Trials Through 1991, continued

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
MALIMBA Used as parent in PNL 1989 and 1990 peanut crosses.			
MANDINGU	No information.		
NGAVUKA	No information.		
P 43 Described as "Zaïrois variety", along with A 65, in the PNL 1988 annual report; used as the check entry at M'Vuazi and Kiyaka, 1988 and 1989; used as parent in 1989 PNL peanut crosses.		INERA	Bas-Zaïre
ROBUT 33-1 Large seed.			N. Shaba
TATU-1 Used as parent in PNL 1989 and 1990 peanut crosses.		INERA	Kasai
TSHIMBELE Large seed.			Kasai

Table B.4. Important Cowpea Lines in Zaïre

A. Cowpea Varieties Recommended by PNL for Release Through 1991

Year First Recommended and Variety Name	Experimental Number	Source	Region of Recommendation
1988			
MUYAYA		Origin unknown, or from Kalambayi (PNL, 1989b)	Kasai
Large, red seed; long pods; high number of seeds per pod; spreading growth habit, medium maturity; yield potential higher than most local varieties; distributed through the World Bank PRODALU Project; rated "preferable" by farmers (PNL, 1989-90); susceptible to **Alectra**.			
1990			
MUJILANGA	H4/H36	INERA/INEAC	
Semi-sprawling growth habit; medium maturity; tan seed; susceptible to the parasitic plant **Alectra**; widely adapted throughout the mid- and low-altitude regions of Zaïre; stable yield in the absence of **Alectra**; rated "tolerable" by farmers (PNL Annual Report, 1989-90); "Mujilanga" is Tshiluba for "ally" or "allied."			
JAMASHI	H 204	INERA/INEAC	
Semi-erect; brown seed; medium maturity; tolerant of **Alectra**; rated "acceptable" by farmers (PNL, 1989-90); originally from Colombia (PNL, 1989b); "Jamashi" is Tshiluba for "bean that gives good blood."			

B. Other Important Cowpea Lines in PNL Trials Through 1991

H 295			Kasai
Late maturity; resistant to the parasitic plant **Alectra vogelii**; "blue-coffee" seed color when dry, but said to be the same color as Muyaya, the cultivar with preferred seed quality, when cooked; may be a line from the INERA collection, or (per Kilumba, pers. comm., 1992) may have been collected by PNL in a local market in 1985.			

Table B.4, continued

B. Other Important Cowpea Lines in PNL Trials Through 1991, continued

Experimental Number or Name	Source	Region of Recommendation
IT81D-1137	IITA	Bateke Plateau (Kinshasa area)
Large white seed; bruchid resistant; good yield potential; "widely cultivated in the Kinshasa area" (Kilumba, 1990); rated "very good" in acceptability by farmers and consumers.		
IT82D-889	IITA	
Early maturity; red seed; used as a check in Gandajika in 1986-87.		
IT 83D-442	IITA	
Medium maturity; brown seed; semi-upright; widely adapted throughout mid- and low-altitude regions of Zaïre; rated "tolerable" by farmers (PNL, 1989-90).		
IT84D-460	IITA	
Bruchid resistant; good yield potential.		
TVX 3236	IITA	
Low level of flower thrips resistance.		

Table B.5. Grain Legume Variety Yield Data

A. Yields of Eighteen Bean Varieties Over Six Seasons at Gandajika (Kasai Oriental, mid-altitude savannah)

Variety	1986-1987		1987-1988		1988-1989		Mean
	A	B	A	B	A	B	
	(kilograms/hectare)						
RAO 29	1,538	575	651	776	118	609	711
MCD 201	1,219	804	804	603	649	676	964
RAB 172	1,300	346	480	904	182	767	663
RAB 202	606	449	485	798	506	1126	661
PAN 72	707	254	1,318	722	227	449	613
RAO 24	544	282	343	961	436	868	572
A 411	685	91	299	940	245	1164	567
DOR 308	569	356	1,011	584	145	728	566
Cornell 49240	563	310	430	1,309	136	635	564
PAN 65	550	150	1221	551	189	720	564
RAB 211	601	520	751	739	113	628	559
DOR 335	681	145	578	613	282	1014	552
RAO 35	992	428	698	734	99	398	547
DOR 347	569	409	487	1,056	343	389	542
DOR 334	681	151	522	706	244	915	537
COS 2	638	301	620	753	182	700	532
EMP 147	506	832	586	776	83	360	523
RAB 251	933	333	849	675	87	215	515
A 21	721	237	761	490	174	680	511
Mean	714	310	749	695	182	535	531

Source: Camacho and Kilumba (1990).

Table B.5, continued

B. Yields of Seventeen Bean Varieties Over Six Seasons at Kaniama (North Shaba, mid-altitude savannah)

Variety	1986-1987		1987-1988		1988-1989		Mean
	A	B	A	B	A	B	
	(kilograms/hectare)						
A 445	1,302	568	753	1,512	1,021	678	973
BAT 1449	1,175	804	890	1,344	854	642	951
A 409	781	618	654	1,214	1,054	885	868
A 321	1,458	648	352	1,380	542	581	828
A 442	1,057	522	620	1,358	735	627	820
Carioca-80	560	447	628	1,074	1,636	532	813
Carioca	1,241	691	610	948	698	562	792
A 359	789	528	758	1,208	614	572	735
BAT 1571	813	395	600	997	955	576	723
EMP 112	998	671	434	767	715	297	638
A410	715	943	403	1,102	715	323	625
BAT 1453	1,008	426	542	638	715	394	620
BAT 1297	818	354	630	768	491	493	592
Ex-Rico 25	1,017	547	277	929	527	256	592
A 417	745	324	450	796	715	406	573
PN 50013	244	500	289	898	629	364	487
CENA 164-1	100	556	356	700	715	418	474
Mean	751	502	493	979	716	455	649

Source: Camacho and Kilumba (1990).

Table B.5, continued

C. **Yields of Six Bean Varieties Over Four Years at M'Vuazi (Bas-Zaïre, low altitude)**

Variety	1987	1988	1989	1990	Mean
	(kilograms/hectare, average of Seasons A and B)				
RAB 416	796	1,068	624	697	769
Muhinga	308	741	958	622	657
AFR 252	332	964	557	769	656
G5473	546	389	479	769	546
T-3	427	674	536	622	515
PV014/2	655	81	529	546	453
Mean	511	653	614	671	

Source: Camacho and Kilumba (1990).

D. **Yields of Six Bean Varieties Over Three Years at Lubumbashi (South Shaba, mid- to high-altitude savannah)**

Variety	1988	1989	1990	Mean
	(kilograms/hectare)			
Nakaja	400	1,527	1,430	1,120
PAI 110	407	1,500	1,230	1,045
EMP 143	340	1,200	1,000	846
D6	530	1,160	800	830
Rubona 5	625	800	660	715
Tili Kapira	240	523	580	448
Mean	424	1,128	950	834

Source: Camacho and Kilumba (1990).

Table B.5, continued

E. Yields of Nine Bean Varieties Over Four Years at Mulungu (Kivu, high altitude forest zone)

Variety	1986	1987	1988	1989	Mean
	(kilograms/hectare, average of Seasons A and B)				
G 2333	1,285	3,239	3,392	1,902	2,454
Puebla Criolla	1,966	1,985	3,682	582	2,054
G 2331	1,358	2,801	1,753	792	1,676
Cuarantino 0817	957	1,672	1,974	1,894	1,612
Cornell 4924D	2,667	1,003	1,040	126	1,209
Nain de Kyondo	1,486	1,352	1,084	914	1,209
Nakaja	1,215	1,251	300	1,020	1,196
Rubona 5	1,046	982	769	820	906
D6	948	809	314	693	916
Mean	1,486	1,678	1,752	970	1,459

Source: Camacho and Kilumba (1990).

Note: G2333, Puebla Criolla, G 2331, and Cuarentino 0817 are climbing beans; the others are bush beans.

Table B.5, continued

F. Yields of Eight Soybean Varieties over Eight Seasons at Gandajika (Kasai Oriental, mid-altitude savannah)

Variety	1985-86		1986-87		1987-88	1988-89		1990	Mean
	A	B	A	B	A	A	B	A	
	(kilograms/hectare)								
TGX814-26D	578	1,740	1,298	1,275	861	457	607	1,804	1,090
TGX536-02D	824	1,930	912	982	1,195	447	756	1,186	1,029
IAC73-5115	1,241	1,300	1,175	1,401	711	459	555	675	1,027
SIATSA-194	876	1,650	1,137	1,183	848	980	306	950	991
UFV-1	943	1,600	901	887	1,050	709	1,024	711	978
TGX849-294D	363	1,510	1,492	1,187	893	535	629	1,134	968
TGX573-209D	958	1,305	904	1,110	915	526	634	453	851
SJ 127	580	1,373	1,203	1,070	806	315	807	1,134	856
Mean	795	1,551	1,140	1,139	910	526	665	950	974

Source: Camacho and Kilumba (1990).

G. Yields of Three Cowpea Varieties Over Six Seasons at Gandajika (Kasai Oriental, mid-altitude savannah)

Variety	1986-1987		1987-1988		1988-1989		Mean	% of check
	A	B	A	B	A	B		
	(kilograms/hectare)							
H204 (Jamashi)	732	1,190	1,516	1,504	1,460	1,567	1,328	154%
H36 (Mujilaga)	1,212	1,065	1,279	1,630	1,272	879	1,223	142%
Muyaya	353	836	679	1,423	909	946	858	100%

Source: Kilumba (1990).

Table B.6. Bean Crosses Made or Evaluated by PNL

Parents	Cross Designation	Attribute	Latest Generation (year)	Number of Lines Selected[1]
A. CIAT crosses listed by Mbikayi et al., Développement variétal et amélioration du haricot commun au Zaïre: Esquisse de Travaux de Recherche, 1985-1990:				
A 240 x Inyumba	SMMH 1	Root rot R	F6 (1990)	2
A 240 x A 339	VMMH 1	Root rot R	F6 (1990)	2
A 339 x Rubona 5	SMMH 3	Root rot R	F6 (1990)	2
Rubona 5 x BAT 1769	SCAM-210-Q2	Root rot R	F6 (1990)	7
Rubona 5 x BAT 1769	SCAM-210-Q3	Root rot R	F6 (1990)	1
Rubona 5 x BAT 1769	SCAM-210-Q4	Root rot R	F6 (1990)	6
Rubona 5 x BAT 1769	SCAM-210-Q6	Root rot R	F6 (1990)	2
A 240 x A 339	VMMH 1	Root rot R	F6 (1990)	2
BAT 1510 x Mbagarumbise	SMMH 5	Root rot R	F6 (1990)	1
A 240 x BAT 1510	VMMH 2	Root rot R	F6 (1990)	4
Rubona 5 x A 240	SDMA 26	Root rot R	F6 (1990)	2
Urubonobono x V 79020	SACD 1	Root rot R	F6 (1990)	1
Urubonobono x Turkbrown	--	Root rot R	F6 (1990)	1
G 10357 x U 1004-112	SXCM-86-Q1	Root rot R	F6 (1990)	1
Rubona 5 x BAT 1673	SCAM-183-P8	Root rot R	F6 (1990)	3
G 11826 x PAD 29	SCAM-226-Q5	Root rot R	F6 (1990)	1
A 240 x Urubonobono	SMMG 1	Root rot R	F6 (1990)	1
Rubona 5 x MCD 251	SDAM-1-Q1	Root rot R	F6 (1990)	1
BAT 1510 x Inyumba	SMMH 7	Root rot R	F6 (1990)	1
Rubona 5 x PAD 29	SCAM-216-Q4	Root rot R	F6 (1990)	1
B. CIAT crosses reported in PNL Annual Report, 1991, Phytopathology Section:				
A 484 x BAT 431		ALS resistance	F7 (1990)	
A 197 x A 240		ALS resistance	F7 (1990)	
				Σ 19
--	B/SC	ALS resistance	F5 (1990)	22
--	C	ALS resistance	F5 (1990)	9
PVA 563 x S 25009	VUAA-3		F5 (1990)	12
PVA 563 x AFR 181			F5 (1990)	
AND 377 x S 25004			F5 (1990)	6
BAT 129 x S 25004	SCAL-4		F5 (1990)	4
Muhinga x G 2333	SAAA-15		F5 (1990)	5
S 25004 x AFR 188	HG-38		F5 (1990)	0
S 25004 x AFR 204	SCAU-31		F5 (1990)	0
Muhinga x VCB 81012	SDDD-31		F5 (1990)	4
Muhinga x ACV 83034			F5 (1990)	

Table B.6, continued

Parents	Cross Designation	Attribute	Latest Generation (year)	Number of Lines Selected[1]
C. Bean crosses made by PNL at Mulungu and reported in Mbikayi et al., Développement variétal et amélioration du haricot commun au Zaïre: Esquisse de Travaux de Recherche, 1985-1990:				
D 6 x A 285	ALSMUL-1	ALS resistance	BC1 (1991)	
D 6 x A 345	ALSMUL-2	ALS resistance	BC1 (1991)	
D 6 x A 140	ALSMUL-3	ALS resistance	BC1 (1991)	
D 6 x XAN 68	ALSMUL-4	ALS resistance	BC1 (1991)	
D 6 x A 300	ALSMUL-5	ALS resistance	BC1 (1991)	
Rubona 5 x A 285	ALSMUL-6	ALS resistance	BC1 (1991)	
Rubona 5 x A 345	ALSMUL-7	ALS resistance	BC1 (1991)	
Rubona 5 x A 140	ALSMUL-8	ALS resistance	BC1 (1991)	
Rubona 5 x XAN 68	ALSMUL-9	ALS resistance	BC1 (1991)	
Rubona 5 x A 300	ALSMUL-10	ALS resistance	BC1 (1991)	
Munyu x A 285	ALSMUL-11	ALS resistance	BC1 (1991)	
Munyu x A 345	ALSMUL-12	ALS resistance	BC1 (1991)	
Munyu x A 140	ALSMUL-13	ALS resistance	BC1 (1991)	
Munyu x XAN 68	ALSMUL-14	ALS resistance	BC1 (1991)	
Munyu x A 300	ALSMUL-15	ALS resistance	BC1 (1991)	
D. Bean crosses made by PNL and listed by Frangoie as being in the F5 and F6 at Gandajika (letter to Camacho, September 1991):				
A 21 x RAO 35	PGK 001			
BAT 1572 x A 21	PGK 002			
MCD 201 x RAB 181	PGK 003			
MCD 201 x RAB 302	PGK 004			
RAB 181 x MCD 201	PGK 005			
RAB 302 x RAB 304	PGK 006			
RAO 35 x XAN 162	PGK 007			
RIZ 53 or 58 x RAB 380 or 350	PGK 008			
XAN 162 x XAN 191	PGK 009			

Note: Blanks indicate information was not available.

[1] As of year specified in previous column, or, as of 1991.

ALS = angular leaf spot; B = bush growth habit; C = climbing growth habit; and SC = semi-climbing growth habit.

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Table B.7. Peanut Crosses Made by PNL

Year of Cross	Parents	Cross Designation	Latest Generation (year)	Number of Lines Selected[1]
1990	G 17 x A33	AGX90A-807	F4 (1991)	1
1990	Tatu-1 x A 65	AGX90A-110	F4 (1991)	3
1990	A 33 x ICGS(E)-4	AGX90A-719	F4 (1991)	2
1990	E 285 x A 65	AGX90A-408	F4 (1991)	2
1990	ICGMS-55 x A 65	AGX90A-610	F4 (1991)	2
1990	A 33 x ICG(FDRS)-4	AGX90A-718	F4 (1991)	2
1990	JL 24 x A 65	AGX90A-310	F4 (1991)	2
1990	HYQ(CG)S-10 x A 65	AGX90A-510	F4 (1991)	1
1990	Malimba x G 17	AGX90A-208	F4 (1991)	2
1989	Malimba x G 17	AGX89B-208	F5 (1991)	2
1989	A 65 x Malimba	AGX89B-1002	F5 (1991)	1
1989	ICGV-SM85027 x A1052	AGX98B-916	F5 (1991)	1
1989	JL 24 x ICGV-SM86051	AGX98B-317	F5 (1991)	2
1989	ICGV-SM85027 X G 17	AGX98B-908	F5 (1991)	1
1989	ICGV-SM85027 x A 1052	AGX98B-916	F5 (1991)	1
1989	B24 x ICGS(E)-4	AGX98-1518	F6 (1991)	1
1989	Blanche de Kaniama x ICGS(E)-4	AGX89-1318	F6 (1991)	2
1989	A1208/2 x P43	AGX89-1112	F6 (1991)	1
1989	P 43 x A1208/2	AGX89-1211	F6 (1991)	1
1989	JL 24 x ICGS(E)-4	AGX89-318	F6 (1991)	2
1989	Robut 33 x ICBS(E)-4	AGX89-1418	F6 (1991)	3
1989	A1208/2 x TATU-1	AGX89-1101	F6 (1991)	2
1989	A1208/2 x ICGS(E)-4	AGX89-1118	F6 (1991)	2
	HYQ(CG)S-57 x G 17			
	ICGV-SM 86051 x G 17			

Note: Blanks indicate information was not available.

[1] As of year specified in previous column, or, 1991.

Table B.8. Soybean Crosses Made or Evaluated by PNL

Data on these crosses exist in PNL records but could not be obtained.

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Table B.9. Cowpea Crosses Made or Evaluated by PNL

Parents	Cross Designation	Attribute	Latest Generation (year)	Number of Lines Selected[1]
1987				
H 36 x TVX 3236	(successful[2])			
H 36 x IT82E -16				
H 36 x IT82D-716				
H 36 x Muyaya	(successful[2])			
Muyaya x TVX 3236				
Muyaya x IT 82E-16	(successful[2])			
Muyaya x IT 82D 716				
H36 x IT 83S 875	(successful[2])			
IT 82E-32/1 x H204		Alectra tolerance	F8 or F9 (1991)	83
H 204 x IT 82D-786		Alectra tolerance	F8 or F9 (1991)	37
H 204 x IT 84D-552		Alectra tolerance	F8 or F9 (1991)	48
IT 82D-889 x H204		Alectra tolerance	F8 or F9 (1991)	119
H 204 x IT 84S-2081		Alectra tolerance	F8 or F9 (1991)	85
Total Alectra-tolerance crosses				372

Note: Blanks indicate information was not available.

[1] As of year specified in previous column, or, 1991.

[2] This note in the PNL annual report for 1987 may indicate that none of the pollinations for the other crosses were successful.

Table B.10. PNL Germplasm: Recommendations for Preservation

A. Beans

High Altitude

Recently recommended bean varieties, ca. 1990

Aliya (CIAT G 2333), climbing bean
Cihembe (CIAT G 2331), climbing bean

Bean varieties in final testing before release as of early 1992

Climbing beans (all CIAT):	Bush beans (all CIAT):
AND 10	AND 658 (Namafungo 2)
VB 81012	AND 687 (Muduku 3)
M211/V	AND 667 (Muduku 8)
ZAV 83052	Ecuador 299 (Nakadukura 1)
VCB 81013	AND 618 (Muduku 7)

Bean varieties with high yields in association with maize

ASC 42 (CIAT)
ACV 83031 (also high yield in monoculture) (CIAT)
G 5173 (yield satisfactory without depressing maize yield) (CIAT)

Bean varieties recommended during early years of RAV I, 1985-1988

Kirundo (bush) Nain de Kiyondo Nakaja

Bean varieties recommended by INERA Support Project, 1979-1985

Nain de Kyondo	Muhinga 8
BAT 873 (CIAT)	Munyu

Local bean varieties or locally preferred introduced varieties

Rubona 5 (CIAT ?) Muhinga D 6

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Table B.10, continued

A. Beans, continued

Mid-Altitude

Recently recommended bean varieties, ca. 1990

Wambedi (MCD 201) (CIAT), bush
Kyakulwa (BAT 1449) (CIAT), semi-climbing

Elite bean varieties in mid-altitude trials, 1990-91 (all CIAT)

RAO 29	RAB 267
XAN 192	RAB 273

Bean varieties recommended during early years of RAV I, 1985-1988

None

Bean varieties recommended by INERA Support Project, 1979-1985

A 21 (bush)

Low Altitude

Recently recommended bean varieties, ca. 1990

None

Bean varieties in final testing before release as of early 1992

RAB 246, RAB 219, and others are "promising"; data inconclusive.

Bean varieties recommended during early years of RAV I, 1985-1988

None

Table B.10, continued

A. Beans, continued

White-seeded bean introductions with good yield performance over one to three seasons (1990C, 1991A, 1990C) (data still inconclusive)

ABA 36	WAF 32	4416	WAV 68

Bean varieties recommended by INERA Support Project, 1979-1985

Cuarentino 0817 (white-seeded climber)	Ntendezi
Muhinga	PVO 14/2
Lundamba	

Bean lines with good yield potential on poor soils

RWR 779	RWR 971	RWR 957	RWR 1077
RWV 968	RWR 866	RWR 969	RWR 1081
RWR 950	RWR 897	RWR 972	RWR 1091
RWR 221	RWR 925	RWR 990	RWV 1092
RWR 1083	RWR 951	RWR 1058	RWR 914
RWR 1080	RWR 956	RWR 1059	

Bean lines with tolerance to acid soils

DOR 351	III 714 (ACC)	7/4
IMBIRAMBIRA	NANGURUBWA	

Bean line with bean fly resistance

RWR 45

Hybrid bean populations with drought resistance (preliminary obs., 1991)

PGK 001 through PGK 009

Table B.10, continued

A. Beans, continued

Disease-resistant bean lines

Disease codes: ALS, angular leaf spot; FLA, floury leaf spot; Anth., anthracnose; As, Ascochyta blight; H, halo blight; CBB, common bacterial blight; WB, web blight; R, rust; RR, root rots; T, tolerant. All numbered lines are CIAT lines.

Line	Resistance	Line	Resistance
57 I	ALS	BAT 1559	ALS; CBB (T), WB (T)
1198	ALS	BLM 32	CBB, R
A 4/10	CBB (T), WB (T)	BRU 14	ALS
A 54	ALS, R	BRU 17	ALS
A 75	ALS	BRU 18	ALS
A 83	CBB (T), WB (T)	BRU 21	ALS
A 140	ALS	CAL 9	ALS
A 162	CBB	CLH 13	(mult., unspec.)
A 163	ALS	DOR 308	ALS, FLS
A 182	ALS	DOR 333	CBB
A 212	ALS	DOR 340	(mult., unspec.)
A 216	ALS	EMP 81	ALS
A 240	ALS	EMP 84	CBB, other unspec.
A 285	ALS	EMP 87	ALS, FLS
A 300	ALS	EMP 143	(")
A 339	ALS	EMB 154	CBB (mod.)
A 340	ALS	G 858	ALS, H, Anth, As
A 345	ALS	G 2331	ALS, FLS
A 348	ALS	G 2333	ALS, FLS
A 387	ALS	G 2337	ALS
A 409	ALS	G 2641	ALS, Anth
A 411	ALS	G 2676	ALS
ACV 22	ALS	G 2858	ALS
ACV 8331	(multiple, unspec.)	G 3367	ALS, Anth
AFR 260	(")	G 4000	CBB (T), WB (T)
AFR 340	(")	G 4169	ALS
AND 552	ALS	G 4459	ALS
AND 558	(mult., unspec.)	G 4603	ALS, As
AND 661	(")	G 5473	ALS
APN 84	CBB	G 10747	ALS, As
ASC 3	ALS	G 11060	ALS
BAC 76	ALS, Anth, H	G 11516	ALS, Anth, H
BAT 67	ALS	G 12582	ALS, As
BAT 76	ALS	G 35182	(")
BAT 434	ALS	GLP 1125	Anth, H
BAT 805	CBB	GUANAJUATO 10-A-5	R, ALS
BAT 1432	ALS	ICA Linea 65	ALS, CBB
BAT 1449	ALS	ICM 2525-25	(mult., unspec.)

Table B.10, continued

A. Beans, continued

Disease-resistant bean lines, continued

Line	Resistance	Line	Resistance
IMBO BLANC	ALS	RAO 24	ALS
IZ 306-1	(mult., unspec.)	RIZ 35	(mult., unspec.)
IZO 2528-1	(")	RWK 3	(")
KARBANIMA	ALS, FLS	RWK 45	Anth, As
LIB 5	ALS	RWR 96	ALS, CBB
LIB6	ALS	RWR 163	ALS
LIB9	ALS	RWR 359	(mult., unspec.)
M 200	ALS	RWR 602	(")
M211	(mult., unspec.)	RWR 603	(")
MBIKEKURE	ALS	RWR 612	(")
MCD 201	CBB, WB (mod)	TO-15(2-16/13/9)	(")
NAIN DE KYONDO	CBB (mod)	UBOSOSERA 6	ALS, H
PAC 41	CBB, R	UROBONOBONO	(mult., unspec.)
PAN 38	CBB	VNB 81005	ALS, H, As, Anth
PAN 71	CBB	VRA 81051	ALS, As
PAN 105	CBB	XAN 37	ALS
PAN 194	CBB/R	XAN 63	CBB
PAV or PVA[1]307	CBB, ALS	XAN 68	ALS
PVA or PAV[1]779	ALS, H	XAN 76	(unspec.)
PVA 800A	Anth, As, H, ALS	XAN 162	(mult., unspec.)
PVA 880	Anth, H, ALS	ZAV 28	ALS
PVA 1258	Anth, H	ZAV 83101	ALS
PVA 1435	ALS, CBB	ZAV 84098	CBB, ALS
RAB 202	CBB	SCAM-80-CM/2	RR
RAB 210	CNN, WEB	MORE 90026[2]	RR
RAB 211	ALS, FLS, CBB, WB	MORE 88003	RR
RAB 213	ALS, CBB	MLB-38-89A	RR
RAB 214	ALS, FLS	MLB-47-89A	RR
RAB 251	CBB, WB	MLB-40-89A	RR
RAB 263	CBB	MLB-39-89A	RR
RAB 268	ALS, CBB	MLB-36-89A	RR
RAB 273	(")	MLB-49-89A	RR
RAB 397	ALS	MLB-45-89A	RR
RAB 398	ALS	MLB-42-89A	RR
RAB 404	ALS	MLB-43-89A	RR
RAB 406	ALS, CBB	MLB-14-88A	RR
RAB 412	ALS	MLB-48-89A	RR
RAD 14	ALS	RWR-719	RR

[1]Both codes appear commonly with these numbers in PNL records.
[2]MORE, MLB, and RWR lines are selections made by ISABU Burundi, PNL Zaïre, and ISAR Rwanda, respectively, from hybrid populations received from CIAT.

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Table B.10, continued

B. Peanuts

Peanut varieties recommended by RAV I

Bubanji (JL 24) (ICRISAT)

Peanut varieties in final testing before release as of early 1992 (all ICRISAT)

ICGS(E)-4	ICGS(E)-18	JL 12

Peanut varieties recommended by INERA Support Project, 1979-1985

A 65 (INERA)	A 1052 (INERA)	G 17 (source ?)
P 43 (source ?)		

Local peanut varieties or locally preferred introduced varieties

Blanche de Kaniama	Mandingu	Malimba
Ngavuka	Tshimbele	

Peanut lines with possible rosette resistance in Zaïre

A 1397 (INERA)	A 1429 (INERA)	D 44/3 (source ?)
JL 12 (ICRISAT)	E 22/1 (source ?)	

Peanut lines with moderate cercospora resistance in Zaïre

A 1543 (INERA)	ICG(FDRS)-26 (ICRISAT)	ICG(FDRS)-4 (ICRISAT)
ICG(FDRS)-17 (ICRISAT)	ICG(FDRS)-6 (ICRISAT)	ICG(FDRS)-18 (ICRISAT)

Other peanut lines used as parents in PNL crosses

A 1208/2 (INERA)	A 33 (INERA)	HYG(CG)S-10 (ICRISAT)
B 24 (source ?)	E 285 (source ?)	Robut 33/1 (source ?)
TATU-1 (source ?)		

Table B.10, continued

C. Soybeans

Mid- and Low Altitude

Recently recommended soybean varieties, ca. 1990

Munanga (TGX 814-26D) Afja (TGX 849-249D) (ICRISAT)

Soybean varieties in final testing before release as of early 1992

Name not yet determined (IAC 73-5115) (Colombia) (ICA ?)
TGX 814-27D

Soybean varieties recommended during early years of RAV I, 1985-1988

SJ 127 (INERA ?)	Hernon	Jupiter
SJ 61/1	UFV-1 (Brasil, ISVEX)	Patience
SAM 86		

Soybean varieties recommended by INERA Support Project, 1979-1985

SJ 127 (INERA ?)	UVF-1	Jupiter
IAC-6 (Colombia?)		

Local soybean varieties or locally preferred introduced varieties

None

High Altitude

Recently recommended soybean varieties, ca. 1990

None

Table B.10, continued

C. Soybeans, continued

Soybean varieties in final testing before release as of early 1992

CH 3	DAVIS	IMPERIAL
ORIBI	PD 308	SABLE
SH 99	UFV-1	

Soybean varieties recommended during early years of RAV I, 1985-1988

UFV-1

Soybean varieties recommended by INERA Support Project, 1979-1985

Tokyo Vert (via INERA)	Bossier	Davis
Columbus	Haut Mulito	Sable
Imperial	UFV-1	

D. Cowpeas

Recently recommended cowpea varieties, ca. 1990

Mujilanga (H4/H36) (INERA)
Jamashi (H 204) (INERA)

Cowpea varieties in final testing before release as of early 1992

IT81D-1137 (IITA)

Cowpea varieties recommended during early years of RAV I, 1985-1988

Muyaya (local Kasai ?)
IT 82D-889 (IITA) (used as check in early RAV I trials)

Table B.10, continued

D. Cowpeas, continued

Cowpea varieties recommended by INERA Support Project, 1979-19--

None

Local cowpea varieties or locally preferred introduced varieties

None ?

Cowpea lines with some insect resistance and good yield potential

IT84D-460 (bruchid R) (IITA)
IT82E-16 (good yield potential with less insecticide) (IITA)

Cowpea lines with insect resistance (R)

TVX 3236 (low level R to flower thrips) (IITA)
IT 82D-716 (R to bruchids; low level R to thrips) (IITA)
IT 81D 1007 (R to bruchids) (IITA)
IT 81D 1137 (R to bruchids) (IITA)
IT 82D-716 (moderate R to flower thrips) (IITA)
IT 84S-2246-4 (R to thrips, bruchids) (IITA)
(*Note: IITA will likely preserve insect R IITA lines*)
H 288 (indeterminate; appears to escape insects) (INERA)

Cowpea lines resistant (R)/tolerant (T) to Alectra (paras. plant)

H 295 (R) H 204 (T)

Other cowpea lines used as parents in PNL cowpea crosses

IT 83S 875 IT 82E-32/1 IT 82D-786
IT84D-552IT 84S

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