INTER-CENTRE REVIEW ON ROOTS AND TUBERS RESEARCH IN THE CGIAR

Towards Formulating a Systemwide Strategy
Issues and Options

A paper prepared by the Centro Internacional de Agricultura Tropical
for the Workshop on Roots and Tubers Research in the CGIAR.
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Issues and Options

1. Preamble

To discuss issues and options requires a clear understanding of where the goal posts are. That is, are we looking to

(a) provide the same output with fewer resources, or
(b) increase the output with the same resources, or
(c) increase the output by attracting more resources?

For many of us in the Workshop (a) is threatening (b) appeals to our common sense and (c) is the preferred option.

In the spirit of the process unleashed by the Chairmen of CGIAR, Ismael Serageldin, we hope that the objective of the exercise is to work towards (c). It is in this vein that we have prepared this paper following the guidelines suggested by the TAC Secretariat.

2. Inter-centre collaboration

Issue: Within the present organization of root and tuber research in the CGIAR, what is the actual level and nature of collaboration, and what further inter-centre synergies might be captured and how?

CIAT has formed a number of collaborative links with its sister centres in the CGIAR. The present on-going collaborative activities are summarized in Appendix 1, Table 1A. Likewise, Appendix 1, Table 2A lists potential areas of additional collaboration that might capture further synergies.

The conclusions that can be drawn from perusal of these tables are:

(a) There is active on-going collaboration with IITA in all project areas. Collaboration with IITA dates back to the early 70s but has intensified over the past five years.

(b) Collaboration with CIP at the present time is limited to the postharvest area. Activities with CIP were more extensive during the 1980s, especially in the area of human resource development. This collaboration was driven by a joint project, together with IITA, which ran for nine years and was funded by the UNDP. Strictly outside the area of root and tuber research, CIAT has recently reached an agreement with CIP on participating in CONDESAN, providing GIS expertise for site characterization.

(c) The principal benefits accrued to the Centres and the System, beyond the enhancement of the efficiency of the research process, include: 1. The generation of additional resources through special projects, 2. Feedback information between centres which aids in the setting of priorities, 3. Rationalization of centre contacts and support to national programs, 4. Sharing of human and physical resources.

(d) There exist a number of potential areas for further inter-centre collaboration that need to be explored. Consultative meetings at the technical level would be required to determine the cost and potential benefit that might be accrued from these additional collaborative activities.

(e) Beyond structural changes (see Section 4 below), the best way to promote and initiate a greater level of intercentre collaboration on roots and tubers research would be to make resources available for joint exploratory planning sessions by area of research interest, for example: 1. Genetic resources collection, characterization and conservation, 2. Crop improvement, 3. Crop management (subdivided by biotic and abiotic stresses), 4. Postharvest processing and marketing, 5. Institutional development. The inclusion of scientists from key non-CGIAR institutions that are involved in root and tuber research with international projection would be important. In the postharvest area this process has been initiated with participation of CIP, IITA, CIAT, NRI, CIRAD/ORSTOM and FAO in a meeting held in Salvador, Brazil in November 1994.

3. Comparative advantage/non CGIAR institutions

Issue: Given the rapidly changing institutional environment, have the centres adjusted their research agenda to complement and not duplicate the efforts of other institutions?

The wide range of institutions with which the CIAT Cassava Program interacts can be appreciated by examining the background document "Cassava Program: Project areas, projects and resource distribution" in which research partners are named by project.

Advanced labs

The trend over the past 5 years has been one of increasing interest on the part of advanced labs in developed countries to be involved in aspects of cassava research. The formation of the Cassava Biotechnology Network in 1992 has been instrumental in further promoting this interest and ensuring a flow of information between the interested parties and between them and CIAT and IITA. A list of the advanced labs, and the areas in which they are working, is provided in Appendix 2.

The role of CIAT and IITA as a conveners and catalysers of complementary research on cassava has therefore become immensely important. These two Centres also provide the essential function of linking the efforts of advanced labs to the needs and priorities of national programs.

Non-CGIAR institutions that have cassava programs/projects with international or regional projection

ORSTOM, Montpellier undertakes research on cassava in the areas of genetic resources, pathology (ACMV, CBB), entomology (mealybug and mites), agronomy (soil fertility and erosion), and fermentation technologies.

CIRAD-CA and CIRAD-SAR, Montpellier carry out cassava research and development work on germplasm evaluation, starch quality, postharvest processing and marketing and small enterprise development.

NRI, Chatham focus their attention on improving traditional African products, starch extraction and flour production processes, quality aspects such as postharvest deterioration and cyanogen removal through processing.

ETH, Zurich are involved in research on genetic transformation, and pest and soil/crop management, with interest in widening their scope to other areas.

There are European universities, such as Höhenheim and Göttingen, that carry out research principally in the areas of cassava soil/crop and pest management with staff working with CIAT and IITA.

The CGPRT Centre, Bogor carries out socio-economic studies and maintains date bases on cassava production and utilization in S.E. Asia. AIT, Bangkok is initiating a program on postharvest processing of cassava.

CATIE, CARDI and CERAT in the Latin American and Caribbean region maintain root and tuber research activities.

National programs

Issue: To what extent can centres share responsibilities with national programs?

CIAT has invested heavily in the development of human resources for cassava research and development and undoubtedly the capacity of national programs now is considerably greater than 20 years ago. In Latin America, with the exception of Brazil and Cuba, the number of national program researchers dedicated to cassava is extremely small. In addition, the funds available for cassava research are scarce. Over the past 10 years, interest in the crop has been shown increasingly by the development sector, including

NGOs and farmer organizations, and more recently, by the private sector. These latter organization have little or no capacity for undertaking research on cassava except at the level of field testing of technology components with farmers. In Asia, the major producing countries (Thailand, India, Indonesia, China, Vietnam and the Philippines) have maintained a relatively stable core of cassava researchers and the benefits of this investment are now becoming clearly evident. Thailand and India stand out as the countries with a capacity to undertake research across the whole spectrum of basic, strategic, applied and adaptive research. Tables 3A and 4A in Appendix 2 provide an idea of the relative strengths and stage in development of national cassava research systems in Latin America and Asia.

CIAT has formed what might be termed "strategic" alliances with the Brazilian and Thai national programs and have entered into a research partnership with shared responsibility for certain areas of research, particularly germplasm improvement and, in the case of Brazil, IPM. While these partnerships are proving to be very fruitful, the resources required, from both sides, to build them should not be underestimated.

4. Structural efficiency: options for change

Issue: Could structural reorganization of roots and tuber research within the CGIAR bring greater efficiency in the use of resources?

<u>Pros and cons of the present organization</u>

There are numerous possible permutations for rearranging root and tuber research. To be able to evaluate the different options requires first a determination of what are the advantages and disadvantages of the present organization. Any restructuring would then ostensibly have to provide an improvement on what we have now (i.e. reinforcing the advantages and eliminating the disadvantages). Some of the advantages and disadvantages of present organization of root and tuber research are noted in Table 1.

Advantages	Disadvantages
• Multicommodity centres have led to positive intra-centre synergies and economies of scale.[1]	• "Mandates" and "responsibilities" lead to territoriality.
• Integration between commodities and ecoregional activities are facilitated in those centres that have dual responsibilities.[1]	• Division of mandates between centres leads to competition for resources.
• Coincidence of global mandates with centres of origin is scientifically advantageous.[2]	• Different organizational structures between centres does not facilitate closer collaboration.
• Representation and research capacity in secondary centres of diversity addresses regional constraints and opportunities, and provides global coverage.	• Division of mandates and responsibilities lead to relatively high transaction costs.
• Strong identification with the mission of the individual centres, with consequent exceptional dedication of senior and support staff.	• Different corporate cultures can lead to difficulties in communication.
• Infrastructure and resources built up and in place for carrying out the job and producing outputs.	• Division of mandates results in inefficiencies in relations with national institutions that have combined roots and tubers programs.
	• Autonomous and independent nature of the centres may hinder closer collaboration.

Table 1. Advantages and disadvantages of the present root and tuber research organization.

[1] See Appendix 3 for a discussion of the synergies and spillovers of housing cassava research in a multi-commodity and ecoregional setting.

[2] See Appendix 4 for a discussion of the pros and cons of housing strategic research on cassava at the centre of origin and diversity of the crop.

Criteria

From these advantages and disadvantages can be drawn a number of criteria against which options can be compared. Possible criteria that could be included are shown in Table 2.

- Economies of scale in research administration and management.
- Economies of scale in research.
- Economies of scale in outreach.
- Efficiency and transparency in planning and priority setting across root and tuber crops.
- Global coverage and effective support to NARS.
- Access to research support (e.g. biotech, GIS, etc.).
- Transaction costs for enhanced levels of collaboration.
- Transition costs from present organization to preferred option.
- Competition for research funds for root and tuber crops.
- Corporate culture and mission orientation.
- Integration of activities with ecoregional initiatives.
- Compatibility between organizational structures of collaborating centres/programs.
- Probability of achieving the desired increase in efficiency.

Table 2. Criteria for evaluating different organizational structures for root and tuber research.

For each criteria and each option a score could be assigned from, say, +3 to -3 depending on whether the option is likely to improve (+) or worsen (-) the present situation. There may be the need to weight the criteria.

"Form" follows "function"

Strictly speaking "form" should follow "function". In reality, the process should probably be iterative, especially as no decision has been made as to whether or not some of the functions presently undertaken by the centres in root and tuber research will be abandoned, or to the contrary, a reorganization would seek to expand the level of activity. Without this information it will be assumed that any structural changes are looking to position the CG towards growth in root and tuber research.

Possible options

1. A global root and tuber program.

   Mechanism: A convening centre is named and an executive committee formed with representation from the interested centres. The executive committee could include representation of non-CGIAR institutions active in root and tuber research with international projection and national program representatives. The executive committee would be responsible for formulating a common planning, prioritization and evaluation framework within which root and tuber research is conducted. Resource allocation would be through the Program.

2. Two global programs:
   (1) Potato, sweet potato and andean root crops
   (2) Cassava and yams
   Mechanism: As for option 1

3. Two global programs:
   (1) Potato and high andean root crops
   (2) Tropical root crops (cassava, sweet potato, yams, etc.)
   Mechanism: As for option 1

4. Three centres with no change in present mandates but with compatibilization of planning, prioritization and evaluation procedures, enhanced collaboration in areas of common interest, and sharing of facilities where appropriate.

   Mechanism: creation of an inter-centre planning and evaluation body with rotating chairmanship.

5. One root and tuber centre with decentralized research housed within existing centres.

   Mechanism: Formation of new Board and Management responsible for setting up the new centre and negotiating terms for housing research in the most appropriate existing facilities. This would be close to the concept of a centre without walls.

The relative merits of these options could be evaluated using the scheme presented in the section on criteria using a matrix as represented in Table 3.

Issue: Are there sufficient similarities between the constraints and opportunities faced by root and tuber crops to merit a significant structural reorganization of research?

Just as cassava research has prospered in multicommodity centres such as CIAT and IITA, so might research prosper in an organization that brings the crops closer together. Appendix 5 presents some of the differences and similarities of root and tuber crops.

	Economies of scale in research administration and management	Economies of scale in research	Economies of scale in outreach	Efficiency and transparency in global planning and priority setting	Global coverage and effective support to NARS	Access to research support (e.g. biotech. and GIS)	Transaction costs	Transition costs	Competition for research funds for root and tuber crops	Corporate culture and mission orientation	Integration of activities with ecoregional initiatives	Compatibility between organizational structures of collaborating centres/programs	Probability of achieving desired increase in efficiency
Global root and tuber program													
Two global programs (1) Potato, sweet potato, (2) Cassava and yams													
(1) Potato high andean root crops (2) Tropical root crops													
Three centres with enhanced													
One root and tuber centre													

Table 3. Comparative evaluation of options for reorganizing root and tuber research.

5. Adoption and impact

Issue: Does root and tuber research at the international level provide a good return on investment?

Ex-post assessment

Monitoring of cassava varietal releases and adoption levels in Asia and Latin America (CIAT Cassava Program Socio-economics data base, 1995) show that 21 and 23 improved cassava varieties have been released in Latin America and Asia respectively. These varieties are either based on CIAT germplasm and/or were selected with CIAT collaboration. Varietal adoption (1994) is estimated at 100,000 ha in Latin America, and 270,000 ha in Asia, generating additional annual revenues of 86 million US$. Since the late 1980's, varietal adoption has accelerated, especially in Indonesia and Thailand (Henry and Gottret, 1994; Henry et al., 1994).

Cassava adoption studies in the North coast of Colombia (Henry et al., 1994) have shown that, based on the Integrated Cassava Research and Development Project (ICRDP) concept, 65% of farmers had adopted at least one technology component. Adoption levels were significantly higher in areas with newly introduced cassava chipping and drying plants. Subsequent cassava yields showed an increase of approximately 3 ton/ha over the last decade. An analysis of the economic benefits from ICRDP cassava production, processing and market technologies indicated that total benefits to small farmers were 15 million US$ for the 1984-91 period, while total net benefits to society were 22 million US$ (Gottret et al., 1994), returning US$18 for every dollar invested.

ICRDP projects involving cassava starch, flour or dried chips processing have also being developed in Ecuador, Brazil, Peru and Bolivia. It is estimated (Ospina et al., 1994) that more than 300 small (cassava) farmers' organisations are currently in operation in Latin America.

Norgaard (1988, AJAE 70:366-371) estimated that through IITA/CIAT bio-control interventions against mealybug in Africa, average farmer yields in the target areas, increased by 2 ton/ha. He estimated that the technology was established in 90% of the affected area by 1987. He also calculated that this effort would generate 1.8 billion US$ by the year 1992/93, with a R&D benefit/cost ratio of 149 to 1.

In South and Central Brazil, effective biological control of the cassava hornworm has been achieved, based on a specific baculo-virus, which can be formulated into a spray by simple low-cost technology. In 1994 it was estimated that this control is being used on more than 40,000 ha, reducing pesticide use by approximately 40%. The same technology has been adopted in Venezuela and Colombia (CIAT document for 1995 CGIAR Lucerne meeting).

Ex-ante assessment

Henry (1995) estimated, with the help of a partial equilibrium model, the expected benefits from cassava R&D including pipe-line and future research activities. Past (concluded) research activities were not included. Total expected benefits by the year 2028 are estimated to be 5 billion US$, with an estimated one third or 1.7 billion attributable to CIAT input. At least 68% of the benefits will directly accrue to poor cassava farmers or poor cassava product consumers.

The cassava research areas of gene pool development and crop management will generate 38 and 16% of expected benefits, respectively. The cassava post-harvest and institutional development research areas will generate 24 and 23% of benefits respectively.

Besides expected benefit streams, Internal Rates of Return (IRR) were also estimated. It was shown that the area of institutional development proved to be the "best" investment at an IRR of 85%. The average cassava research activity IRR was 65%. Benefits to the environment, or contributions to sustainability were also assessed.

6. Programme Priorities

Issue: What role for the CGIAR in commodity research?

The Cassava Program at CIAT is accustomed to taking hard decisions about priority activities. In 1983, the Program was cut by 20% (two core scientist positions out of 10) and frozen in 1984 for a period of 4 years. Further cuts were instigated in 1991 as resources were transferred within CIAT to establish the resource management programs and again in 1993 as a result of a reduction in core funding to CIAT and the revaluation of the Colombian peso (two core scientists out of 11 and over 30% in operations). Additional reductions in resources for R and T research at the CG level would require a review of the responsibilities of the CG with respect to research on a particular commodity, in CIAT's case cassava.

At present CIAT, in fulfilling its global cassava mandate, attempts to:

- Conserve *Manihot* genetic diversity
- Generate knowledge and develop technology components for cassava improvement
- Provide conceptual and intellectual leadership to the cassava R and D community
- Support IITA in its cassava improvement endeavor in Africa
- Strengthen NARDS R and D capacity in Latin America and Asia

The assets that the Cassava Program has at its command to do this job (which confer a comparative advantage with respect to certain research tasks) include:

- The world *Manihot* germplasm collection
- Scientific competence in germplasm conservation, characterization and improvement, crop management and market research
- Access to research support in biotechnology, virology and GIS
- Research infrastructure and well trained support staff
- Collaborative links with advanced labs and national programs

An analysis of the distribution of the resources (human and operational) across the Program's project areas (Figure 1) reveals that core research resources are invested principally in Genetic Diversity and Gene Pool Development. That is, in those areas which represent CIAT's comparative advantage in holding the world germplasm collection. In the areas of Crop Management and Processing and Market research, the Program maintains a competency and capacity to link with other research partner and provide conceptual input into cassava R and D. The levels of complementary funding that have been attracted give an indication of the demand that exists for access to the research expertise and infrastructure that CIAT can provide in the latter two areas.

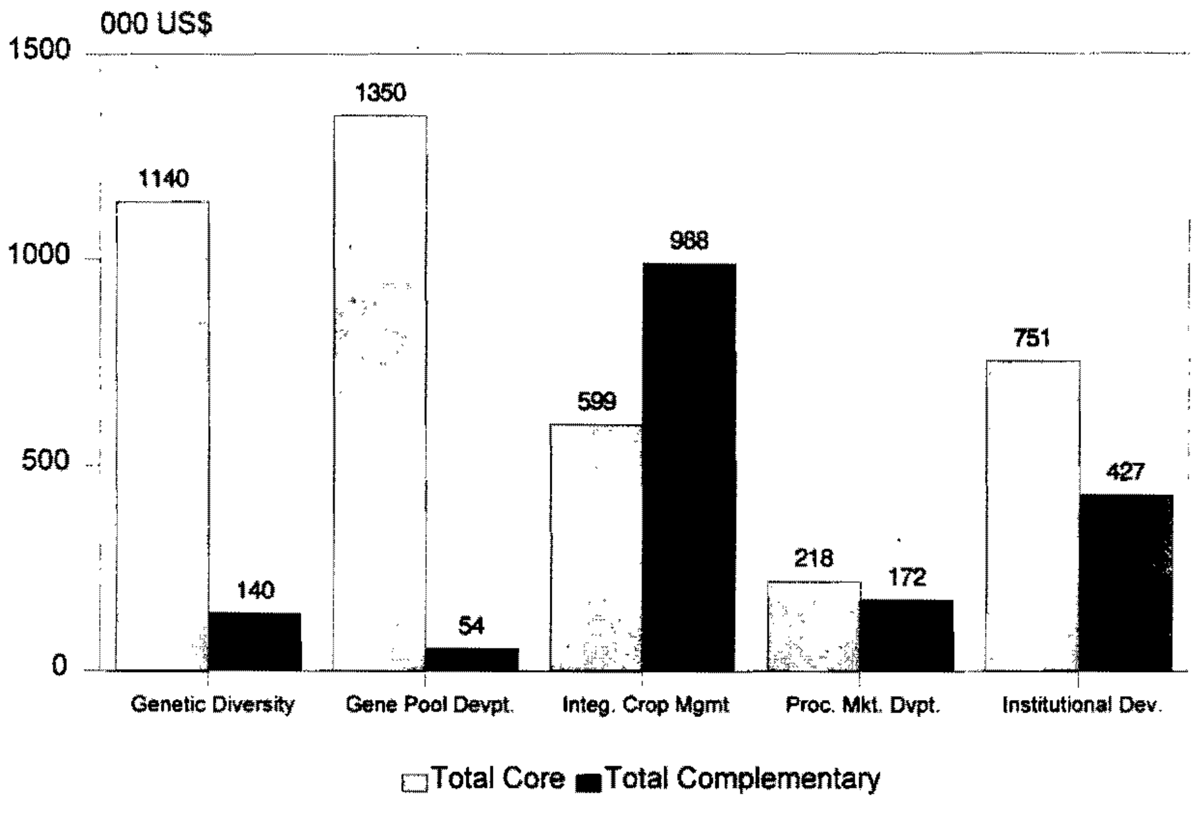

Figure 1. Distribution of total (core plus complementary) cassava research resources by project area, 1994.

(Note: the input of associate members of senior staff seconded from other institutions has not been monetarized)

To be able to fulfil its perceived role, the Program considers itself to have inadequate (below optimum) core competence in the following areas:

- Quality
- Plant nutrition - soil management
- Process and product development

Issue: By maintaining an interdisciplinary, integrated approach to cassava R and D CIAT's Cassava Program seeks to provide conceptual leadership to its research partners. Does this continue to be an appropriate role for a CG centre?

CIAT believes that the CG should in no way relinquish the basic functions or responsibilities with respect to crops such as cassava. The challenge is to put into place creative mechanisms for pyramiding the collective assets of the CG and non CG institutions that together can contribute to fulfilling those responsibilities.

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Acronyms

ACMV	African cassava mosaic geminivirus
AIT	Asian Institute of Technology
AJAE	American Journal of Agricultural Economics
CARDI	Caribbean Agricultural Research and Development Institute (Jamaica, Barbados, Trinidad & Tobago, St. Kitts & St. Lucia)
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Costa Rica)
CBB	Cassava bacterial blight
CBN	Cassava Biotechnology Network
CERAT	Centro de Raizes Tropicais, Botucatu, Sao Paulo (Brazil)
CG	Abbreviation of CGIAR
CGIAR	Consultative Group on International Agricultural Research (USA)
CGPRT	Regional Centre for Research and Development of Coarse Grain, Pulses, Roots and Tubers (Indonesia)
CIAT	Centro Internacional de Agricultura Tropical (Colombia)
CIP	Centro Internacional de la Papa (Peru)
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (France)
CONDESAN	Andean Ecoregion Consortium
ETH	Eidgenössische Technische Hochschule (Switzerland)
FAO	Food and Agricultural Organization of the United Nations (Italy)
GIS	Geographical Information Systems
ICRDP	Integrated Cassava Research and Development Project (Ecuador)
IITA	International Institute for Tropical Agriculture (Nigeria)
IPM	Integrated pest management
IRR	Internal rate of return
NARDS	National Agricultural Research and Development Systems
NARS	National Agricultural Research Systems
NGOs	Non-Government Organizations
NRI	Natural Resources Institute (United Kingdom)
ORSTOM	Office de la Recherche Scientifique et Technique d'Outre-Mer (France)
SAR	Département des Systemes Agro-alimentaires et Ruraux (CIRAD)
TAC	Technical Advisory Committee of the CGIAR (FAO-Rome, Italy)
UNDP	United Nations Development Programme (USA)

Appendix 1.

ON-GOING AND FUTURE POSSIBILITIES FOR INTER-CENTRE COLLABORATION

Table 1A. CIAT's on-going collaboration with other CGIAR centres, by project area and project.[1]

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CD. *Manihot* Genetic Diversity					
CD01	Conservation and characterization of *Manihot* Genetic Resources	IITA, IPGRI 1992	Safe conservation and exchange of *Manihot* germplasm	Founding of the *Manihot* Genetic Resources Network	• Set of activities jointly prioritized with sister centres and national partners • Prospective reduced risk of loss of genetic resources • Limited benefit in concrete activities due to lack of resources
		IITA 1993	Determination of the genomic structure of *Manihot* as a tool for enhanced breeding efficiency	Joint project on the construction of a molecular map	• Incorporation of African cassava constraints as targets of future application of molecular markers • Prospective accelerated application of molecular markers • Access to molecular techniques and collaboration with advanced labs
		IPGRI 1989	Development of safe, lower cost methods of germplasm conservation	Joint project (1989) and proposal (1995) for development of cryopreservation	• Prospective reduced cost of safe *Manihot* conservation • Cryopreservation of *Manihot* can be used as a model for other CG crops

[1] For a description of project areas and projects see the background document "Cassava Program: Project areas, projects and resource distribution".

Table 1A (Cont.)

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CD01	(Cont.)	IPGRI 1993	Collection of *Manihot* species in Brazil	Joint sponsorship of national program to undertake collection	• Closer intercenter and national program collaboration in an area of mutual interest and priority • Shared responsibility for conserving genetic diversity
CD02	Defining Desirable Characteristics of Cassava Germplasm for more Efficient Gene Pool Development	IFPRI 1994	Exploration of the genetic potential for improving iron, zinc, iodine and vitamin A content of cassava	Joint project with participation in planning and evaluation meetings	• Prospective generation of additional resources • Enhanced ability to tackle secondary but important breeding objectives for improved root quality • Access to methodological techniques and collaboration with advanced labs.
CG Improved Cassava Gene Pools					
CG01	Development of Cassava Gene Pools with Global Perspective	None			
CG02	Deployment of Improved Cassava Germplasm in Latin America	None			
CG03	Deployment of Improved Cassava Germplasm in Asia	None			

Table 1A (Cont.)

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CG04	Broadening the Genetic Base for Cassava Breeding in Africa	IITA 1990	Introduction to Africa and joint evaluation of exotic germplasm	CIAT scientist as a member of IITA's TRIP	• Feedback for generation of gene pools appropriate for African conditions • Greater access to African genetic materials for incorporation of important traits • Enhanced level of collaboration and joint planning
CG05	Tools and Methodologies for Gene Pool Development	None			
CI Cassava Integrated Crop Management					
CI01	Integrated Pest and Disease Management	IITA 1977	Stabilization and increase in crop productivity without recourse to agrochemicals, through integration of host plant resistance, cultural and biological control of pests and diseases	Joint project with (a) shipment of natural enemies from L.A. to Africa (b) exchange of information on IPM strategies and methodologies (c) development of data bases (d) reciprocal participation in evaluation and planning meetings	• Generation of additional resources for fulfilling mandated activities • Reciprocal use of expertise in (a) rearing and releasing natural enemies, (b) use of diagnostic survey techniques, (c) farmer participatory methodologies for IPM • Accelerated solution to major pest problems

Table 1A (Cont.)

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CI02	Integrated Soil Crop Management	IRRI, ICRAF 1994	Increased productivity and sustainability of cassava-based farming systems through soil fertility management and soil erosion research in Asia	Informal at present. Possible incorporation into Asian ecoregional initiative	• Prospective accelerated impact on soil fertility and erosion problems through heightened interchange of experiences and methodologies • Rationalization of approaches to national partners
CM Cassava Markets					
CM01	Cassava Product, Process and Market Development	IITA 1994	Enhance the profitability of processing and quality of cassava products	Preparation of joint proposal for postharvest project in E/S Africa	• Prospective generation of additional resources • Access to experiences and technologies across continents
		CIP, IITA 1987	Disseminate the experiences of CIAT, CIP and IITA in process, product and market development of root and tuber crops	Preparation of a manual on product development for root and tuber crops and joint workshops	• Access to experiences and expertise from sister centres • Rationalization of contacts with national program partners
		CIP 1994	Identify areas for future postharvest innovation with potential to enhance the welfare of rural populations	Joint project	• Rationalization of relations with national partners • Identification of areas for future collaborative research

Table 1A (Cont.)

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CM01	(Cont.)	CIP, IITA 1994	More effective and efficient use of human and physical resources dedicated to postharvest root and tuber research and development	Initiative to form an interinstitutional consortium for postharvest research on roots and tubers Preliminary meeting of CIAT, CIP, IITA, CIRAD/ ORSTOM, NRI and FAO in Salvador, Brazil	• Prospective generation of additional research resources • More complete global coverage • Rationalization of contacts with national partners • Reduced duplication and greater complementarity between centres/ institutions
CC Institutional Development					
CC01	Research planning, Information exchange, Project Design and Networking	IITA 1988	Provision of sound socio-economic data on which to base priorities for resolving constraints to and realizing opportunities for cassava production in Africa	Participation in Phase I of the Collaborative Study of Cassava in Africa (COSCA) and Membership of the project Steering Committee	• Feedback on constraints to and opportunities for cassava development in Africa for orientation of strategic research on the crop • Access to CIAT's GIS facility and expertise

Table 1A (Cont.)

Project area/Project		Collaborating Centres and year of initiation	Purpose of collaborative activity	Mechanism of collaboration	Benefit accrued to the Centre and the System
CC01	(Cont.)	IITA 1988	Assessment of needs and priorities for cassava biotechnology research; linkage of national institutions with advanced labs and promotion of cassava biotech research; information exchange	Participation in the Cassava Biotechnology Network and Membership of the Network Steering Committee	• Prospective generation of additional resources to further work of both centres • Use of existing regional cooperation networks • Global perspective and set of agreed priority research needs in cassava biotechnology
		IITA 1992	Information exchange among cassava workers worldwide	Joint publication of the Cassava Newsletter	• Global coverage and information exchange on cassava
		IITA 1994	Realization of cassava's full potential for food security and income generation in Africa	Preparation of joint proposals for integrated cassava research and development projects in Africa	• Reciprocal use of expertise and experiences in the design of institutional models for linking research with development • Accelerated adoption of technologies

Table 2A. Potential areas of intercenter collaboration to capture additional synergies.

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CD. *Manihot* Genetic Diversity				
CD01	Conservation and characterization of *Manihot* Genetic Resources	IITA	Studies on the relative genetic diversity between centres of origin and secondary centres of diversity	• Development of global germplasm conservation and deployment strategies
		IITA, CIP	Conservation and propagation methodologies for vegetatively propagated crops	• Strengthening strategic research within CGIAR system • Interchange of experiences on cryopreservation, seed/pollen conservation, use of core collection concept and duplicate identification, assessment of gentic variability using molecular-based technologies and agroecological data. • Joint training of national program personnel in these areas
		IITA, CIP	Germplasm exchange and distribution	• Interchange of experiences and expertise (e.g. CIP;s Propagation and Redistribution Units) and sharing of quarantine facilities • Safer transfer of germplasm between countries and continents
		IITA	Evaluation and utilization of *Manihot* species	• Complementary expertise in use of *Manihot* species • IITA's experience in cytogenetics of *Manihot* • Build up of basic research on physiology and molecular biology of *Manihot*

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CD02	Defining Desirable Characteristics of Cassava Germplasm for more Efficient Gene Pool Development	IITA	Mechanisms and use of resistance to whiteflies, mites Physiology of drought tolerance in cassava Photosynthetic potential in relation to crop productivity Nutrient use efficiency in relation to plant type and crop management practices in marginal environments	• Evaluation of germplasm on both continents • Complementary expertise and reciprocal exchange of information on constraints of global significance
		IITA, CIP	Methods of screening for quality, in particular starch	• Rationalization of cost of analysis and greater complementarity in expertise requirements
		IITA	Application of molecular map to breeding objectives	• Identification of markers for agreed upon priority traits, e.g. ACMV and CBB resistance, CN potential

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CD02	(Cont.)	IITA, CIP	Molecular measure of diversity in crop genepools	• Central CG facility and strategy for evaluation of different commodities at the molecular level may be economical, CIAT has comparative advantage at HQ; CIP has regional experience in transfer (of isozyme fingerprinting) to NARS; shared Latin American regional activities in training and characterization at NARS level may be economical; shared facility at CG level for storage and distribution of DNA clones may be economical; ecoregional research on biodiversity taking advantage of shared habitats (cassava, sweet potato relatives, others?) family similarities (within Euphorbiaceae and within Solanaceae) may be economical

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CG Improved Cassava Gene Pools				
CG01	Development of Cassava Gene Pools with Global Perspective	IITA	Development of resistance germplasm for whiteflies, mites, CBB, root rots Breeding for low nutrient tolerance, particularly low-K, low-P and low-Ca Genepools for high β-carotene Improved genepools for semiarid, subtropical, humid and highland ecosystem	• Exchange of germplasm and improved screening methodologies • More rapid progress in meeting breeding objectives • Better understanding of needs and opportunities across continents • Addressing the sustainability issue through genetic solutions
CG02	Deployment of Improved Cassava Germplasm in Latin America	CIP	• Support to National R&T programs in countries where sweet potatoes and cassava overlap (e.g. Cuba)	• Training of common personnel, share infrastructure and varietal diffusion channels
CG03	Deployment of Improved Cassava Germplasm in Asia	CIP/IITA	• Support to National R&T programs in countries where sweet potatoes and cassava overlap (e.g. Vietnam) • Gene pool development with resistance to ACMV/ICMV to deploy in India	• Training of common personnel, share infrastructure and varietal diffusion channels • Common sources of resistance to ACMV and ICMV will be used to solve a major constraint in India
CG04	Broadening the Genetic Base for Cassava Breeding in Africa	IITA	Introduction to Africa and joint evaluation of exotic germplasm	• Feedback for generation of gene pools appropriate for African conditions • Greater access to African genetic materials for incorporation of important traits • Enhanced level of collaboration and joint planning

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CG05	Tools and Methodologies for Gene Pool Development	IITA	Farmer participatory research approach for the development and diffusion of cassava varieties Deployment of cassava transformation techniques when available GxE studies on the homology between regions	• Improved efficiency in breeding

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CI Cassava Integrated Crop Management				
CI01	Integrated Pest and Disease Management	IITA, CIP and other centres	Development of IPM technologies to control whiteflies and the plant virus diseases they vector in a variety of crops Use of entomopathogens (fungi, bacteria and viruses) for control of cassava, potato, and sweet potato arthropod pests Crop management strategies to control plant pathogens in root crops Training in virology and biotechnology Identification and study natural enemies including parasitoids, predators, and pathogens of mites, mealybugs, and whiteflies on cassava Employment of baculoviruses for hornworm control in cassava and sweet potato (Asia) Biological control of mites in cassava and sweet potato Pest population dynamics in cassava-sweet potato-based agroecosystems Participatory methods for IPM implementation in tropical agriculture	• Exchange of expertise, methods and results • Exchange of natural enemies • Analysis of constraints to scaling up from small scale to wider implementation of IPM • Synthesis of global experiences in client driven research and training • Enhanced feedback to researchers in different centres

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CI02	Integrated Soil Crop Management	IITA, CIP	Quantification of the effects of natural and simulated erosion on crop productivity on inceptisols Agronomic and economic evaluation of hedgerow components for mid altitude hillsides and other erosion control	• Assessment of erosion impact for African and other Andean inceptisols • Validation of model equations for erosion impact • Creation of common data bases or expert system for characterization and selection of soil conservation options
CI03	Planting Material Propagation	IITA, CIP	Development of true seed propagation techniques	• Possible application of CIP's experience to cassava • IITA's experience on the reproductive biology of cassava
		IITA	Improvement of nutritional status of cassava planting material	• Validation and application of results obtained in Latin America • Optimization of varietal release and diffusion process
CM Cassava Markets				
CM01	Cassava Product, Process and Market Development	IITA, CIP	Demand and market studies on flours and starches in specific countries	• Creation of common databases • Reduced cost of obtaining information • Information on which to base joint product research proposals
CC Institutional Development				
CC01	Research planning, Information exchange, Project Design and Networking	IITA, CIP	Central American and Caribbean Root and Tuber Research Network	• Rationalization of support to national programs • Support to region that should receive greater attention

Table 2A. (Cont.)

Project area/Project		Collaborating Centres	Area of collaboration	Synergies captured or benefit obtained
CC01	(Cont.)	IFPRI, IITA, CIP	Impact of international trade agreements and trade liberalization policies on the potential of root and tuber crops and their products	• Information that will permit more precise priority setting
		ISNAR	Biotechnology planning, prioritization and impact assessment	• Reciprocal interchange of experiences and methodologies • Information that will permit more precise priority setting
		IITA	Production of joint scientific or other publications on cassava	• Greater coverage, using IITA's ability to translate into French
		IITA, CIP	Development of bibliographic resources and product based on CD-ROM technology	• Avoidance of duplication and maximising of coverage
		IITA, CIP	Training of national program personnel biotechnological skills, conservation and utilization of R and T crops biodiversity Development of training of trainers initiatives and farmer participatory research skill among common national program partners	• Avoidance of duplication and rationalization of cooperation with NARS

Appendix 2.

A. CASSAVA RESEARCH UNDERTAKEN BY ADVANCED LABS
Activities grouped according to CBN priority areas

April 1995

This list is organized to show the most significant activity in each CBN research priority area. Refer to the current listing of CBN research priorities as a guide.

As categories, priority areas are not exclusive. Some activities are listed more than once. For example, a project on cloning genes for starch quality will be found under the tool being developed (useful genes) and again under the application (starch quality).

I. BIOTECHNOLOGICAL TOOLS: FOR GENETIC IMPROVEMENT OF CASSAVA

Molecular and cytogenetic characterization of *manihot* genomes

1	Brazil	CENARGEN/EMBRAPA, Cx. P. 02372, 70700 Brasilia, DF	G.S.C. Buso, L.J.C.B. Carvalho	Brazilian *Manihot* spp.: diversity and relationships
2	International	CIAT, Biotechnology Research Unit and Cassava Program, A.A. 6713, Cali, Colombia	J. Tohme, M. Fregene, F. Angel, M. Bonierbale, C. Iglesias, C. Ocampo	Molecular markers for management of world *Manihot* collection
3	International	*Manihot* Genetic Resources Network (MGRN), c/o CIAT Genetic Resources Unit, AA 6713, Cali, Colombia	M. Bonierbale, J. Tohmé, C. Guevara	Relational genomic database for cassava
4	United Kingdom	Univ. Newcastle upon Tyne, Dept. Biochem & Genetics, Medical School, Newcastle upon Tyne, NE2 4HH	H.R. Haysom	Phylogeny of *Manihot*
5	United States	Washington Univ., Biology Dept., One Brooking Drive, Campus Box 1137, St. Louis, MO 63137	B. Schaal	Phylogeny of *Manihot*

Molecular map of cassava

1	International	CIAT, Biotechnology Research Unit and Cassava Program, A.A. 6713, Cali, Colombia	J. Tohme, F. Angel, M. Fregene, M. Bonierbale	RFLPs and RAPDs mapping, genome analysis
2	United States	Univ. of Georgia, Botany Dept., Athens Georgia 30602	G. Kochert P. Chavarriaga	Microsatellites and marker discovery

Useful genes and gene promoters characterized and/or cloned

1	International	CIAT, Biotechnology Research Unit, A.A. 6713, Cali, Colombia	J. Mayer L. Destefano	Cassava photosynthesis
2	Netherlands	Agric. Univ. Wageningen, Dept. Plant Breeding, PO Box 386; 6700 Wageningen	E. Jacobsen, R. Visser	Starch quality and quantity
3	United Kingdom	Univ. Newcastle upon Tyne, Dept. Biochem & Genetics, Medical School, Newcastle upon Tyne, NE2 4HH	M. Hughes	Key enzymes in cyanogen metabolism

Improvement of cassava plant regeneration and genetic transformation

1	Brazil	CENARGEN/EMBRAPA, Cx.P.02372, 70700 Brasilia, DF	C.B. Cabral; F.J.L. Aragao; D. Monte-Neshich	Somatic embryogenesis; transformation of protoplasts
2	France	Univ. de Paris Sud 11; Morphogeneses Vegetale Experimentale, Bat. 360; 91405 Orsay Cedex	G. Ducreux	Regeneration and organogenesis
3	International	CIAT, Biotechnology Research Unit, A.A. 6713, Cali, Colombia	W. Roca E. Torres N. Balcazar	Agrobacterium- mediated transformation
4	Netherlands	Agric. Univ. Wageningen, Dept. Plant Breeding, PO Box 386; 6700 AJ Wageningen	E. Jacobsen R. Visser C.J.J.M. Raemakers	Somatic embryogenesis systems; agrobacterium-mediated transformation
5	Switzerland	Inst. Planzenwissenschaften, Universitatstr. 2, ETH-Zentrum/LFW E 16, CH-8092, Zurich	I. Potrykus, J. Puonti-Kaerlas, C. Stauffer	Transformation methods: Agrobacterium, biolistics, electroporation, use of protoplasts
6	United Kingdom	Univ. Bath, School of Biological Sciences, Claverton Down, Bath BA2 7AY	G. Henshaw N. Taylor	Regeneration systems incl. somatic embryogenesis
7	United Kingdom	Rothamstead Exp't. Station, Harpenden, Hertfordshire, AL5 2JQ	P. Lazzari P. Shewry	Genetic transformation via electroporation
8	United States	International Lab. for Tropical Agricultural Biotechnology (ILTAB) /(ORSTOM), The Scripps Res. Inst., 10666 N. Torrey Pines Rd., La Jolla, CA 92037	C. Fauquet C. Schopke R. Beachy	Agrobacterium, microprojectile bombardment, and combined methods
9	United States	Purdue Univ., Dept. of Biology, West Lafayette, Indiana 47907; Ohio State Univ., Dept. Plant Biology, Columbus OH 43210-1293 USA	S. Gelvin (Purdue); R. Sayre (Ohio)	Agrobacterium-mediated transformation

Regulation of reproductive biology

1	China	South China Institute of Botany, Guangzhou	Xian, Yunlan	Anther culture

II. BIOTECHNOLOGICAL TOOLS: FOR CONSERVING, EXCHANGING, AND PROPAGATING MANIHOT GENETIC DIVERSITY

Diagnostic and phytosanitary methods for safe cassava germplasm transfer

1	France/ International	ORSTOM, Lab. Phytopathologie, 2051 ave du Val de Montferrand; BP5045; 34032 Montpellier; CIAT	V. Verdier	Diagnostics: cassava bacterial blight
2	International	CIAT, Biotechnology Research Unit and Genetic Resources Unit, A. A. 6713, Cali, Colombia	C. Guevara,	Thermotherapy for virus cleanup
3	United Kingdom	Scottish Crops Research Institute, Invergowrie, Dundee, DD2 5DT	B.D. Harrison, M.M. Swanson, D.J. Robinson	Diagnostic methods for ACMV, other viri

Cryopreservation for long-term conservation of cassava genetic resources

1	International	CIAT, Biotechnology Research Unit, A.A. 6713, Cali, Colombia	W. Roca, R. Escobar, C. Guevara	Shoot tips routine implementation Long-term effects; genotype range
2	United Kingdom	Univ. of Bath, School of Biological Sci., Claverton Down, Bath BA2 7AY	G. Henshaw	Cryopreservation of somatic embryos

Tissue culture: technology improvement

1	International	CIAT Biotechnology Research Unit & Genetic Resources Unit, A.A. 6713, Cali, Colombia	W. Roca; C. Guevara, G. Mafla	In-vitro germplasm conservation
2	International	IITA Genetic Resources, Oyo Road, PMB 5320, Ibadan, Nigeria	S.Y.C. Ng	In vitro germplasm conservation & exchange; African germplasm
3	United Kingdom	Univ. of Bath, School of Biological Sciences, Claverton Down, Bath, BA2 7AY	G. Henshaw, N. Taylor	Enhanced in vitro systems for cassava

III. BIOTECHNOLOGY APPLICATIONS: *FOR REALIZING CASSAVA OPPORTUNITIES*

Starch quantity and quality for diverse end uses of cassava

Molecular genetics: transgenic approaches

1	Netherlands	Univ. of Wageningen, Dept. Plant Breeding; PO Box 386; 6700 AJ Wageningen	E. Jacobsen R. Visser	Gene cloning and genetic transformation
2	United Kingdom	Long Ashton Research Station, Long Ashton, Bristol, BS18 9AF	P. Shewry	Cassava starch synthesis biochemistry

STARCH QUANTITY AND QUALITY FOR DIVERSE END USES OF CASSAVA

Via microbial postharvest alteration

1	Colombia/ France/ International	UNIVALLE/CIRAD/CIAT/ORSTOM: Univ. del Valle, Proyecto Amidon Agrio, A.A. 25360, Cali, Colombia; CIRAD/CIAT, c/o CIAT Cassava Program, A.A. 6713, Cali, Colombia; ORSTOM, c/o UNIVALLE, A.A. 32417, Cali, Colombia; CIRAD/SAR, 2477 Ave. du Val de Montferrand, BP5035, 34032 Montpellier, cedex 1	A.-L. Jaime (UNIVALLE), D. Dufour (CIRAD/SAR/ CIAT); M. Raimbault, D. Alazard (ORSTOM); J. Mayer (CIAT); N. Zakhia (CIRAD/SAR, France)	Enhanced lactic acid bacterial fermentation for breadmaking capacity in cassava sour starch; microbial taxonomy of lactic acid bacteria
2	India	CTCRI, Sreekariyam, Trivandrum 695 017, Kerala	S. Moorthy; M. George	Starch characterization; microbial fermentation

Enhanced post-harvest keeping quality of cassava

1	International	CIAT, Biotechnology Research Unit and Cassava Program, A.A. 6713, Cali, Colombia	J. Mayer G. O'Brien	Biochemistry of post-harvest deterioration

Microbial biotechnologies for new or improved cassava products

1	Argentina	Univ. Buenos Aires, Dpto. Quimica Organica, FCEyN-UBA, Lab. Microbiologia Alimentos, Pab.II, Piso 3, Ciudad Universitaria(1428), Buenos Aires	S. de Fabrizio	Genetic transformation of starter bacteria for phage resistance
2	Brazil/France	Univ. Estatual Paulista (UNESP), Botucatu, SP, Brazil (CERAT); CIRAD/SAR, France	M.P. Cereda, I. Takitane, O.L.G.S.Nuñez (UNESP) O. Vilpoux, G. Chuzel (CIRAD)	Enhancement of cassava starch via lactic acid bacteria hydrolysis
3	Brazil/France	Univ. Fed. dó Parana, Lab. de Processos Biotecnologicos, Dpto.Ingenharia Quimica, 81531-970 Curitiba, PR, Brazil; ORSTOM/Colombia	C. Soccol (U. Fed. Parana) M. Raimbault (ORSTOM)	Fermentation for protein enhancement and amylase production
4	Colombia/France	ORSTOM, Ave.5A Nte. 20-08 (501), AA 32417, Cali, Colombia/Univ. del Valle, Process. Biol., AA 25360, Ciudad Univ. Melendez, Cali, Colombia	M. Raimbault (ORSTOM) D. Alazard (ORTOM/UNIVALLE)	Lactic acid bacterial ferm., reactor design for protein enrichment, ethanol production, other
5	France	CIRAD/SAR, 2477 ave. du Val de Montferrand, BP 5035, 34032 Montpellier, Cedex 1	D. Griffon N. Zakhia	Fermentation and other processes; sour starch; gari; other
6	India	CTCRI, Sreekariyam, Trivandrum 695 017, Kerala	C. Balagopalan; M. George; S.N. Moorthy C. Ray; G. Padmaja	Food, feed, & industrial products from fermentayion (single-cell protein, starchy flour, commercial enzymes, quick foods
7	International	IITA, Root and Tuber Improvement Prog., Oyo Rd, PMB 5320, Ibadan, Nigeria	M. Bokanga	Food products from fermentation (taste, nutrition, texture, safety)
8	Thailand	Kasetsart University, Dept. of Biotechnology, Bangkok, 10903; Dept. of Microbiology, Bangkok 10900	K. Sriroth (Biotech) B. Yongsmith (Microbio)	Fermentation for food coloring, protein enrichment; bioconv. for L-lysine; glutamic and citric acids
9	United Kingdom/ Tanzania	NRI, Chatham Maritime, Chatham, Kent, ME4 4TB; Tanzania Food and Nutrition Center, 22 Ocean Drive, Dar es Salaam	A. Westby, Z. Bainbridge (NRI), W. Lorri, N. Mlingi (TFNC)	Enhanced traditional fermentation processes

Molecular/transgenic approaches for new cassava products

(See "Starch quantity and quality"; no other activity at this time)

Improved cassava nutritional quality

1	United Kingdom	Long Ashton Research Station, Long Ashton, Bristol, BS18 9AF	P. Shewry	Molecular biology of cassava protein quantity and quality

Cassava performance in stress environments:

Plant-soil relationships, nutrient cycling efficiency, photosynthesis, biofertilizers including mycorrhizal interactions

1	France	ORSTOM, Lab. des insectes nuisibles, Parc scientifique Agropolis Bats B5-B6, 34397 Montpellier cedex 5	T. Lamaze, P.A. Calatayud	Physiology of cassava in drought stress
2	International	CIAT, Cassava Program, A.A. 6713, Cali, Colombia	J. Mayer; M. El-Sharkawy	Photosynthesis, including mechanisms of CO_2 assimilation; P/K utilization

Integrated pest management for cassava,

Including host/pathogen and host/pest interactions

1	France	ORSTOM, Lab. des insectes nuisibles, Parc scientifique Agropolis Bats. B5-B6, 34397 Montpellier cedex 5	B. Le Ru, P.A. Calatayud	Biochemical physiology of plant defense against cassava mealybug
2	France	ORSTOM, Lab. de Phytopathologie; 2051 ave du Val de Montferrand; BP 5045; 34032 Montpellier	V. Verdier B. Boher	Molecular analysis of the genetics of CBB
3	International	CIAT, Cassava Program, A.A. 6713, Cali, Colombia	Cassava Pathology Section	Antagonistic fungi for control of root rot
4	International/ Benin/Brazil/ Cameroon/Ghana/ Nigeria	South America c/o CIAT, Cassava Prog., A.A.6713, Cali, Colombia; PROFISMA, CNPMF/EMBRAPA, CP007, 44.380 Cruz das Almas, Bahia, Brazil. Africa c/o ESCaPP, IITA Benin, BP08-0932, Cotonou, Rep. Benin	S. Lapointe, L. Smith, A. Bellotti (CIAT); A. Pires de Matos (CNPMF), S. Yaninek (IITA)	Molecular markers for monitoring release of biocontrol organisms
5	United Kingdom	Univ. of Bath, School of Biological Sciences, Claverton Down, Bath BA2 7AY	R. Cooper G. Henshaw	Biochemical physiology of plant defense (CBB)

Resistance to important viral diseases of cassava

1	International	CIAT, Virology Research Unit, AA 6713, Cali, Colombia	L. Calvert	Resistance & diagnostics, CCMV, CVMV, Frogskin viral diseases
2	United Kingdom	John Innes Institute, Inst. of Plant Science Research, Colney Lane, Norwich NR4 7UH	J. Stanley	Molecular charact .of ACMV, virus infection and replication
3	United Kingdom	Scottish Crops Research Inst., Invergowrie, Dundee DD2 5DT	B. Harrison	Molecular char.& diagnostics, ACMV and related viri
4	United States/ France	International Lab. for Tropical Agricultural Biotechnology (ILTAB) /(ORSTOM), The Scripps Res. Inst., 10666 N. Torrey Pines Rd., La Jolla, CA 92037	C. Fauquet R. Beachy	Genetic transformation for ACMV resistance using viral coat protein

Cassava cyanogenesis: genetics, biochemistry, physiology

1	Denmark	Royal Vet. & Agric. Univ., Plant Biochem. Lab, 40 Thorvaldsenvej, DK-1871 Frederiksberg, Copenhagen	B. Moller	Biosynthetic pathway and enzyme systems
2	Germany	Univ. of Braunschweig; Botanisches Inst., Mendelssohnstr. 4; Postfach 3329; D-38092 Braunschweig	D. Selmar	Translocation of cyanogens
3	India	CTCRI, Sreekariyam, Trivandrum 695 017, Kerala	B. Nambisan	Physiology of cyanogenesis
4	International	IITA, Root & Tuber Improvement Prog., Oyo Rd, PMB 5320, Ibadan, Nigeria	M. Bokanga	Biosynthetic pathway
5	Thailand	Mahidol Univ. Dept Biochem., Rama 6 Rd, Bangkok	M. Chulavatnatol	Biochemistry (enzymes in cyanogenesis)
6	United Kingdom	Univ. of Newcastle upon Tyne, Dept. Biochem & Genetics, The Medical School, Newcastle upon Tyne, NE2 4HH	M. Hughes J. Hughes	Biochemistry and gene cloning
7	United States	Ohio State Univ., Dept. Plant Biol. and Biochem., 2021 Coffey Rd, Columbus, Ohio 43210-1293	R. Sayre	Biochemistry and gene cloning

Enhanced fermentation systems for cyanogen reduction in cassava processing

1	India	CTCRI, Sreekariyam, Trivandrum 695 017 Kerala	G. Padmaja, M. George	Enhanced fermentation for detoxification
2	International	IITA/TRIP, Oyo Rd., PMB 5320, Ibadan, Nigeria	M. Bokanga	Microbiology of cassava fermentation
3	Netherlands	Agric. Univ. Wageningen, Dept. of Food Science, 6703 HD Wageningen	A. Essers	Enhanced village-level fermentation
4	United Kingdom /Tanzania	NRI, Chatham Maritime, Chatham, Kent, ME4 4TB; Tanzania Food & Nutrition Centre, PO Box 977, Dar es Salaam, Tanzania	A. Westby Z. Bainbridge (NRI); N. Mlingi (TFNC)	Enhanced village-level fermentation

Enhanced fermentation systems for waste management in cassava processing

1	Brazil	Univ. Estatual Paulista (UNESP), Fac. Ciencias Agronomicas, Dpto. Tecnol. dos Productos Agropecuarios, Cx.P. 237, CEP 18603-970, Botucatu, SP; Inst. Agronomico do Parana, Est. Exp. de Paranavai, PR, Brazil	M.P. Cereda (UNESP) M. Takashashi (Paranavai)	Characterization and treatment of cassava processing wastes
2	India	CTCRI, Sreekariyam, Trivandrum 695 017, Kerala	C. Balagopalan R. Ray	Value-added processing for waste water and residues

List of abbreviations

Organizations:

CENARGEN:	Centro Nacional de Pesquisa de Recursos Geneticos e Biotechnologia, Brazil
CIAT:	Centro Internacional de Agricultura Tropical, Colombia
CIRAD:	Centre de Coopération International en Recherche Agronomique pour le Développement, France
CTCRI:	Central Tuber Crops Research Institute, India
DGRST:	Direction General de Recherche Scientifique et Technique, Congo
EMBRAPA:	Empresa Brasiliera de Pesquisa, Brazil
IITA/TRIP:	International Institute of Tropical Agriculture, Nigeria; Root and Tuber Improvement Program
NRI:	Natural Resources Institute, UK
ORSTOM:	Institut Francais de Recherch Scientifique pour le Développement en Coopération, France
ORSTOM/LRGAPT	ORSTOM/Laboratoire de Ressources Génétiques et Amélioration des Plantes Tropicales

Diseases and Organisms:

ACMV:	African Cassava Mosaic Virus
CBB:	Cassava bacterial blight
CCMV:	Common cassava mosaic virus
CVMV:	Cassava vein mosaic virus
ICMV:	Indian cassava mosaic virus

B. Comparative development of NARS in Latin America and Asia

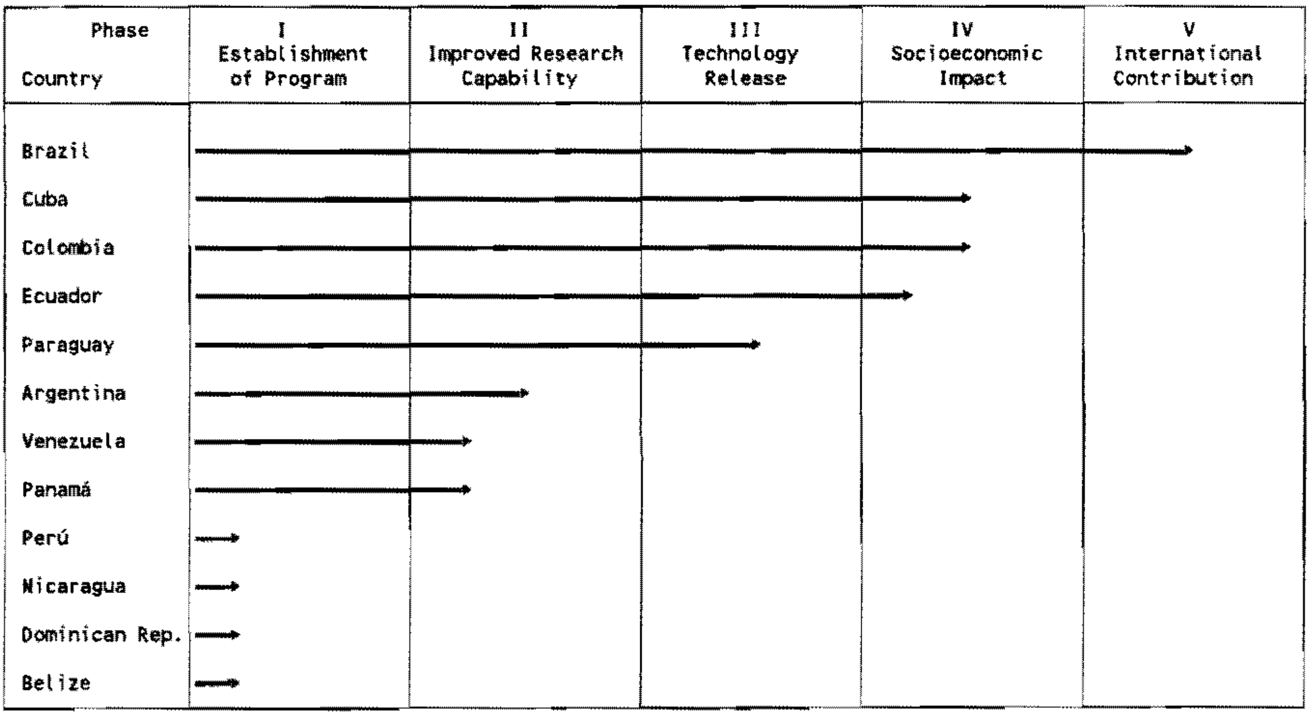

Table 4A. Situation of Latin American national cassava research systems.

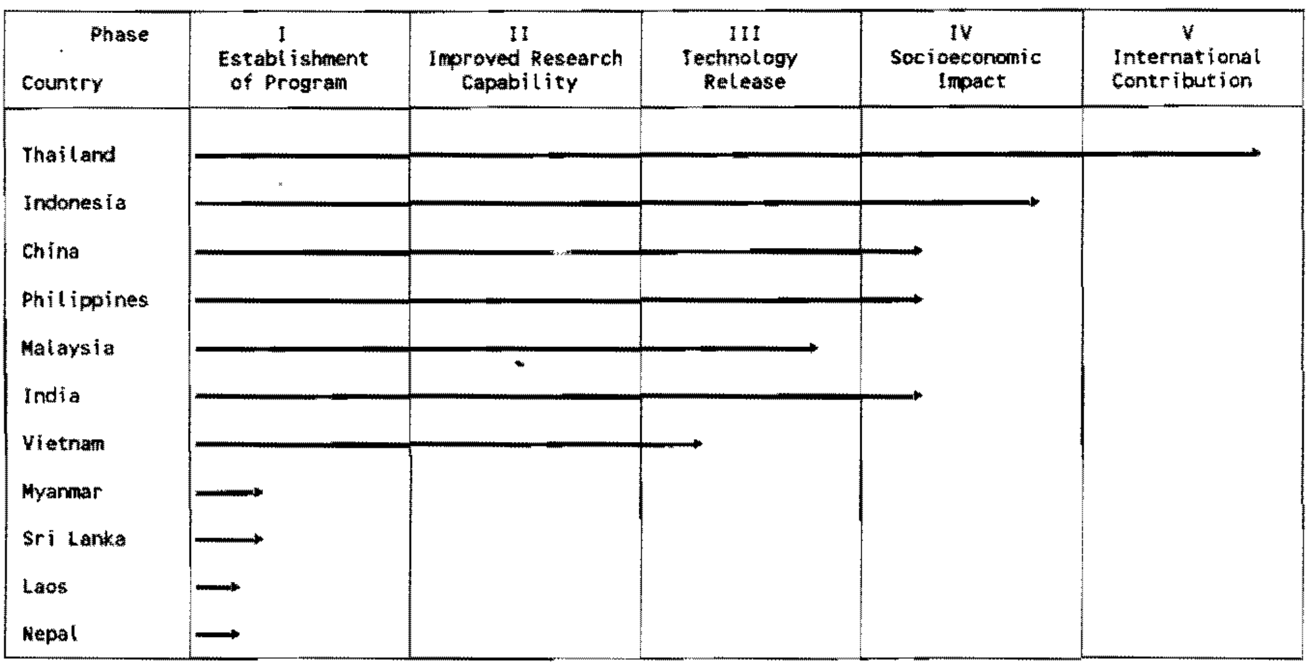

Table 4B. Situation of Asian national cassava research systems.
Adapted from Kawano, K. 1994. CIAT Cassava Program Annual Report 1993.

Appendix 3.

CASSAVA IN A GLOBAL, MULTICOMMODITY AND ECOREGIONAL SETTING: SYNERGIES AND SPILLOVERS

COMMODITY MANDATE BENEFITTING NEW ECOREGIONAL RESPONSIBILITY

Although with a global mandate, commodity research programs, including the Cassava Program, have consistently built on an ecoregional foundation through a set of research activities that are based on the development of sound components of production technology that improve agricultural sustainability in the targeted ecoregional zones in its global mandate i.e. Latin America, Asia and Africa. Furthermore, the commodity-oriented and multidisciplinary approach of the Cassava Program was pivotal in initiating and promoting an effective and integrated cassava production, processing and marketing model that was successfully implemented in several Latin American countries.

The recent designation of CIAT as the CGIAR's ecoregional convening center for Latin America and the Caribbean should enhance the adoption and spread of the cassava integrated model in the targeted ecoregions in the lowland and the highlands tropics where cassava plays an important role in food production and poverty alleviation. Over the past 15 years, the Cassava Program has been active in the area of natural resource management including genetic diversity and integrated crop management (including pests and diseases) in Latin America and Asia, and provided support to IITA in its program on biological control of cassava pests.

The research has targeted the highest priority ecoregions designated by TAC in the warm humid, sub-humid, semi-arid tropics and subtropics of Asia and sub-Saharan Africa; and the warm humid and sub-humid tropics and subtropics in LAC. For example, the germplasm development project, funded by IFAD, focuses on the semi-arid tropics and the humid subtropics both in LA and Africa. The integrated crop and pest management project, funded by UNDP, focusses on developing, testing and validating technology components in cassava-based production systems in the humid and sub-humid and semiarid regions of Brazil and Africa. The Sasakawa funded project in Asia focuses on developing technology components for sustainable agriculture in cassava-based production systems in the humid and sub-humid ecoregions in several Asian countries. These projects are making a significant contribution to the ecoregional approach across continents. Impact has been well documented and has been widely recognized. <u>CIAT as a multicommodity and ecoregional center should build on these initiatives across the CGIAR system as a means of enhancing its global mandate for cassava and its ecoregional mandate in LAC.</u>

Multicommodity synergies

The Cassava Program benefits from being located in a multicommodity centre by tapping the resources and services available in the research support units (e.g. Genetic Resources Unit, GRU, Virology Research Unit, VRU, Biotechnology Research Unit, BRU, Geographic Information System; GIS and Land Use) and by collaboration with the ecoregion-oriented programs (i.e. Tropical Lowland and Hillside) as platforms from which to launch its technology into the targeted LAC agroecosystems. These synergies are of paramount importance toward strengthening a productive and cost-effective CIAT.

Mutual benefitting inter-program activities:

A case in point is the interprogram collaboration with the Hillside Program in the area of on-farm testing, validation and evaluation of technology components minimizing soil erosion, and hence improving sustainability, in cassava-based cropping systems in the Andean region of Colombia. Feed-back from farmers' participation in technology evaluation helps the cassava researchers in gaining a better understanding of the complexity of existing hillsides systems and their constraints. On the other hand, the Hillsides Program is benefitting from the integrated cassava R&D approach.

The use and identification of useful and less competitive forage legume species as a live cover crop in cassava-based farming systems in hilly lands in Cauca, Colombia is another example of synergies among CIAT programs and activities. The spill-over of such approach is the acquisitions of data base and useful information in both areas of germplasm development as well as natural resource management that should benefit the international and national research partners of CIAT in its ecoregional mandate.

Benefits, synergies & spillovers from Research Units:

The **Geographic Information Services** (GIS) available at CIAT have contributed to describing and defining ecoclimatic zones relevant to cassava germplasm evaluation and enhancement. Through this mechanism cassava accessions are classified as to their ecological provenance, and testing sites are defined for the documentation of performance across primary production ecosystems, toward prediction of suitability for diffusion in the diverse settings of our clients. The GIS is currently being applied to improving conservation capacity for the wild relatives of cassava. In addition, GIS plays an important role in cassava constraints assessment.

The **Biotechnology Research Unit**, with expertise in molecular biochemistry, tissue culture and genetics and facilities to experiment with new methods of genetic analysis and manipulation, is an asset to the commodity program. Through in-house collaboration between the BRU and the Cassava Program we ensure that our target crop can benefit from modern biotechnologies such as transformation, molecular biology, cryopreservation. Simultaneous access to cassava germplasm, germplasm evaluation sites and expertise, and facilities for the application of the tools of biotechnology shorten the gap in time between technology development and its practical use. The link between the Cassava Program and the BRU has also resulted in the formation of the Cassava Biotechnology Network (CBN), exposing CIAT's cassava research to inputs from advanced biotechnology laboratories around the world, especially in developed countries.

The role of the **Germplasm Resources Unit** is of vital importance to the Cassava Program in carrying out its world mandate. The unit provides the essential infrastructure and services for Program scientists to carry out strategic germplasm improvement. Besides conservation, production of virus-free clones, and international germplasm exchange, the unit provides the Program with germplasm characterization through isozyme fingerprinting and molecular markers.

The inadequate core staffing of the Cassava Program in the area of crop\soil management further points to the need of inputs from other CIAT programs with experties in this area of research, particularly where cassava is a component in the production systems of CIAT's mandated ecoregions. So far, the Cassava Program has partly alleviated this deficiency through acquisition of complementary funds both in Latin America and Asia.

Inter-centre synergies

Inter-center synergies in the area of cassava research and development can be illustrated through the collaborative research efforts between IITA in Africa and CIAT in the area of germplasm exchange and improvement as well as integrated pest and disease management. The biological control of cassava mealybug in Africa is a case in point where CIAT, being located in the center of origin of cassava, played a key role in determining the origin of the pest and contributed to identifying, collecting and rearing of certain natural enemies which were shipped and released in Africa by IITA. A similar effort with the cassava green mite (CGM) has already introduced numerous predator species from the Americas into Africa, and from the northern region of South America (the origin of the CGM) into Brasil. To increase genetic diversity and enhance specialized genepools in Africa, CIAT has collaborated with IITA to cross and select ACMV resistant germplasm with LAC cassava germplasm **through the intervention of the Virology Research Unit**. These materials are being tested in a variety of ecosystems by IITA.

In addition, the Cassava Program is developing collaborative projects with other centres (IITA,CIP) and international institutes (NRI,ORSTOM,CIRAD) on root & tuber post-harvest and market R&D in Asia and Africa, using the integrated project approach. These projects form a first step towards inter-centre and inter-agro-ecological collaboration in an effort to improve efficiency and effectiveness.

Appendix 4.

PROS AND CONS OF HOUSING STRATEGIC RESEARCH ON CASSAVA AT THE CENTER OF ORIGIN AND DIVERSITY OF THE CROP

Given constraints on international movement of germplasm, CIAT's location in Latin America, the center of origin and domestication, and the primary center of diversity of cassava, is essential to the global germplasm and crop development efforts. This proximity facilitates the collection of germplasm; as well as an appreciation of the gene pool structure with respect to origin, domestication and improvement, and of the crop's position in ecological communities consisting of associated microorganisms, pests, and respectively, their natural enemies. However, as cassava is immensely important in newer, secondary centers of diversity it is essential to maintain scientific and logistical capacity for cassava research in those regions as well. The following considerations relate to the importance of housing strategic research on cassava at the center of origin and diversity of the crop.

1. **Establishment of a representative collection of cassava germplasm**
The world cassava collection at CIAT provides the genetic base for improvement of the crop in the Center's breeding program and those of the many national and international programs. Germplasm acquisition is facilitated by proximity to Latin American countries, where the largest proportion of diversity for the crop has been developed and maintained in farmers' fields. Cassava from 23 countries is represented in the world collection, and the diversity of the collection has been evaluated comprehensively in several distinct ecosystems relevant to international germplasm needs. This process provides security through duplication of germplasm, and contributes valuable characterization data. The goal of germplasm conservation is to represent the largest amount of diversity possible at an affordable cost. While Latin America is the center of origin, domestication and the primary center of diversity of cassava, Africa and Asia are important secondary centers of diversity accounting for respectively, 49 and 33% of world production (1993 statistics). Cassava was introduced to Africa 400 years ago; development and use of the crop since then have generated many new variants which are at present poorly represented in the world collection. A global initiative is needed to overcome quarantine restrictions toward safe exchange of cassava germplasm among primary and secondary centers of diversity. Due to the presence of the majority of diversity in Latin America, it is most appropriate that this global effort be based there, with a regional mandate in Africa.

2. **Evolution of the crop with potential pests and pathogens**
In its center of origin, cassava and its relatives have had a long history of co-evolution with other species, such as the biological agents of disease and arthropod pests, as well as exposure to predominant stressful ecosystems which constitute constraints to agricultural production. Characterization data for cassava germplasm in the world collection includes, in addition to morphological and biochemical description, reaction to the critical biotic

and abiotic constraints in the crop production context. Evaluation is conducted in the field with naturally prevalent insect, disease or environmental pressures (see table). This allows the recognition of desirable sources of genetic variability. Strategic crop improvement research into the mechanisms and control of tolerance to biotic and abiotic stresses relies on parallel observations in conditions of natural and experimental or controlled exposure.

Pests and pathogens evolve with crops outside as well as within their centers of origin, such as in regions to which they are introduced and extensively cultivated. A case in point is the African Cassava Mosaic Virus. ACMV constitutes a major threat to Latin American germplasm, but can only be combatted by concerted efforts among scientists in Africa. For this reason, and due to other distinct needs in germplasm enhancement for Africa, it is essential to maintain a critical mass for cassava germplasm research and conservation in both Latin America and Africa, to which continents the crop plays a crucial role in food security.

3. **Deployment of natural enemies for crop protection**

Knowledge of pest and disease complexes, gained through research in the center of origin is highly relevant to crop protection in other regions. Complex ecological communities in which crops evolve commonly include natural enemies or agents of disease control, which check populations of potential pests. In Asia, to which cassava was introduced, there are no major pests of cassava, and thus fewer natural agents of pest control; in addition, no reserve of resistant genotypes has been developed. In such situations, populations of accidentally introduced pests may explode rapidly. In Africa, with a longer history of cassava production, pests have already followed the introduction of the crop. When mites, and then mealybugs, were introduced to Africa from Latin America, the Latin America-based cassava program was prepared to transfer natural enemies for release in homologous ecosystems.

4. **Tracing the path and process of crop domestication**

Identification of, and access to, the source and process of crop domestication in the crop's center of origin is a valuable component of conservation and germplasm utilization strategies. Although it is not known whether the domestication of cassava was accomplished in parallel in different regions of Latin America, or only once, followed by migration to the present secondary centers of diversity within and outside the Americas, it is likely that cassava has evolved in areas with well marked dry seasons, providing selection pressures for building up food reserves in the roots, and efficient physiological adaptation mechanisms to withstand drought. It is possible that this path may be traced and related directly to strategic germplasm enhancement. Innovative research approaches such as those under development at CIAT will enhance our understanding of key physiological processes of cassava growth, assimilation and adaptation, which are necessary for more expeditious breeding.

5. **Enhancing the genetic base of cassava in Africa and Asia**

Production of cassava is now more concentrated in Africa and Asia than in its center of origin. Statistics for 1993 report regional distribution of production to be 49%, 33%, and 18%, respectively for Africa, Asia and Latin America. Production demands and genetic improvement in these regions rely on the infusion of genetic diversity, particularly as original introductions are understood to have been quite restricted. Through the definition of a series of 'ecological homologues' among the three continents, and the identification of representative testing sites in Latin America, cassava diversity from Latin America has been strategically introduced to Africa and Asia, as specifically oriented segregating progenies from the gene pool development program at CIAT. This entails collaboration not only in terms of ecologic/ biological matching, but also in the selection of appropriate germplasm for what may be distinct crop uses and farming practices.

6. **Access to a reservoir of wild and primitive germplasm**

Cassava (*Manihot esculenta*) is the only known cultivated species of the genus. Nearly 100 wild *Manihot* species are considered to have originated and diversified in the Americas, providing an extraordinarily rich untapped source of genetic diversity for cassava improvement. Practically all past efforts to improve the crop have utilized diversity within cassava, especially more evolved cultigens in terms of adaptation and yield. Recently however, attention of cassava breeders has been broadened to include genetic resources found in the wild relatives of *Manihot*. This reservoir becomes increasingly important as new crop characteristics are sought for distinct production or use systems. The development of modern molecular marker technology and genome mapping of cassava will greatly expand our access to genetic variability in the wild *Manihot* gene pools, and expedite its utilization in breeding programs. CIAT is currently engaged in developing such new tools for cassava, but their full utilization will involve cooperation with secondary centers of diversity such as Africa and Asia. Furthermore, research on genetic diversity of cassava and its wild relatives can be related to research on ecosystem diversity with strategic implications for understanding evolution, and rationalization of conservation (e.g. development of core collections and designing of *in situ* conservation strategies) and utilization of the gene pools in its primary and secondary centers of diversity.

Table. Description of edaphoclimatic zones defined by CIAT Cassava Program for germplasm development*

No	Description	Representative Countries/Regions	Principal Constraints[1]
1	Subhumid lowland tropics.	NE Brazil; Colombia (Atl. coast and Santanderes); N. Venezuela; Mexico (Yucatan Peninsula); N.E. Thailand; E. Java; subhumid belt of sub-sahelian Africa; S. India.	Drought stress; mites; thrips; *Diplodia* and *Fusarium* root rots; mealybug.
2	Acid soil, lowland tropical savannas.	Brazil (Cerrado); Colombia (Llanos; Venezuela (Llanos); Philippines; W. Africa savannas.	Soil acidity; bacterial blight; superelongation; anthracnose; mites; mealybug; African Cassava Mosaic Virus.
3	Humid lowland tropics.	Amazon basin (Brazil, Colombia, Peru); West Java and Sumatra; Malaysia; S. Vietnam; Equatorial West Africa.	*Phytophthora* and *Fusarium* root rots; African Cassava Mosaic Virus; anthracnose *Cercospora* and *Cercosporidium* spp. mealybug.
4	Mid-altitude tropics (800-1400 masl).	Andean zone; central Brazilian highlands; Jos plateau of Nigeria; Cameroon, East Africa.	Thrips; mites; root rots.
5	High altitude tropics (1400-2200 masl).	Andean zone; Rwanda, Burundi.	Concentric ring leaf spot; low temperature.
6	Subtropics	S. Brazil; N. Argentina; Paraguay; Cuba; China; N. Vietnam; S. Africa.	Low winter temperature; bacterial blight; superelongation; *Cercospora* and *Cercosporidium* leaf spots.
7	Semiarid lowland tropics	NE Brazil; NE Colombia (Guajira); semiarid belt of West Africa; Tanzania; Mozambique; Rwanda; Burundi.	Drought stress; mealybug; mites.

[1] Not all constraints are found in all regions of a given edaphoclimatic zone.

* Major germplasm development efforts use a condensed version of this table, in which edaphoclimatic zones 1&2 and 4&5 are considered together.

Appendix 5.

ROOT AND TUBER CROPS: DIFFERENCES AND SIMILARITIES

Differences:

1. The ecosystem of potatoes and the rest of the root and tuber crops are very different. Potatoes are grown in fertile soils in the high altitude tropics and the temperate zone. There is overlap between potato and sweet potato in the temperate areas. Cassava grows in the greatest range of ecosystems in the tropics and its range overlaps both sweet potato and yams. Nevertheless, these crops are quite unique because of their respective cropping systems. There is also overlap in the distribution of the wild relatives of cassava and sweet potatoes.

2. Germplasm improvement is very crop specific. Given the differences in cropping systems and specific constraints, the breeding programs would probably benefit very little from interaction with the various root and tuber crops.

3. Although some diseases and pest are widely distributed, most are ecosystem and crop specific. While there are many areas within the same crop for greater cooperation and coordination, there are fewer examples of cross commodity benefits in the area of pest management which would be specific to root and tuber crops.

4. Several of the root and tuber crops contain toxic chemicals such as cyanide and alkaloids. While processing serves to eliminate or reduce toxicity in cassava, this is not true for potatoes. Genetic solutions are crop specific. Even biotechnological solutions are different since different biosynthetic pathways are involved and potatoes are easy to genetically engineer versus cassava which has proven difficult to transform.

Similarities:

1. The root and tuber crops are vegetatively propagated crops which all have problems and limitations with seed production (both true seed and vegetatively propagated planting material). There could be benefits from combining efforts and knowledge in the area of seed production systems. This is one area where pathology may benefit from cooperation since the pathogens are transmitted through vegetative propagation and the methods of production of pathogen-free planting material are similar across the crops.

2. Genetic resource database development and access are activities that lend themselves to common solutions. CG activities in these areas could benefit not only from greater coordination within the root and tuber crops, but with most of the crops within the CG

centers.

3. The root and tuber crops share allogamy, are polyploid and have similar breeding schemes, which align them to procedures of genetic analysis, including gene mapping which are different from other CG crops.

4. GIS is another area that has benefits across commodities, and not just root and tuber crops.

5. Processing and marketing of root and tuber crops are often very similar. The principal processed products are starch and flour and many of the processing techniques are similar. In the marketplace, the products of the root and tuber crops can either complement or compete with each other, and there are often similar constraints such as the bulkiness of the fresh market product.

6. In some national programs the responsibility for root and tuber crops is grouped together in the same institution with shared personnel. There are opportunities for closer collaboration, for example in training, between the IARCs and the NARS.

Conclusions

This is a very brief treatment of some of the differences and similarities between the root and tuber crops. There are substantial differences between the crops and this has been reflected in the historical development of the CG centers and programs that are involved in research on root and tuber crops. There are also many areas of similarity and certain advantages could be achieved by coordinating research approaches and efforts. There is a need to ascertain whether the activities are unique to just root and tuber crops or if they apply to the mix of crops that are currently in the IARCs mandate. Before major changes are implemented, there is a need to fully understand the ramifications of any proposed changes. Enhanced communication across centers among scientists in related disciplines could be a first step in analyzing the synergisms that can be gained throughout the root and tuber crops.

Some characteristics of the major root and tuber crops

Species	Reproduction system	Market product	Center of diversity	Seed Production	Gene bank collections	Ecosystem	Crop management
Cassava *Manihot esculenta*	Vegetative propagation Allogamous	Root	Primary center of domestication: Northern South America Secondary center of diversity: Africa	High levels of sterility.	*In vitro* and field collections. Cultivated. CIAT: 5500 IITA: 2000	Humid or dry, low and mid-altitude tropics.	6-24 month growing cycle. Grows on infertile acid soils.
Potato *Solanum tuberosum*	Vegetative propagation Allogamous	Tuber	Primary center of domestication: Andes. Secondary center of diversity: Europe	High levels of sterility.	*In vitro* and field collections. Cultivated CIP: 5000 World: 42,000 Wild spp. CIP: 1500 World: 15,000	Humid high altitude tropics and temperate zone.	4-6 month growing cycle. Requires fertile soils.
Sweet Potato *Ipomea batatas*	Vegetative propagation Allogamous	Root	Primary center of domestication: Pacific Coast of S. America Distribution: Pan tropical	Auto-sterility & cross incompatibility (poor seed producer)	*In vitro* and field collections. Cultivated. CIP: 5,200 World: 6,000 Wild spp: 550	Low to mid altitude humid tropics.	4-6 month growing cycle. Grows on infertile soils.
Yam *Dioscorea* spp	Vegetative propagation Allogamous	Tuber	Primary center of domestication: India. Secondary center of diversification: Africa.		*In vitro* and field collections. Cultivated. IITA: 1000 World: 8,200 Wild spp: 60	Low altitude humid tropics.	4-6 month growing cycle. Requires fertile soils.