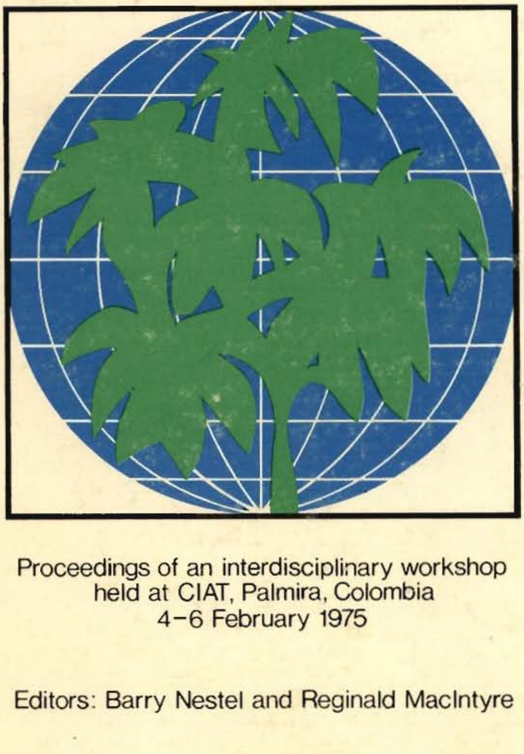
IDRC-049e

The International Exchange and Testing of CASSAVA GERM PLASM



Proceedings of an interdisciplinary workshop held at CIAT, Palmira, Colombia 4–6 February 1975

Editors: Barry Nestel and Reginald MacIntyre

Cosponsored by the
International Development Research Centre
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Contents

There is a wide range of variation in the characteristics encountered with the major cassava germ plasm collections.

Foreword

This is the seventh IDRC report relating to cassava and the sixth which records the proceedings of a multidisciplinary cassava workshop (see list at end of Foreword). It differs somewhat from earlier reports. The first five workshops were planned to identify research priorities relating to different aspects of cassava production and utilization. The present workshop was designed to establish guidelines for the "international exchange and testing of cassava germ plasm."

In the past three years, the new international agricultural research centres in Colombia (CIAT) and Nigeria (IITA) have made substantial progress in obtaining a better understanding of the potential of cassava as a crop and in demonstrating the possibilities for increased production from it. These achievements have aroused considerable interest due to the rapidly expanding use of cassava as an animal feed. International trade in cassava processed for this purpose has increased very rapidly and in 1974 its value to Southeast Asian exporting countries exceeded $200 million (US). This is more than double the 1972 value.

Since cassava has, in the past, been the subject of very little agricultural research, increases in production in recent years have been largely attributable to an increase in land area under the crop and to the cultivation of traditional varieties. However, the work at CIAT and IITA and at certain national centres, such as the Central Tuber Crops Research Institute in India, has indicated that there is a very wide range of genetic variation within the crop, and that the potential for increased yield and improved disease and insect resistance through the use of modern plant breeding techniques is considerable. In order that this potential might be exploited, it appeared desirable to bring together a number of cassava research workers from different countries to explore the possibilities for exchanging and evaluating both existing and new cassava germ plasm at the international level. To meet this objective, IDRC, in conjunction with CIAT, sponsored a workshop at CIAT in Colombia from 4-6 February 1975. Research workers from 12 Latin American and Asian cassava-producing countries participated. Invitations were not extended to representatives from African countries because the presence of common cassava mosaic on that continent raises particularly difficult phytosanitary problems relating to the exchange of cassava germ plasm between Africa and other continents. However, representatives of IITA did participate in the workshop with a view to using its structure and conclusions as guidelines for the organization of an identical type of meeting for African cassava-producing countries in Nigeria at the end of 1975.

The first day of the workshop set the framework for the subsequent discussions. During the day representatives from IITA, Indonesia, Peru, Colombia, Malaysia, Guatemala, the Philippines, Ecuador, Thailand, Venezuela, India, and Brazil presented situation papers relating to cassava production in their countries. The author of each presentation was requested to cover the following points:

1) Cassava germ plasm available in his country;
2) Status of evaluation of this germ plasm, including the characteristics being noted;
3) The area devoted to cassava and whether this was principally single or multiple cropped and an estimate of whether this area was likely to increase or decrease in the future;

4) The status of research on the crop with a brief summary of the work in progress and that planned for the future;
5) The human and financial resources devoted to research and extension on cassava;
6) The names and incidence of the most important diseases and pests of the crop;
7) The quarantine requirements for importing cassava germ plasm.

The day was concluded with a presentation by *Kawano* which provided a brief description of CIAT's large germ plasm bank and discussed the availability of this material for other institutions.

The theme of the second day's presentation related to the preparation of suggested guidelines for international cooperation in the exchange, testing, and evaluation of cassava germ plasm. The initial paper by *Lozano and van Schoonhoven* discussed the disease and pest risks associated with the international transfer of both vegetative cassava material and seed. The authors presented some preliminary guidelines for the reduction of disease risks associated with the interchange of cassava material. Following the discussion on their presentation, they were joined by *Belloti, Booth,* and *Terry* to constitute a working party which prepared a revision of the guidelines for the international movement of both vegetative propagating material and true seed. The revised guidelines were presented at the following day's session.

The next paper was a presentation by *Kartha* dealing with the potential value of a tissue culture technique for producing mosaic-free cassava. This paper aroused considerable interest and discussion. Although it was recognized that, in the absence of any reliable diagnostic test for common cassava mosaic, it would be impossible to prove that material was free from it, it did appear that the tissue culture technique was producing symptom-free plants from infected material and that it offered sufficient promise to warrant further evaluation.

The third paper at this session by *Andersen and Díaz* dealt with the role of agroeconomic studies in determining priorities for resource allocation in cassava research. This paper did not relate directly to the conference theme, but served as an information activity in relation to an allied network to the international testing one which CIAT is in the process of developing. The final presentation on the second day commenced with a paper by *Toro and Franklin* on an experimental design for an international testing program for cassava, followed closely by a related presentation by *Cock and Toro* tabulating the specific requirements for a cooperative international testing program.

The final day of the meeting was given over to three theme sessions which attempted to synthesize the contributions of the first two days. The first of these discussions related to the revised presentations by *Lozano et al.*, with respect to the preparation of suggested guidelines for the international movement of cassava germ plasm. This was followed by a revised presentation of the *Cock* and *Toro/Franklin* papers providing suggested guidelines for the design of standardized agronomic trials for evaluating promising cassava cultivars. The final paper, by *Kawano*, presented a list of characteristics, categorized at three levels of priority, for evaluating germ plasm in comparative international testing programs.

The country papers have been summarized for publication, but the theme papers are presented in full. Following these is a short summary of the conclusions of the meeting and three annexes which present in full the suggested guidelines agreed upon by the meeting.

This is the first workshop in the series that has dealt with methodology and it was encouraging to note that every country invited sent participants. Throughout the meeting, there was an excellent level of discussions and IDRC is indebted to the workshop participants for the time, effort, and expertise that they contributed to making this meeting successful. Particular thanks are due to Drs F. Martin and W.

Tossell for their chairmanship which maintained the sessions on schedule and kept the discussions sharply focussed.

IDRC is grateful to Dr John Nickel, the Director General of CIAT, not only for opening the meeting, but also for making available the resources and supporting services of CIAT for the meeting. Thanks are also due to Dr E. Alvarez-Luna who was responsible for most of the local arrangements of the meeting, and to Mr D. Evans of the CIAT conference staff whose activities contributed so greatly to the smooth running of the whole program.

Barry L. Nestel
Associate Director
Agriculture, Food and Nutrition Sciences

Earlier publications on cassava included:

Report of a CIAT/IDRC-sponsored cassava program review, Cali, January 1972; published by CIAT, Apartado Aéreo 67-13, Cali, Colombia

Report on an IITA/IDRC-sponsored workshop on cassava mosaic, Ibadan, December 1972; published by IITA, Ibadan, Nigeria

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Phillips, T.P. 1974. Cassava utilization and potential markets. IDRC-020e, Ottawa, 183 p.

Araullo, E.V., Barry Nestel, and Marilyn Campbell (ed.) 1974. Cassava processing and storage: proceedings of an interdisciplinary workshop, Pattaya, Thailand, 17-19 April 1974. IDRC-031e, Ottawa, 125 p.

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Participants

International Development Research Centre

B. L. Nestel
Apartado Aéreo 53016
Bogota D. E., Colombia

Reginald MacIntyre
Box 8500, Ottawa, Canada

E. J. Weber
Box 8500, Ottawa, Canada

Ana Cecilia Munoz
Apartado Aéreo 53016
Bogota D. E., Colombia

Centro International de Agricultura Tropical (CIAT) (Apartado Aéreo 67-13, Cali, Colombia)

J. Nickel, *Director General*
E. Alvarez
K. Kawano
P. Andersen
R. Howeler
A. van Schoonhoven
J. Cock

A. Bellote
J. C. Lozano
J. C. Toro
R. Díaz
R. Booth
M. A. dos Santos

Latin America

Ing Antonio Jose da Conceicao
Universidad Federal da Bahia
Convenio UFBA/Brascan Nordeste
Escola Agronomica
Cruz das Almas, Brazil

Ing Jairo Gartner
CNIA-ICA
Palmira, Colombia

Ing Leon Gomez
ICA-TIBAITATA
Apartado Aéreo 7984
Bogota, D. E., Colombia

Lauro Lujan
Director
Programa Nacional de Tuberosas
ICA-TIBAITATA
Apartado Aéreo 7984
Bogota, D. E., Colombia

Edmundo Perez M.
CNIA-ICA Tibaitata
Apartado Aéreo 7984
Bogota, D. E., Colombia

Ing Fernando Paz Briz
Cervezas Nacionales Cia. Anonima
Casilla 519
Guayaquil, Ecuador

Ing Astolfo Fumagalli
Subgerente General, ICTA
Galerias Espana, 5o. Piso
Av. 67, No. 11-59, Zona 9
Guatemala

Ing Furmencio Perez Notario
Albamex
Merida, Mexico

Ing Armando de la Cruz
Banco Agrario
Merida, Mexico

Ing Juan Carlos Rosas Sotomayor
Departamento de Yuca, Camote y Otras Raices
Centro Regional de Investigacion Agraria "La Molina"
Apartado 2791
Lima, Peru

Ing Carlos Arias
Programa de Raices y Tuberculos
CENIAP
Ministerio de Agricultura y Cria
Maracay, Venezuela

Asia

N. P. Hrishi
Director
Central Tuber Crops Research Institute
Trivandrum 17, Kerala, India

T. S. Dharmaputra
University Brawijaya
Facultas Pertanian
Malang, Indonesia

Chan Seak Khen
MARDI
P. O. Box 208
Sungai Besi, Serdang
Selangor, Malaysia

Danilo Baldos
Philippine Council for Agricultural Research
Los Baños
Laguna, Philippines

Banjerd Boonsue
Head, Department of Plant Sciences
Kasetsart University
Bangkok, Thailand

Sophon Sinthuprama
Department of Agriculture
Ministry of Agriculture and Cooperatives
Rajadamnern Avenue
Bangkok, Thailand

Others

D. G. Coursey
Ministry of Overseas Development
Tropical Products Institute
56-62 Gray's Inn Road
London WC1Z 8LU, England

K. K. Kartha
Prairie Regional Research Laboratory
National Research Council
Saskatoon, Saskatchewan

F. W. Martin
Mayaguez Institute of Tropical Agriculture
P.O. Box 70
Mayaguez, Puerto Rico 00708

E. Terry
International Institute of Tropical Agriculture
Oyo Road, P.M.B. 53-20
Ibadan, Nigeria

W. E. Tossell
Dean of Research
Office of Research
University of Guelph
Guelph, Ontario N1G 2W1

Some cultivars are highly susceptible to pests and diseases. In this picture a severe attack of Phoma leaf spot is illustrated.

For a number of important pests and diseases there exist cultivars with varying degrees of resistance. The degree of resistance of some pests/cultivars can be quite marked. Here the researcher is screening for resistance to Phoma leaf spot.

T.S. Dharmaputra

Cassava *(Manihot esculenta)* is not native to Indonesia. According to Koens (1948) the Javanese still did not know cassava as a food crop in 1838. In 1852 the government imported cassava cuttings from Surinam. After being propagated at the Botanical Garden in Bogor, they were distributed in 1854 to all residencies (subdivision of a province) throughout Java. It took many years for cassava to become an important food crop in Indonesia. The major spreading of cassava as an agricultural crop took place between 1914 and 1918, when the rice supply was threatened. Indonesia now ranks second in world cassava production after Brazil (FAO Yearbook 1971). Ninety percent is consumed domestically as human food.

Cassava may have the potential to overcome world hunger. It has, however, been almost neglected by research workers. To help make up for this lack of attention, and to divert more research effort toward this important crop, it is essential to establish at this time international cooperation in cassava research. The following should be included in such a program: exchange of germ plasm resources; standardize evaluation procedures of cassava cultivars; comparative testing programs should be carried out; and international meetings on the development of cassava research should be held.

Germ Plasm Collected

The CRIA has nine improved cultivars in its collection: Valenca and Sao Pedro Petro SPP originated in Brazil; Bogor (from the cross Maleka × Basiorao), Muara (from the cross Bogor × Basiorao), Gading from West Java, Ambon (from Ambon), and three Bogor selections (Ambon × Gading, V-629; Mangi × Ambon, W-78; and W-236).

Germ Plasm Evaluated and Characteristics Observed

The existing cassava cultivars in Indonesia were derived either from introduction or resulted from hybridization (either natural or by researchers).

It is not uncommon for one cultivar to have different names at different locations. No standard classification of cassava cultivars has been developed in Indonesia.

Projects in Progress and Planned

Although cassava is one of the most important food crops in Indonesia, as in many other cassava-growing countries the plant has been usually overlooked by researchers. Research on cassava is mainly carried out by the Central Research Institute for Agriculture (CRIA) and Brawijaya University. The research at CRIA is mainly carried out by the Agronomy Division as part of their program in tuber crops research. The activities cover maintenance of the cassava collection, selection and hybridization, variety yield trials, and fertilizer experiments (Soenarjo and Wargiono 1972; Staf Pemuliaan Pemupukan Ubi-ubian 1970, 1971, 1972, 1973).

Selections of the clones resulting from hybridization and variety yield trials have been the main activities in the plant-breeding work since 1969. Adaptation tests of the cassava clones are carried out at the institute's experimental fields in Java and other main islands in Indonesia. Collections of cassava are maintained at nine experimental fields in Java, the big ones being at Tamanbogo,

University Brawijaya, Facultas Pertanian, Malang, Indonesia.

Muneng, and Cikeumeuh. Fertilizer trials have been conducted in several experimental fields with an NPK combination, to establish general fertilizer recommendations for the farmers.

Research carried out at Brawijaya University is concentrated on studying the Mukibat system of cassava production. The system basically is a grafting or budding of *Manihot glaziovii* onto a stock of *Manihot esculenta* (de Bruijn and Dharmaputra 1974). The system was invented in 1952 by a farmer named Mukibat. Until 1973 when Brawijaya University initiated research on the Mukibat system, no systematic scientific research on the agronomy and economic feasibility of the system had been carried out. The Mukibat system is now steadily expanding in Indonesia, especially in East Java. In some villages the system even has superseded the ordinary cassava production system almost completely, with an estimated doubling of the yield.

Human and Financial Resources for Research and Extension

Funding by IDRC of research on the Mukibat cassava production system was initiated in September 1973 at Brawijaya University. The main objectives of the research program are to study the economic feasibility and methods of improving the system from the agronomic point of view. Experiments are carried out in a number of major cassava-producing areas in East Java. A survey was carried out in July 1974 to study the extent of the system in the major Mukibat cassava-producing areas.

Important Diseases and Pests

Disease is not a major problem in Indonesia so far. Although cassava mosaic was reported in Indonesia by Muller (1931), the prevalence of the disease has not been confirmed.

Bacterial wilt disease seems to occur in Java. One of the objectives of the Plant Breeding Program carried out by the CRIA is to obtain clones resistant to bacterial wilt.

The red spider mite *Tetranychus bimaculatus* is the most widespread cassava pest in Indonesia, especially in the drier regions. A selection and hybridization program carried out by CRIA is aimed at producing clones which are resistant to this pest, which was a problem in one of our experimental fields during the 1974 dry season. *Manihot glaziovii* of the Mukibat cassava was also seriously attacked by the mites.

Quarantine Restrictions

Import and export permits from the Minister of Agriculture are required for cassava plants and planting material. International phytosanitary certificates must accompany all plant material, and they must enter or be exported through specified ports.

Applications for import or export permits should be forwarded to the Directorate-General of Agriculture, Jakarta. Applications for permits should include the name, address, and occupation of the consignor and consignee; the variety and quantity of plants and planting material and the place of origin; the method of shipment, port of entry or export; the purpose for which the plant material is imported or exported and the place where it is to be grown.

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Juan Carlos Rosas

A great variety of genetic traits is found in cassava material cultivated in Peru. However, research to develop new varieties has mostly ignored harvesting or the establishment of a germ plasm base.

The traditional cropping system for local consumption has resulted in farmers growing more than one variety of cassava. In each small plot, area, and zone there are different varieties with variable genetic traits and characteristics. Six species of *Manihot* have been found in Peru.

Germ Plasm Collected

The germ plasm in Peru is distributed as follows:

"La Molina" Experimental Agricultural Station: 164 cultivars from Peru; 34 from Brazil; 24 from Paraguay; 17 from Bolivia; 10 from Colombia; 5 from Ecuador; and 1 species *M. glaziovii* for a total of 255.

Tulumayo (Tingo Maria) Experimental Agricultural Station: 74 cultivars from Peru (16 from "La Molina").

Yurimaguas and Tarapoto Experimental Agricultural Field: 46 cultivars from Peru (11 from "La Molina"). *Other experimental farms and stations:* An average of 10 different cultivars, the majority from "La Molina." Peru has a total of 347 cultivars and one species of different established germ plasm.

Germ Plasm Evaluated and Characteristics Observed

At the La Molina Station, using the total cultivated, the following characteristics were determined: weight yield of fresh roots; weight yield of dry roots; weight yield of fresh foliage; harvest index; roots: starch — protein 80%, HCN (Guinard) 50%; type of stalk growth; root colour: peel, phelloderm, pulp; root shape; peduncle and depth of rootage; resistance to the root-knot nematode (*Meloidogyne incognita*): 30% of the total; defoliation during harvesting (qualitative evaluation); and resistance to the red spider mite (*Tetranychus* sp.): 50% of the total.

At the Tulumayo Station only the weight yield of fresh roots and the flour yield (50% of the total) were determined. The weight yield of fresh roots and the starch content were recorded at the Tarapoto experimental agricultural field.

Area Devoted to Cassava and Future Land Requirements

The area devoted to cassava in Peru covers 36,075 ha, producing 481,925 metric tons, with an average yield of 13,365 kg/ha. (Agrarian Statistics Peru 1971).

Since the tradition of one-family farms still dominates, the farmers prefer to establish small, independent single-crop plots, occasionally intercropping with maize. The coastal zone has larger plots of several hectares to supply the big markets close by.

The root is usually eaten in fresh form, and only a small percentage is sent to factories for conversion into starch and flour.

The demand for fresh cassava is increasing slightly, which should result in a modest increase in the total area under the crop. A large increase in area under cultivation is dependent upon the establishment of industries to produce flour and starch.

Projects in Progress and Planned

Although a reduced number of ex-

La Molina Experimental Agricultural Station, Apartado 2791, Lima, Peru.

perimental goals have been considered for the immediate future (e.g. germ plasm and genetic improvement, fertilization, weed control and physiology, cultural work, conservation of products, production alternatives, animal nutrition, pests and diseases), it is likely that resources to carry out these investigations will be scarce. In spite of the need to develop techniques consistent with the importance cassava could hold in Peru, the cutback in the budget will reduce activities in several ways. The projects *in progress* include: a) germ plasm: agronomic evaluation; b) genetic improvement through unrestricted crossbreeding; c) comparison of cultivars; d) sowing distances; e) NPK fertilization; f) weed control; g) physiological studies; h) sowing methods and types of stakes; i) chemical root analysis (proteins, starch, HCN, flour); j) production alternatives (crop rotation); k) sowing and harvest times; and l) swine feed. Our future plans include work on storage and drying.

Human and Financial Resources for Research and Extension

Since money for research is very scarce, there is no financing from the Ministry of Agriculture.

At present, the experimental stations have the following personnel: *La Molina,* 2 agronomists (80% time), *Tingo Maria,* 1 agronomist (20% time), *Tarapoto,* 1 agronomist (25% time), and *Others:* (Lambayeque, Cuzco, Satipo) 1 agronomist (50% time).

The Tingo Maria project is the only one that offers extension services, with one agronomist for every 2000 ha.

Important Diseases and Pests

Cassava in Peru is attacked by many pests and diseases, but the incidence is seldom considered important by farmers. The economic loss through such attacks is unknown, since they are ignored or go unnoticed.

South American cultures were quarantined in 1969-71 to control diseases present, and only nematodes were evaluated.

Diseases and pests that attack cassava include: brown leaf spot, *Cercospora henningsii,* white leaf spot, *Cercospora caribaea,* leaf spots, *Phyllosticta* sp., stern rot, *Botryodiplodia* sp., (pests): Hornworm, *Erinnys ello,* Shoot fly, *Silba pendula,* Red spider, *Tetranychus,* sp., Broca de la Yuca, *Eubulus* sp., and Root-Knot Nematode, *Meloidogyne incognita.*

Quarantine Restrictions

Although there are no written regulations concerning the entry of vegetal material into Peru, the following requirements must be met: authorization of the Department of Inspection and Agrarian Control in the Ministry of Agriculture; phytosanitary certificate indicating the material is free of diseases and pests; and, a period of quarantine during which the material is observed.

Unfortunately, these regulations are not strictly enforced, so there are risks of diseases and pests being brought in that affect the crops and could cause serious agricultural problems.

Lauro Lujan

Sweet cassava varieties are traditionally grown in Colombia and most of the crop is produced by small farmers for home consumption. About 70% of cassava production is used as a human food, 20% for industrial purposes, and 10% as a livestock feed.

Germ Plasm Collected

In Colombia research work on cassava was started in 1967 by the Instituto Colombiano Agropecuario (ICA) through its National Root and Tuber Crops Program. Initially 330 accessions were assembled in the Colombian Manihot Collection (CMC). A group of 256 clones of cultivated cassava collected from Colombia, Venezuela, and Brazil is being maintained at the ICA Research Centre at Palmira (VALLE), which is still free from bacteriosis and superelongation diseases. There is another group of 74 cultivars in Caribia (Sevilla-Magdalena) which was gathered from the northern states of Colombia, including the wild species *Manihot carthagenensis*.

Germ Plasm Evaluated and Characteristics Observed

The available material was evaluated in the major cassava-producing areas during several years. Observations were made on phenotypic and agronomic characteristics, and reactions to pests and diseases were noted.

The main characteristics recorded were: *Foliage* Germination, branching habit, plant height and vigour, leaf size and retention, flowering and fruit setting, and maturity; *Roots* Number and shape, length and diameter, skin, phelloderm, and flesh colour, weight, specific gravity, starch content, HCN content, perishability, and cooking quality.

The harvest index was 10 months. Reaction to pests: Thrips, spider mites, shoot flies; Reaction to diseases: bacteriosis, *Phoma, Cercospora*.

The regional and repeated evaluation work contributed to the identification of 20 promising cultivars, from which four superior clones were selected as varieties: Llanera (CMC-9), ICA Palmira (CMC-76), ICA Montería (CMC-40), and ICA Caribia (CMC-84).

Area Devoted to Cassava and Future Land Requirements

Cassava is grown throughout the country in small plots widely scattered below 2000 metres. The crop covers about 160,000 ha/year, with an average cost of $8000/ha (Colombian peso $30 to $1 US) and the production of 1,320,000 tons of roots valued at 1320 million pesos, and employing 200,000 people.

Approximately 60% of the acreage is grown by traditional methods, consequently the level of applied technology is low. About 30% of the total acreage is intercropped with maize, plantain, coffee and beans according to the region.

There are strong indications that there will be an increase in both acreage and yield in Colombia. If only 1% of the total surface below 2000 metres (1,002,320 ha/km^2) could be devoted to cassava, a potential of 10 million hectares of land would be available.

Director Programa Nacional de Tuberosas, Instituto Colombiano Agropecuario (ICA), Apartado Aéreo 151123, El Dorado-Bogota, Colombia.

Projects in Progress and Planned

The ICA cassava research projects are aimed at genetic improvement, cultural practices, and utilization. The research work is located in Caribia (Sevilla-Magdalena) to cover the northern plains, in Palmira (Valle) and Nataima (Tolima) to cover the interandean lowlands, and in La Libertad (Meta) to cover the eastern-Llanos. These three major cassava production regions have different soil and ecological conditions. There is close cooperation on cassava research between ICA and CIAT.

Through our breeding work we hope to obtain early varieties with good agronomic characteristics and low HCN content. Selfing and controlled crossing yielded 5000 seedlings, from which 60 promising clones were selected. At the moment, this material is undergoing yield trials from which the best ones will be taken to regional trials. The preliminary Colombian cassava catalog includes four registered varieties. Basic seed is delivered to the growers mainly through Palmira, Caribia, and Nataima research centres.

The following cultural practices were considered best: a) planting date: March and September; harvest after 9-11 months; b) spacing: 1 × 1m; each variety needs different spacing according to the use of the crop; c) planting methods: mostly by hand; 20-30-cm stakes placed at 45° gave best yields; d) fertilization: in its initial stages; critical levels of NPK are being studied countrywide; e) control of diseases and pests; restricted to commercial crops; use of healthy seed and few sprays with pesticides.

Cassava utilization methods are mostly traditional. However, there is an increasing interest in improving the small processing plants to produce cassava flour to supplement wheat flour in bakery products. The use of cassava as feed for dairy cattle and swine gave promising results.

Human and Financial Resources for Research and Extension

The Root and Tuber Crops Program of ICA has a research group of seven full-time agronomists and seven field assistants working in cassava, with an annual budget of 2.5 million pesos. The research results are made available to the growers by the Rural Development Programs located in the lowlands, through a group of 14 full-time agronomists and 30 field assistants with an annual budget of 4 million pesos.

Important Diseases and Pests

Diseases Cassava bacterial blight: Of economic importance, prevalent in regions of high relative humidity and mean temperatures of 25-30°C; *Cercospora* leaf spots: Widespread in the country but does not cause serious damage; brown and white leaf-spots are always present; *Phyllosticta* leaf-spots: Common in cooler cassava-growing regions; Superelongation disease: This is a serious yield-reducing factor, recently found in several areas; Root-rot diseases: Caused by fungi of germs *Phytophthora* and *Rosellinia*, occurring in badly drained organic soils in regions of heavy rainfall. Virus diseases: Still unknown in Colombia.

Pests Thrips: Widespread in Colombia, with some varietal resistance having been observed; Mites: The common species belong to the genera *Monychus* and *Tetranychus;* Hornworm: Usually present in small populations, and has natural predators; Stem-borers: Most frequent in eastern Llanos and northern plains; Shoot-fly: Common in most growing areas; Ants: Species of germs *ATTA* are the most frequent.

Quarantine Restrictions

Colombia follows the international agreement signed in Rome, December 6, 1951, which was approved by the Law 82 of 1968. The pertinent regulations established by the Ministry of Agriculture are applied and enforced by ICA.

Permission must be obtained from ICA to import plant material into Colombia. The material may be admitted or rejected by the Sanitary Inspection Service at port of entry. Quarantine measures were strictly applied to cassava germ plasm at Tibaitata (Bogotá), in cooperation with CIAT's plant pathologists.

S.K. Chan
S.L. Tan
S.L. Geh

Germ Plasm Collected

Cassava was first cultivated in Malaysia on a large scale in Malacca about 1851. In 1883 Cantley reported four races: Red Brazilian and White Brazilian which ripened in 9 months, Singapore in 15 months, and Mauritius in 18 months. In 1886 he introduced more cassava races from Brazil. The Department of Agriculture later introduced many more varieties from South America via Java and the Philippine islands. In 1946, the Department reported that the stock of cassava varieties at the Central Experiment Station, Serdang, was lost during the Japanese occupation and a fresh collection of varieties from different parts of Peninsular Malaysia was started. It included the present varieties, Medan (Kekabu), Jurai, Betawi (Berat), Puteh 1, Ladang (Btg. Puteh), Pulut, Lemak, and Sakai. In 1955 two varieties, Black Twig and Green Twig, which were extensively cultivated in Perak for the production of tapioca flour, were collected by the Department. The more recent introductions are KGT 44 from Indonesia, Bangkok 1 and Bangkok 2 from Thailand, and the South American varieties Llanera, Brazil, Itu 1507720, Fowlfat, and El Salvadore. To date, there is a total of about 40 local and introduced varieties and about 1000 clones from seeds. The original source of germ plasm collection in Peninsular Malaysia is probably Brazil. The present widely cultivated variety for tapioca flour and chip production is Black Twig and for food supplement Medan is used.

Germ Plasm Evaluated and Characteristics Observed

The collection is divided into four main groups, according to mature stem colour (light brown, dark brown, silvery, and orange). The next subdivision is based on leaf lobe length/width ratio. Narrow leaf lobes will be those having a ratio of $>10:1$. Normal leaf lobes exhibit a ratio of $<10:1$. Also used as a subdivision at this level is the early leaf edge as compared to normal or narrow leaves. Shoot colour or the colour of young leaves provides three categories: completely green shoots, brownish shoots, and purplish red or reddish green shoots. A minor fourth group is included based on variegated leaves.

The fourth morphological character used in the classification is petiole colour which is of three main types. Red petioles would be those completely red or with a greater proportion of red as compared to green. Slightly red petioles are largely green but with a distinct or faint tinge of red. Green petioles are without any trace of red.

The final grouping is made on the basis of the outer skin colour of the tuber which is of two major colours: light brown and dark brown (inclusive of reddish brown colouration).

Area Devoted to Cassava and Future Land Requirements

The actual area is difficult to estimate. According to statistics of the Ministry of Agriculture and Cooperatives about 20,000 ha are under cassava. Most of the crop is for starch and chip production. Multiple cropping is practised when cassava is planted as a food crop. The present area in Malaysia is expected to increase since some state governments and private concerns are setting up starch and chip factories.

Projects in Progress and Planned

The following projects are now underway:

MARDI, P.O. Box 208, Sungai Besi, Serdand, Selangor, Malaysia.

1 breeding and selection of varieties
2 cultural improvement of cassava production
3 identification of diseases and evaluation of their economic importance

Under the agronomy project (2) the following studies are being carried out: a) feasibility of planting longer stem-cuttings upright as a means of achieving early harvestability, high yield, and mechanical weed control effects of ridging vs. flat planting, and time of fertilizer application are incorporated in the study; b) effects of planting varieties side by side to find the best varietal combination for high yield of roots; c) feasibility of using oil palm branch waste for the mulching of cassava to achieve high yield through possible benefits of weed control, soil moisture retention, nutritive supply, etc; d) nutrient requirements of cassava in the field under continuous cropping. Diagnostic indicators such as changes in leaf nutrient levels and morphological characteristics are incorporated in the study.

Human and Financial Resources for Research and Extension

Beginning in 1975, in addition to the present full-time agronomist, MARDI has assigned a breeder and a plant pathologist to work full-time on the breeding and diseases of cassava. The local team is further strengthened by an IDRC scientist who, besides other duties, will work with the local team for four years looking into the physiological aspects of cassava. MARDI has also requested another overseas expert from the Tropical Products Institute in England to study storage problems and to devise practical methods to store roots. MARDI has plans to increase the local research staff to six within the next five years, to include an economist, an agronomist (or physiologist), and an engineer.

Important Diseases and Pests

Die-back of shoots and angular leaf spots, symptoms similar to those of cassava bacterial blight were observed on several cassava plantings in Serdang, Selangor. Bacteria isolated from these lesions are pathogenic and were identified as *Xanthomonas manihotis*. This disease was also observed on cassava plants of a large planting grown on newly cleared jungle land in Kota Tinggi area (about 200 miles south of Serdang). However, no die back was found on this plantation where more than 900 acres of cassava have since been planted.

Amongst the various leaf spot diseases recorded for cassava, those caused by *Cercospora* spp. appear to be most prevalent, the commonest being caused by *Cercospora henningsii*. A white leaf spot disease, similar to that caused by *Cercospora caribaea*, was widespread in the cassava plantation in Johore. However, its occurrence in Serdang is sporadic. There is no record of any extensive damage induced by these leaf spots.

White root disease caused by *Fomes lignosus* is found occasionally on cassava crops but does not cause extensive damage. It is more prevalent in areas previously planted with rubber (a known host of this disease). Cultural practices such as removal and burning of old rubber stumps would help in checking the spread of the disease.

Apart from the diseases considered above, others recorded on cassava include leaf spot (*Choanephora cucurbitarum*), red root disease (*Ganoderma pseudoferrum*), wilt (*Sclerotium rolfsii*), and root disease (*Sphaerostilbe repens*). Several minor leaf spot diseases caused by *Glomerella cingulata, Mycosphaerella manihotis, Periconia byssoides,* and *Pestalotiopsis* sp. have also been reported.

Pests are usually of minor importance. Common ones are red spider mites, beetles, scale insects, and white ants. In plantations, cassava is occasionally damaged by rats, wild pigs, and monkeys.

Quarantine Restrictions

Materials from South America and Africa An import permit must first be obtained from the Senior Plant Quarantine Officer giving details on the type of material, botanical name, whether cuttings, bulbs, or seeds, purpose, country of origin, quantity, method of sending, port of entry, date and time of arrival. The permit, if granted, will be subject to such conditions as certificate of health, pretreatment against pests and diseases, intermediate quarantine at a recognized institute (e.g. CMI or Royal Institute of Tropical Agriculture, Amsterdam), and also local quarantine before releasing for field planting.

Materials from countries other than South America and Africa An import permit is required from the Senior Plant Quarantine Officer who may in this case allow the materials to be imported without going through intermediate quarantine provided certain conditions are fulfilled, such as certificate of health, pretreatment against pests and diseases, and local quarantine before planting in the field.

Astolfo Fumagalli

Many varieties of cassava are cultivated in Guatemala and one variety often has many names, depending on the zone in which it is cultivated.

Cassava cropping is limited almost exclusively to the eastern and southern parts of the country. This satisfies the internal demand for food and industrial needs. Of the total production, 80% is made into starch and the remaining 20% is used for both human and animal food.

Despite the fact that there are two factories for the processing of cassava, it is still processed primarily by individuals and families.

Germ Plasm Collected

Research on available germ plasm is just beginning, and there is no improvement program for cassava.

The San Carlos University has 86 cultivars, most of which originated in Costa Rica, with a few from Brazil, Cuba, and Colombia.

Germ Plasm Evaluated and Characteristics Noted

Little research on germ plasm evaluation has been done, and there is little data on yields, production costs, and profitability.

In 1964, the School of Agronomics of San Carlos University introduced 80 cultivars from Costa Rica. Apparently this material has no advantage over local materials.

Area Devoted to Cassava and Future Land Requirements

There are approximately 2800 ha under cultivation with an average production of 19,000 metric tons and a yield of from 5000 to 20,000 kg/ha.

The eastern cassava-production area is characterized by low precipitation, thus limiting the productive capacity of the area, and lengthening the growing time to 18 months. The average yield is 11,676 kg/ha.

The southern area on the Pacific coast seems to be the best suited economically for increasing cassava for industrial purposes. Because of the favourable soil and climatic conditions this area has an average yield of 22,700 kg/ha.

The economic prospects for cassava seem good, mainly because of the growing demand for starch. The starch is extracted in very small rustic plants except for one large factory in the east. The demand for fresh cassava in urban markets is limited. Guatemala cannot meet the demands for cassava-derived products, and will only be able to compete through lower production costs and an increase in yields.

Projects in Progress and Planned

The Institute of Agricultural Science and Technology (ICTA) is planning a study with cassava as swine feed, using grains only for human food. Young agronomists for this program will be trained in CIAT.

Financial and Human Resources for Research and Extension

Almost without exception cassava is cultivated in small family plots (less than 1 ha). This causes an absence of order in the crop and an inadequate supply of raw material for industry. The techniques used in production vary from rudimentary methods to the adoption of improved cropping systems. There is no research or extension effort to increase cassava production in Guatemala.

Subgerente General, ICTA, Galerias Espana, 5o. Piso, Ave. 67 No. 11-59, Zona 9, Guatemala.

Important Diseases and Pests

Diseases and pests of importance are not reported. However, it is suspected that super-elongation, shoot fly, thrips, and spider mites are problems.

Quarantine Restrictions

Guatemala is presently participating in a quarantine program for the Central American area, Panama, and Mexico. This program prohibits the importation of vegetative parts of various plants. The quarantine measures are very strict, making importation of material difficult.

A.L. Carpena
D.P. Baldos

In the Philippines, most root crop varieties, particularly cassava, are characterized by low yield (national average is 5.6 tons/ha), low protein, and low starch content, mostly attributable to inferior genetic make-up.

Germ Plasm Collected

The germ plasm resources for cassava are limited, and very little morphological variation exists. In fact, most of the local collections closely resemble the widely cultivated "Balinghoy" variety. In developing for high-yielding varieties, our breeding program must therefore rely very heavily on foreign varieties from various international centres.

There is probably only one native variety of cassava in the Philippines. It is a sweet variety which we call "Balinghoy." This is the term used for cassava in the Tagalog region of the Philippines. Roots of this variety have from light to dark pink skin and white flesh (cortex). The plant is non-branching and grows to about 300 cm high. In a test we conducted this variety yielded only 23 tons/ha (65% of the yield obtained from Vassurinha, a well-known variety from Brazil), and gave only 17% starch (fresh weight basis).

Germ Plasm Evaluated and Characteristics Observed

There appear to be only three other cassava varieties in the Philippines (not including starch varieties grown in commercial plantations which imported their original materials), and they are not as widely grown as Balinghoy. One variety has leaves about the size of Balinghoy but slightly different in shape, with green stalks when young and green petioles (Davao City 1). Another variety looks like Balinghoy when young but it has a different stem colour when mature (Paste Collection). A third variety differs from the others in having yellow root flesh (Golden). The last two varieties were tested once for yield and other characteristics. In that test, the variety that looks like Balinghoy gave about the same yield of marketable roots as Balinghoy but slightly higher starch yield (21%). The first two varieties (both have white cortex) are probably also "native" varieties, but they are not as well liked as Balinghoy. Golden is definitely a newly introduced variety in the Philippines. Its origin is not known. In our collection there is one variety from Cambodia that looks very much like this variety.

Because of the limited germ plasm variability of cassava in the Philippines, we must depend on other countries for expansion of our varietal collection. Money for foreign travel is scarce, so the collection increases very slowly. We have not found it easy to obtain planting materials of cassava from other countries through correspondence. We now have 53 varieties in our collection including the four local varieties mentioned above and four varieties which seem to be duplicates of Balinghoy and Golden, including: Bogor, Vassourinha, Jurai, Hawaiian 4, Indonesian Acc. 15, Hawaiian 2, Ubi Puteh. We have sufficient morphological variation in our collection. The varieties vary in leaf size and shape, stem colour (both when mature and young), petiole colour, growth rate, etc. Most have a white cortex. We have not analyzed them for hydrocyanic acid content, but the results of analyses of some by other workers show more than 50% of our varieties are "bitter."

We tested only 26 varieties for yield and other characteristics. The highest yielding variety is (only one test made) Hawaiian 1, which gave 36 tons/ha (this is 1 ton higher than the yield obtained from Vassourinha). A variety from Indonesia had the highest starch content (27%, Indonesian 17).

Our foreign introductions include the starch variety grown in commercial cassava plantations in the Philippines (called Java Brown).

Philippine Council for Agricultural Research, Los Baños, Laguna, Philippines.

The brown in the variety name describes the colour of the sheet apex of this variety. It yielded only 19 tons/ha and had 19% starch in one test conducted at UPLB. Researchers at a commercial cassava plantation in southern Philippines claim that they can get as high as 28% starch from this variety.

Area Devoted to Cassava and Future Land Requirements

Approximately 80,000 ha are used for cassava in the Philippines. Usually it is intercropped under coconuts or with corn. Partly for this reason average yields are about 5 tons/ha, well below the world average, and total production exceeds 400,000 tons. Most is used for direct human consumption although there is considerable interest in using the crop for animal feed and as a source of industrial starch. A substantial potential for increasing production is therefore envisaged.

Human and Financial Resources for Research and Extension

Under the auspices of the Philippines Council for Agricultural Research the government has established a long-term program for root crop research in which a major emphasis is devoted to cassava. For the period 1974-76 the budget for this program is 5.1 m Philippine pesos. The program is now staffed with experienced personnel who only work in the program part-time. Proposals have been drawn up for a substantial training program from 1975 to 1980 which would provide a strong and broadly based commodity team. At present there are eight scientists (four at the doctorate and four at the master's level) working in root crop research. Two devote about half of their time to cassava and the others only between 10 and 15%.

The Philippines Council for Agricultural Research proposals for expansion of the root crop program on a long-term basis are currently under study, and include a 7-year funding projection of almost 10 m Philippine pesos.

Important Diseases and Pests

The Philippines has no serious disease problems with cassava, as determined by surveys conducted in 1974 by plant pathologists and entomologists at UPLB. The most common disease observed was *Cercospora* leaf spot; the damage caused was negligible. Rust was also encountered. Spider mites is the major pest, but is still considered minor.

Quarantine Restrictions

Quarantine regulations are not clearly defined. In the past, the regulations were very lax but this is likely to change in the future.

Fernando R. Paz Briz

Cassava has been traditionally grown for human food in Ecuador, primarily by coastal farmers. They usually plant 1-7 ha, using traditional methods.

Germ Plasm Collected

Initially, four cultivars were selected and collected for cropping in the Santo Domingo de los Colorados area. These cultivars were named CADE 1, 2, 3, and 4.

At the request of CIAT, the Pichilingue Experimental Station of the National Institution of Agricultural Research (INIAP) gathered cuttings of the most common cultivars all along Ecuador. The total collection was 193 cultivars. Unfortunately, INIAP has shown little interest in cassava, thereby making it impossible to obtain precise information.

The germ plasm collected so far in Ecuador has not been maintained in adequate condition.

Germ Plasm Evaluated and Characteristics Noted

Cultivars CADE 1, 2, 3, and 4 were evaluated primarily on the basis of their productive capacity; the botanical characterization and a simple agronomic evaluation were also determined.

Five cultivars from INIAP's Pichilingue Experimental Station were studied and the industrial value and agronomic characteristics were evaluated.

Area Devoted to Cassava and Future Land Requirements

According to information obtained from the Ministry of Agriculture, in 1973 there were approximately 52,000 ha planted in cassava, producing 502,000 metric tons and an apparent yield of only 9.4 metric tons/ha. The low-density sowing (1500-3500 plants/ha) was done in a 98% multiple-cropping area. As a single-crop the yield was 20-25 metric tons/ha. It is the eighth most important crop nationally in terms of value. Future land requirements will depend on the market for cassava.

Projects in Progress and Planned

We now have a joint CIAT/INIAP agro-economic study on production costs and losses, and germ plasm is now being maintained by INIAP. We are planning a national program for bananas, tropical fruits, and crops diversification, as well as a program for agricultural diversification through the Ministry of Agriculture.

Human and Financial Resources for Research and Extension

At the moment there is no government aid, and funds come from Agricola Industrial del Litoral, S.A. (AGRIL S.A.), a private company interested in promoting cassava cropping for industrial purposes, principally as a fermentation substitute. This firm has one project engineer and an engineer for cultivation promotion.

Important Diseases and Pests

The important diseases of Ecuador include: white leaf Spot (*Cercospora caribaea*), root rots (*Rosellinia bunodes*), brown leaf Spot (*Cercospora henningsii*), and cassava bacterium blight. Pests include: shoot fly (*Silba pendula*), horn worm (*Erinnys ello*), and stem borers (*Coleosternus* sp.)

Quarantine Restrictions

There are no restrictions for the entry of germ plasm into Ecuador. Because it is possible to import any type of vegetative material, we risk serious damage to our agricultural economy.

Cervezas Nacionales Cia. Anonima, Casilla 519, Guayaquil, Ecuador.

Banjerd Boonsue[1]
Sophon Sinthuprama[2]

Cassava is presently Thailand's fourth major export crop, next to rice, maize, and para rubber. More than 90% of the cassava, or about 2.5 million tons, is exported, mostly to European markets. Most Thai farmers grow cassava soley as a cash crop rather than for home consumption. The fresh roots are normally sold directly to local factories for processing into flours, chips, pellets, etc., for foreign markets.

Germ Plasm Collected

Cassava production goes back to the 18th century. The first cultivar was a "sweet type" known as a "five-minute" cassava, for its cooking time. The bitter varieties, believed to be brought in through Malaysia, were first cultivated as intercrops in young rubber plantations in the south, and later scattered throughout the country. The current well-adapted local varieties may be natural derivatives, if not direct types from this material.

Little research concerning germ plasm improvement and varietal selection has been done in the past, probably because existing cultivars have little or no serious agronomic problems. However, evidence indicates that many cassava strains and varieties, including some material from CIAT, have already been introduced into the country:

Year	No. of introductions	Source
?	?	Malaysia
1937	9	Java
	5	Mauritius
	3	Malaysia
	1	Unknown
1963	7(5)*	Java
1965	44(21)	Virgin Islands
1970	5(5)	Colombia

*Figures in parentheses denote number of varieties still available.

Germ Plasm Evaluated and Characteristics Noted

Unfortunately, not much information on performance is available. The Department of Agriculture recently screened some of the newly introduced material in replicated yield trials at Huai Pong Station. The testing results showed that most available material in the above table (excluding Colombian material) was inferior in root yield to the local varieties. A few were about equal to the standard varieties (Table 1). From these findings, the local varieties are still recommended for commercial production in all cassava planting regions.

Area Devoted to Cassava and Future Land Requirements

The major production areas are concentrated within a 300-km radius of Bangkok where central shipping facilities are located. Various organized systems among farmers, handlers, transporters, processors, wholesalers, and retailers have developed over many years. Thus, most farmers have little or no problem in selling the fresh roots in their own fields right after harvesting.

Because of steadily increasing demands for cassava products in the world markets, Thai root production in 1973 was double that of 1969 (i.e. it rose from 3.1 to 6.4 million tons). It should be noted that the increased quantities were obtained directly from the expansion of growing areas (which increased from 191,000 to 423,000 ha from 1969 to 1973) rather than from any yield increase per unit of land. Most of the new cassava production areas were in the northeast region. The fairly constant country average yield of 15 tons/ha is rather low com-

[1] Dean, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.

[2] Head, Root Crop Section, Dept. of Agriculture, Ministry of Agriculture and Cooperatives, Bangkok, Thailand.

TABLE 1. Average root yields of cassava varieties at Huai Pong Field Crop Station.

Varieties introduced	Harvest age	Best yield	Lowest yield	Yield of local variety
	(months)		*(tons/ha)*	
5 Java (1966-68)	10	17.4	11.3	17.5
7 Virgin Island (1969)	12	24.6	19.8	29.2

pared to the potential yield of more than 50 tons/ha at CIAT (Cock 1974).

The recent rapid expansion of cassava acreage into other upland crop areas is of special concern to the government. The main objections are a fear of soil depletion, pollution from factories processing wastes in the new areas, and over-production. The government has just restricted production expansion to certain zones where suitable soil types and processing facilities already exist. The assigned zones are Cholburi, Rayong, Prachinburi, Chachoengsao, Nakornrajsima, and Chaiphum.

This policy is designed to increase production within the specified areas by using improved varieties are unimproved material, whose genetic base is believed to be narrow and whose maximum yield is around 30 tons/ha under high fertility and good management.

Projects in Progress and Planned

The main attributes limiting the production per unit area are as follows:

The use of unimproved varieties All local varieties are unimproved material, whose genetic base is believed to be narrow and whose maximum yield is around 30 tons/ha under high fertility and good management.

Low fertility in major cultivated areas and no fertilizer supplement It is generally claimed that cassava is a soil-depleting crop. Little research has been done to prove this although some evidence indicates that root yields were reduced about 30% when cassava was planted repeatedly for 7 years on the same soil without any fertilizer. This phenomenon is probably associated with low average yield in Cholburi and Rayong which represent the largest and oldest cassava production regions. Soil erosion is probably another factor which accounts for low fertility in the sandy soils of these areas.

Fertilizer is not commonly used, although research evidence from Huai Pong Station has shown that yields of the local cassava varieties could be increased economically by adding 625 kg/ha of 8-8-4 fertilizers. However it is doubtful whether such practice is economical today because of the recent rise in fertilizer prices.

Poor agronomic practices Many farmers in the old production region, particularly Cholburi, do have some experience in good cultural methods (e.g. deep ploughing by tractors, ridge-planting in wet areas, proper weeding, and use of fertilizer). But in more remote areas primitive management is still practiced. The most common scene in these areas is the unhealthy plants in unweeded fields. Premature harvesting is practiced in times of emergency by many farmers.

Human and Financial Resources for Research and Extension

The Department of Agriculture has been for some years conducting agronomic research on population density, planting methods, fertility trials, proper time and methods for harvest, etc., at Huai Pong Station. However, many research results have not yet been implemented in commercial production fields.

With the exception of the agronomic program at Huai Pong Station cassava has received very little research input in Thailand. In 1974 plans were made for three members of the Kasetsart University agriculture faculty to spend one year training at CIAT, for the Agricultural Economics Department of the Ministry of Agriculture to conduct an agro-economic survey of cassava, for the Animal Science Department of Khon Kaen University to carry out nutritional trials relating processed cassava quality to its value, and for the Asian Institute of Technology to conduct research on pelleting quality.

Important Diseases and Pests

No survey of diseases and pests of cassava has been carried out in Thailand. The country appears to be remarkably free of major diseases. Mosaic is unknown and CBB, if present, is not a major cause of losses.

Quarantine Restrictions

In the past there have been very few restrictions on importation. Recently imports from India and Africa have been restricted as a safeguard against the introduction of common mosaic.

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Carlos Arias

Germ Plasm Collected

The collection of cultivars, the majority of which are Venezuelan with little foreign influence, are distributed as follows:

School of Agronomics Central University of Venezuela	Approx. 350
National Center of Agricultural Research (CENIAP), Maracay, (Ministry of Agriculture and Breeding):	60
Eastern University	30
Venezuelan Corporation of Guayana	unknown

Germ Plasm Evaluated and Characteristics Noted

All of the above-mentioned cultivars have been evaluated for yield, dry matter content, precocity and postharvest deterioration. Other evaluations included: type of growth, presence of flower and fruits, effects of drought (defoliation), and characteristics of the roots.

The 60 CENIAP cultivars have been evaluated for plant and root characteristics, type of growth, presence of flowers and fruits, resistance to pests and diseases, drought resistance, yield, density and approximate starch content, and resistance to postharvest deterioration.

Programa de Raices y Tuberculos, CENIAP, Ministerio de Agricultura y Cria, Maracay, Venezuela.

Area Devoted to Cassava and Future Land Requirements

The western region of Venezuela has a total of 8300 ha under cassava, most of which follows the multiple-cropping system.

In the eastern region increased interest in cassava has resulted in 30,000 ha of savanna soils under the crop. This region offers the best possibilities for the development of cassava making research in agronomic methods necessary.

Projects in Progress and Planned

The program on cassava research presented to the Ministry of Agriculture and Breeding for consideration, recommends: varieties (national collections), seeds (insecticides and fungicides), weed control, fertilization, drying, postharvest losses, mechanization, utilization of foliage, resistance to pests and diseases, and genetic improvement.

The following projects are now in progress: collecting and evaluating cassava cultivars (CENIAP), chemical weed control for cassava, agronomic methods, and census of diseases and damages in roots and tubers.

CENIAP's 1975 program includes: determination of the optimal density of seeding for each of the available cultivars; determination of the best sowing time, using supplementary irrigation when necessary; experiment on foliage production for animal feed, seeding methods, and management of the plots; research on natural drying of roots for the production of outer rind products (raspa); research on management of crop and roots to prevent postharvest deterioration; experiments over different ways to manage planting material to increase its yield; production of disease-free plants with the idea of initiating regional seed plots; increase of the existing seed plots; and initiation of work on genetic improvement.

Financial and Human Resources for Research and Extension

In Venezuela, research on cassava is being carried out at the: 1) National Center of Agricultural Research (CENIAP), Maracay (Ministry of Agriculture and Breeding); 2) Central University of Venezuela; 3) University of Zulia; 4) Eastern University; and 5) Venezuela Corporation of Guayana, through the Foundation Service for the Farmer.

Information on the number of specialized personnel working in these institutions is not available at this time.

Important Diseases and Pests

Only those diseases that have occurred in the culture *introduction nursery* under natural conditions have been evaluated. The most important are: Cassava bacterial blight, Brazilian common mosaic virus, vein mosaic, superelongation, brown leaf spots (*Cercospora henningsii*), white leaf spot (*Cercospora caribaea*), *Cercospora viscosae*, Mycoplasma, and Anthracnose (*Glomerella manihotis*).

Quarantine Restrictions

An official certificate from the country of origin is required to import vegetative material, certifying that the material is free of pests and diseases harmful to agriculture. This certificate must be notarized by the Venezuela Consulate in the country of origin. Also required is an import authorization from the Division of Vegetal Sanitation in the Ministry of Agriculture and Breeding.

N. Hrishi

For many years in Kerala, India's most densely populated state, cassava has provided a much needed supplement to the rice diet. Cassava is used mostly by the poorer people, but it is also beginning to assume greater importance in the diets of the more affluent. Cassava is also an important food crop in the states of Tamil Nadu, Andhra Pradesh, Karnataka, hilly regions of Assam, and other hilly states of Northeastern India.

Cassava chips are sometimes fed to cattle. Spent pulp from starch factories is being fed to pigs and is also included in cattle and poultry feeds.

Cassava is also used as a basic raw material in the manufacture of paper, soap, plywood, acetone, glues, glycerol, glucose, dextrose, dextrin, etc. India is trying to increase production through intensive cultivation, to allow the country to enter the world market for both processed and unprocessed cassava.

Germ Plasm Collected

Cassava germ plasm (exotic types).

Source	No. of varieties	Mosaic resistant
Malaysia	5	-
Thailand	1	1
Fiji	10	1
Brazil	1	-
Colombia	1	-
Tananarive	10	5
Senegal	4	-
Madagascar	120	36
Uganda	14	11
Gabon	5	3
Ghana	74	23
Sri Lanka	6	1
Indigenous collections	1472	300
Total	1723	381

Central Tuber Crops Research Institute, Trivandrum 10, Kerala, India.

Germ Plasm Evaluated and Characteristics Observed

Table 1 shows that about 88% of the material is affected by common cassava mosaic, thereby limiting the use of these stocks in the hybridization program. Mosaic resistance has, to date, been the main criterion for germ plasm evaluation. Varieties are also evaluated for taste, starch content, yield, earliness, and plant type.

Though some of these genotypes possess excellent qualities, only a few can be used in our breeding programs because of their susceptibility to mosaic; a notable example is Kalikalan, which is known for its early maturity and good cooking quality. Therefore obtaining these genotypes helps enrich our germ plasm from exotic sources. Most of the indigenous genotypes showing variability in agronomic characters probably developed through manipulation of genes by frequent human selection.

Selections 300, 2371, 2335, 2398 and 2317 are superior types and are being further evaluated in regional trials.

Area Devoted to Cassava and Future Land Requirements

Of the 6.2 million tons of cassava produced in 1974, 5.6 million came from Kerala, 570,000 from Tamil Nadu, and 13,600 from Andhra Pradesh. Because of the adaptability of cassava in different agroclimatic regions, the country has been divided into eight zones for tuber crops, five of which are suitable for extensive cassava production, especially on marginal lands: (1) the west coast region (heavy rainfall and humid region as rain-fed crop); (2) east coast region (mostly deltaic and sandy soils, irrigated); (3) deccan plateau region (semi-arid, alkaline soils, irrigated); (4) central region (semi-arid, intertropical, red laterite to alkaline soils, irrigated); and (5) northeastern hilly regions (rainfed).

Projects in Progress and Planned

Breeding programs have been set up to meet the following goals: 1) to develop varieties suitable for human consumption, i.e. having a reasonable amount of starch, low HCN, good cooking quality, good palatability, and a high protein content; 2) to develop varieties for industrial purposes, i.e. having a high starch recovery, thin white rind, and low protein.

Other objectives of the program are to breed varieties that will 1) grow under drought conditions, especially in semi-arid zones; 2) resists alkaline and saline soil conditions; 3) tolerate shade, especially for mixed-cropping systems where cassava forms an intercrop with coconuts, bananas, etc.; and 4) resist mosaic disease.

Breeding procedures include introduction and evaluation, selection, a diallel crossing program, back-crossing, mutation breeding, and heterosis breeding.

Through heterosis breeding, three high-yielding hybrids have been evaluated and released to farmers for commercial cultivation. They are H-97 (high starch recovery, 31%), H-165 (early maturing type), and H-226 (good eating qualities).

Two other hybrids, H-1687 and H-2304 are being tested because they show significantly higher tuber yields (33.7 and 37.1 tons/ha) than the control (M-4 21.9 tons/ha).

The varieties generally flower during September-November when crosses are made. We have encountered a lack of flowering in some of the desirable genotypes, a limiting factor in the crossing program. However, flowering can be induced by application of growth regulators like IAA and NAA. Branching of the cassava stem is a precondition for flowering.

Several of the prerelease hybrids are being tested yearly under different fertility levels to select varieties responding to low, medium, and high fertility conditions. Among organic sources, poultry litter was more effective than cattle manure, and the application of poultry litter in a 2/3 dose in combination with 1/3 dose as an inorganic source of N was more effective (2.3 tons/ha) than application of full dose of N (100 kg/ha) from an organic source alone (21 tons/ha). The combination of 120 kg N and 120 g K recorded the highest yield (22 tons/ha). Foliar spray of either N, P, or K was ineffective.

No serious attempt has been made so far to study the transmission of mosaic, except to check varieties for tolerance by the graft technique. Treatments of sets with a mixture of steam and hot air for 30 min at 40, 45, 50, and 55 C did not show any effect, as treated as well as untreated sets gave rise to only diseased plants. More intensive work is planned because most of the good local varieties are affected with this malady, which probably reduces the yield by 35%.

The program includes: 1) identification of mosaic-resistant clones from the germ plasm; 2) breeding of mosaic-resistant varieties; 3) transference of resistant genes from *M. glaziovii;* 4) disease transmission studies; and 5) formulation of control measures.

In addition, effective quarantine measures will be developed, especially for materials brought into the country.

We still encounter many bottlenecks in transferring the new technology to the farmer's field, especially the small holdings. The new knowledge must be tested and the reaction of the farmer must be studied. This will serve as a feedback mechanism for corrections or modifications. Therefore, an operational research program, which was held up due to lack of manpower and funds, is planned. Socio-agro-economic surveys will be made to evaluate the present cropping systems, involving cassava as a single or mixed crop, before the production research programs are introduced to the farmer.

Human and Financial Resources for Research and Extension

The current annual budget of the Central Tuber Crop Research Institute is 1.5 million rupees (Cdn.$200,000). The 5th National Plan calls for a substantial expansion in funds for root crop research.

Genetic upgrading of the cassava materials, improvements in postharvest technology, utilization, and intensive training programs are envisaged. The first training program will aim to increase the competence of the CTCRI senior scientists by studying methods used in CIAT and IITA. The second would provide research fellows to support the programs. The establishment of an agricultural polytechnic school is expected to allow us to train state-level extension workers (i.e. to train trainers), and small farmers on new production systems.

Important Diseases and Pests

Mosaic is the most important disease and it is estimated that this reduces yields by 35%. Other important pests and diseases are red spider mite and leaf spot produced by *C. henningsii.*

Quarantine Restrictions

All imported material must have a permit from the National Bureau of Plant Introduction and pass through a quarantine station. It is proposed to establish a CTCRI quarantine station specifically for cassava, in a non-producing area.

Antonio José de Conceicao

Cassava has grown in Brazil since early times, and is one of the most characteristic and generalized food crops in the country's economy. Production in 1970 was about 29.5 million metric tons. The northeast part of Brazil produces the most cassava.

Germ Plasm Collected

The basic genetic material of Brazil includes 1059 cultivars, distributed as follows:

School of Agronomics of the UFBA	219
EMBRAPA — IPEAL — Cruz das Almas, BSA	213
EMBRAPA — SUDAP — IPEAL — SE	90
EMBRAPA — Urussanga Experimental Station	57
EMBRAPA — IPEACS — Linhares Experimental Station — ES	99
EMBRAPA — IPEANE — SEDE — PE	71
ENCAPA — ES	48
Agricultural College of Jandaira — RN	20
DEMA — GEPU — Agricultural Office 'Gloria de Goita' — PE	12
Lavras Experimental Station — NG	10
Zoobotanical Foundation — Brasilia — DF	7
CEPLAC — Gregorio Bondar Experimental Station — BA	190
Agricultural School of Higher Learning of the UFPE	23
Total	1059

Germ Plasm Evaluated and Characteristics Noted

In the northeast, early maturity and bitter varieties are preferred.

Area Devoted to Cassava and Future Land Requirements

Brazil is the world's largest producer of cassava. There are about 2 million ha under the crop and total annual production is about 30 million tons, 85% of which is used for human food, often after processing. In the rural areas where cassava is grown per capita consumption averages about 100 kg annually. The scope for expansion in production is considerable. It is estimated that 1 million km^2 are suitable for cassava production in Brazil.

Projects in Progress and Planned

With the establishment of the Brazilian University Reform, the School of Agronomics of the Federal University of the State of Bahia in Cruz das Almas started in April 1969 the largest cassava research program ever developed in Brazil. The Priority Project I on Cassava includes: genetic improvement, pests and diseases, soils and fertilization, climatic influence, irrigation, cropping techniques, agricultural mechanization, animal nutrition, chemistry and technology, socioeconomic aspects, and popularization.

Following is a list of states and institutions where cassava research is being carried out and the specific studies being made:

1) *PARA (PA):*
   EMBRAPA (PIEAN) genetic improvement; tests for sowing times; influence of soil humus in field yields; proportioning of bovine manure in dry soils; formulation of rations for animals and selection of preparation processes; chemical control of weeds.
2) *MARANHÃO (MA):*
   EMBRAPA (in Don Pedro): Improvement and phytotechnology
   Secretariat of Agriculture, DEPE: Improvement and phytotechnology
3) *CEARA (CE):*
   CSA: Germ plasm bank and comparison of varieties

Universidad Federal da Bahia, Convenio UFBA/Brascan Nordeste, Escola Agronomica, Cruz das Almas, Brazil.

4) *RIO GRANDE DO NORTE (RN)*:
Agricultural School of Higher Learning — Mossoró: Improvement and phytotechnology
Secretariat of Agriculture: Fertilization

5) *PARAÍBA (PB)*:
SUDENE: Fertility
Secretariat of Agriculture: Fertilization

6) *PERNAMBUCO (PE)*:
EMBRAPA (IPEANE): Improvement and phytosanitation
Secretariat of Agriculture — IPA (in Vitória de Santo Antão): improvement and phytotechnology; (in Araripina) fertilization.

7) *SERGIPE* (SE):
EMBRAPA (IPEAL): Comparison of varieties.

8) *BAHÍA (BA)*
Agreement UFBA/Brascan Nordeste en la EAUFBA: Priority project on cassava
SUDENE: Fertilization
EMBRAPA (IPEAL): Improvement, fertilization

9) *ESPÍRITO SANTO (ES)*:
ENCAPA: Spacing tests, seeding times, and comparison of varieties.

10) *GUANABARA (BG)*
CTAA: Chemical-technological study of cassava and its products.

11) *MINAS GERAIS (MG)*
EMBRAPA (IPEACO): Genetic improvement and phytotechnology.

12) *SAO PAULO (SP)*:
K.A. Campinas: intensive genetic improvement; study of clones and crops for food, forage and industry; (in cooperation with ITAL) studies on the variation of the plant's chemical composition; HCN content; sensory analysis of the roots of new clones.

13) *RIO GRANDE DO SUL (RS)*
Secretariat of Agriculture: Improvement and phytotechnology.

Future projects include the establishment of the National Center for Cassava. The preliminary project for this centre has been developed by EMBRAPA (Brazilian Agricultural Research Company).

The Brascan Nordeste and the School of Agronomics of the Federal University of Bahía have requested financial and planning assistance for the Integrated Project on Cassava Research in the Northeast (PROMADE).

Human and Financial Resources for Research and Extension

In 1972 the UFB/Brascan Nordeste Agreement supported additional researchers for the Priority Project I on Cassava, which now has 16 specialists, many of whom have six or more years of cassava research experience. The Project has 20 full-time researchers, seven of whom participated in the August 1974 Post Graduate Specialization Course for Researchers on Cassava sponsored by CIAT.

Important Diseases and Pests

There is no information available on the economic losses caused by diseases of cassava. The diseases include: cassava bacterium blight (*Xanthomas manihotis* — the most important and the one which inflicts heaviest losses); brown leaf spot (*Cercospora henningsii*); white leaf spot (*C. caribaea*); *Cercospora viscosae*; leaf spots (*Phyllosticta* sp.); cassava rust (*Uromyces manihotis*); cassava ash disease (*Oidium* sp.); anthracnose (*Glomerella manihotis*); root rots (*Rosellinia bunodes, Phytophra drechsleri, Sclerotium rolfsii, Rhizopus nigricans*).

Quarantine Restrictions

All plants entering the country are checked for general condition, and vegetal material (shoots or stalks for planting) is put under necessary quarantine to prevent the introduction of diseases and pests which might harm established Brazilian crops.

Promising new cultivars of cassava need to be tested under a wide range of ecological conditions. Here we see one of the 14 sites used by CIAT in their Colombian Regional Trials to establish the adaptability of cultivars on trial.

Cassava Germ Plasm Resources, Disease Incidence, and Phytosanitary Constraints at IITA, Nigeria

E. Terry

Germ Plasm Collection

The IITA cassava germ plasm collection includes cultivars assembled from Africa, Latin America, and Asia. The variation within the germ plasm of *Manihot esculenta* and the few related species assembled is only a fraction of the total natural global variation within the genus.

The collection is being evaluated for desirable agronomic and botanical characteristics on the basis of both phenotypic and genotypic variation. The evaluation is being carried out under wide-ranging environmental conditions to test for genotype/environment interactions.

The following points should be considered:

1) Global germ plasm collection should be made only in true seed form; 2) Germ plasm in vegetative form should be assembled on a regional basis to overcome regional phytosanitary constraints; 3) A methodology for evaluation of germ plasm should be developed; 4) Germ plasm should be indexed after evaluation, and the information should be made available to cassava researchers; 5) Vegetative and seed material from germ plasm collections should be distributed as planting or breeding material; and 6) A machinery should be set up for the registration of germ plasm and breeding materials.

Cassava Diseases in Africa

A summary of the global distribution of the virus and virus-like diseases of cassava is presented in Table 1. Only two of these (CMD and CBSV) have been reported in Africa but not in America. Four of these diseases, however, have been reported only in America. All six have a high risk potential for in-

TABLE 1. Virus and virus-like diseases of *Manihot esculenta*.

Disease	Causal agent	Distribution in Africa	Distribution in other continents	Risk potential for introduction	Control
CMD	?	All cassava-growing areas	Asia	High	Resistant DFPM
CCMV	Virus	N.R.	America	High	"
CBSV	Virus	East Africa	N.R.	High	"
CVMV	Virus	N.R.	America	High	"
CLV	Virus	N.R.	America	High	"
CSD	Mycoplasma-like	N.R.	America	High	"

CMD Cassava Mosaic Disease
CBSV - Cassava Brown Streak Virus
CLV Cassava Latent Virus
N.R. — Not Reported
CCMV Cassava Common Mosaic Virus
CVMV - Cassava View-Mosaic Virus
CSD Cassava "Superbrotamento" Disease
DFPM Disease-Free Planting Material

Root and Tuber Improvement Program, International Institute for Tropical Agriculture, Ibadan, Nigeria.

troduction into areas in which they are presumed presently absent. As indicated in Table 2, the only economically important bacterial disease of cassava with a high risk potential for introduction is cassava bacterial blight. The disease is presently of limited distribution in Africa. Two fungus diseases, cassava ash and cassava rust are likely to have a high risk potential for introduction into West Africa (Table 3).

TABLE 2. Bacterial diseases of *Manihot esculenta.*

Disease	Causal agent	Distribution in Africa	Distribution in other continents	Risk potential for introduction	Control
CBB (LS, LW)	*Xanthomonas manihotis*	Nigeria Zaire Cameroun	America Indonesia	High	Resistance
Bacteriosis (LS)	*Bacterium cassavae*	Uganda Congo Rwanda	N.R.	?	?
Bacteriosis (LS)	*Xanthomonas cassavae*	Malawi	N.R.	?	?
Bacteriosis	*Bacterium robici*	Madagascar	N.R.	?	?
CBW (LW)	*Pseudomonas solanacearum*	N.R.	Brazil	?	?

CBB Cassava Bacterial Blight
CBW Cassava Bacterial Wilt
LS - Leaf Spotting
LW - Leaf Wilt
N.R. -- Not Reported

TABLE 3. Fungus diseases of *Manihot esculenta.*

Disease	Causal agent	Distribution in Africa	Distribution in other continents	Risk potential for introduction	Control
Cercospora leaf spots	*C. henningsii* *C. caribaea*	All cassava-growing areas	Asia America	None	Resistance
Phyllosticta leaf spots	*Phyllosticta* spp.	All cassava-growing areas	Asia America	None	Resistance
Cassava ash	*Oidium manihotis*	East Africa(?)	Asia America	?	Resistance
Anthracnose	*Glomerella manihotis*	All cassava-growing areas	America	None	?
Rust	*Uromyces* spp.	East Africa(?)	America	?	?
Stem rots	*Glomerella cingulata* *Botryodiplodia theobaomae*	All cassava-growing areas	America	None	?
Root rots	*Phytophthora* spp.	Congo	America	None	?
	Rossellina necatrix	Congo	America	None	?
	Sclerotium rolfsii	?	America	None	
	Fomes lignosus	All cassava-growing areas	America	None	

Phytosanitary Constraints

The Inter-African Phytosanitary regulations regarding cassava are as follows: Quarantine in a station approved by the IAPSC is essential for cassava cuttings. A permit is required specifying the need for a general phytosanitary certificate, with special certificate for active growth inspection at the place of cultivation in quarantine. There are, however, no restrictions on importing seeds.

A further set of regulations (The Plant Protection [Importation] Order) governs importation of *Manihot* species into East Africa. The regulation states that importation of all parts, including cut flowers and foliage, but excepting vegetative propagating material, roots for consumption, and true seeds is prohibited from all countries.

Due to the widespread incidence of cassava bacterial blight disease in Zaïre, Nigeria, and Cameroun, and the recent report of an outbreak of the green mite *Mononychellus tanajoa* in Uganda, importation permits for cassava cuttings are no longer routinely issued by the East and West African Regional Quarantine Stations at Muguga (Kenya) and Ibadan (Nigeria) respectively.

Cassava International Testing Program

The acquisition, evaluation, and utilization of superior material is of vital importance in cassava improvement. The idea, therefore, of an International Cassava Testing Program is most welcome. The following points should be considered in the establishment of such a program: 1) The objectives must be clearly defined; 2) The advantages to be derived from the proposed program by National Cassava Programs be clearly stated; 3) Uniform sets of materials must be tested to determine response to different environments; 4) Testing programs with vegetative material should be organized on a regional basis; 5) National Cassava Programs should cooperate with international institutes for the selection of families and clones of cassava for their particular needs; and 6) The strong evidence of genotype/environment interaction already documented must be seriously considered in setting up testing programs.

Danger of Dissemination of Diseases and Pests Through the Introduction of Material for the Propagation of Cassava

J. C. Lozano and A. van Schoonhoven

PLANT pathogens and pests, which adapt readily to new hosts, always show an extraordinary ability to spread rapidly to new areas, creating a serious threat to the host crops and to other crops in the area.

Thurston (1973) states that for a disease to constitute a serious threat it must be able to spread rapidly, cause considerable losses, and be difficult to control. The same criteria could also apply to insects and mites. To achieve such an evaluation, however, extensive studies on phytopathogens and pests are needed. To determine the spreading capacity of a plant pathogen or a pest would require basic studies of the etiology and epidemiology of the pathogen or the biology of the insect or the mite. A true evaluation of economic losses is very difficult to determine, and would depend on climatic or edaphic interactions in the region in question and/or on the genetic characteristics of the host. The methodology for controlling diseases, insects, or mites is known in some cases, but its effectiveness is not always certain. Also, the application of a known methodology can be uneconomic, because lack of experience in its application, or the conditions of the particular area. These problems cause controversies about the effectiveness of using the same methodology in other areas.

Vegetative material is used almost exclusively for the propagation of cassava, except by geneticists, who use true seed. The exchange of vegetative material encourages the dissemination of pathogens, insects, and mites that attack the crop. This is due to interchanges of propagation material between farmers in the same or different regions, between institutions interested in obtaining new cultivars with better characteristics, or between institutions or governments interested in introducing or increasing cultivation of crops with promising characteristics. In the last few years the cultivation of Cassava has increased in many countries (Thailand, Malaysia, Zaïre, etc.), mainly through the mass movement of propagation material. Unfortunately, most of the introductions of cassava vegetative material have been made without following quarantine restrictions, primarily due to an underestimation of the importance of such measures and, probably more important, by the lack of studies relating to the importance of diseases and insects in the cultivation of cassava.

Many publications have incorrectly claimed that cassava is relatively immune to pests and diseases.

Nevertheless, it is known that cassava is affected by more than 25 pathogenic agents (bacteria, fungi, mycoplasms, viruses, and others), more than 15 species of insects, and 6 species of mites. In some cases these cause considerable losses and, at times, represent a potential danger to the crop.

The most important causal pathogenic agents in cassava, for example those which cause cassava bacterial blight and African mosaic disease, are vascular pathogens that disseminate through the use of infected stakes used for the propagation of the crop (Lozano 1972; Lozano and Booth 1974). The causal agent of the cassava bacterial blight systematically invades the host xylem by penetrating the stomatal openings. Because the causal agent does not degrade the mature tissue of the stalk (Lozano and Sequeira 1974 a, b), and the severity of the attack is related to the environmental humidity and to the soil (Lozano and Sequeira 1974b; CIAT 1974), its presence in the stalk is hidden in the most lignified parts. These are the parts used for propagation. The severity of the disease is also considerably reduced during the dry periods of the year. These conditions make it impossible to visually select healthy propaga-

Centro Internacional de Agricultura Tropical, Apartado Aéreo 67-13, Cali, Colombia.

tion material from an afflicted plantation. Since the causal agent can be disseminated readily by splashing rain, infested tools (Lozano and Sequeira 1974b), insect-infested soil and vegetative material (CIAT 1973, 1974), the dispersion in a plantation from a few infected stakes can occur very fast, causing economic losses of more than 50% (CIAT 1973). If we consider that 1) cassava originates from tropical America, 2) that the pathogen is specific to the *Manihot* species (Lozano and Booth 1974), and 3) that the biochemical, physiological, and serological studies (CIAT 1973, 1974) have shown great similarities between American, African, and Asiatic isolations, we can conclude that this pathogen also originated in America. And so, the bacteria have been introduced into Asia and Africa by the importation of infected propagation material. The pathogen may have been spread to various areas in the same country or state in the same way. Such is the case of CIAT, where in 1971-72 the disease appeared in 87% of the cultivars in the collection (CIAT 1973).

The extraordinary severity, disseminating capacity, and lack of effective control make the African mosaic disease of cassava one of the most serious diseases of the crop in that continent. Its introduction into America represents a serious threat to all cassava-producing areas. At this time, this potential threat is one of the most serious for cassava cultivation since: 1) the disease is spread by *Bemisia* (white flies), one species of which has been identified in America (CIAT 1974); 2) all stakes from diseased plants reproduce diseased plants; and 3) the causal agent is unknown. Also, there is no way of determining the health of any vegetative tissue of cassava. Therefore the introduction of any vegetative material of cassava from Africa or Asia into cassava-producing areas of America is highly risky. Although all the consequences are unknown and unforeseeable, the disease can reduce production by 20-90%.

In general, all viruses and mycoplasms of cassava invade the vascular system (Lozano 1972; Lozano and Booth 1974) and are disseminated mainly by diseased vegetative material. Although they have no present economic significance, their introduction into new areas represents a serious risk. Possibly vectors, hosts, or favourable environmental conditions prevailing in such areas would promote the development of these diseases, again with unknown consequences. The brown streak virus, although restricted only to the west coast of Africa (Lozano 1972; Lozano and Booth 1974), is another disease of that continent which could be introduced into America by importing vegetative material.

Little is known about the dissemination of fungal pathogenic agents of cassava through infected stakes, with the exception of the causal agent of superelongation. This pathogen, which invades the cortical and epidermal tissues, produces spores in epidermal cankers capable of maintaining enough inoculum for secondary infections. By using infected stakes (with cankers) for propagation, the spores in those cankers can serve as sources of inoculum and initiate primary reinfections in a plantation. Because our preliminary results suggest significant longevity for its spores (Krausz and Lozano unpublished data), the dissemination of the pathogen into distant areas after prolonged periods of time seems very probable.

The spores of other fungal organisms, especially those that attack the stalk (*Glomerella, Fusarium,* and *Sclerotium* sp., etc.) could just as easily be brought into other regions through propagation material, since these can adhere to the epidermis of the stakes. If these are sown without chemical treatment, the pathogens can reinfect the stalks and the green tissues of the plantlet immediately after emergence.

The dissemination of the pathogens of cassava through fertilized seeds is unknown, except for some recent studies on the cassava bacterial blight (CIAT 1974). Although the risk of dissemination through the use of fertilized seeds appears limited, its occurrence has been reported in the literature especially of viral agents. Because of this, it is logical to suggest extreme caution until convincing studies prove otherwise.

In vegetative material, the dissemination of eggs of insects and of mites is more probable than that of larvae and adults. Generally, the adults and the larvae live on the epidermis of the stalk and are relatively easy to detect. Nevertheless, as in the case of stemborers, some insects such as the shoot fly and horn worm, thrips, and some species of mites, many pests have only been observed attacking cassava plantations in America. Their dissemination would constitute a serious threat for cassava cultivation in Africa and Asia. A recent example is the introduction of mites into Uganda through the importation of vegetative material of cassava from Latin America. This pest has disseminated into Western Kenya and Tanzania, causing serious problems for cassava cultivation in these areas.

Anyone who has ever visited a cassava plantation will notice that: 1) very few times the plant/surface population corresponds to that sown, due to losses during germination; 2) the size of many plants does not correspond to the normal size of the cultivars used; and 3) there are sizeable variations in production for each plant. It is logical to suppose that variations in environmental and edaphic conditions affect these observations, along with pathogens, insects, nematodes, etc., present in the soil before sowing. Nevertheless, the state of health of the vegetative material used can become the most important factor in the success of the crop. Its economic importance is unknown, but it is clearly one of the factors for a successful crop. For instance, more than 25% of the material planted does not germinate when the stakes are infected with bacterial blight organisms. The losses in germination of cuttings attacked by scale insects (*Aonidomytilus albus*) are often as high as 80%.

Conclusions

Based on the above considerations, we can conclude that: (1) the dissemination of pests and diseases of cassava through vegetative propagation material represents a serious threat for the crops; (2) severe quarantine restrictions are necessary in order to avoid the possible introduction of pathogenic organisms and pests into uninfected areas; (3) there is a great ignorance as to the potential damage that many plant pathogens and pests can cause the cultivation; and (4) cassava, as with all other crops propagated vegetatively, requires careful selection and treatment for all stakes distributed for propagation, either for experimental or commercial use.

It is common knowledge that quarantine for plants refers to their isolation until they are believed to be healthy. However, in broader terms, it refers to all aspects of the movement of propagation material between different regions. Applying general quarantine principles specifically to cassava, it could be suggested that:

1) If possible, importation be made only from a country where important pathogens are absent. Because of African mosaic, it is recommended that no importations into America be made from Africa or Asia. However, movement of plant material in the reverse direction is considered possible;

2) Importation be made from a country with an efficient plant quarantine service, so that inspection and treatment of planting material before despatch will be thorough, thus reducing the likelihood of contaminated plants being received;

3) Planting material be obtained from the safest known source within the selected country;

4) An official certificate of freedom from pests and diseases be obtained from the exporting country. This certificate should be accompanied by a list of pests and diseases for which the material was examined. The certificate should also describe any treatments which the material has received in the country of origin;

5) The smallest possible amount of planting material be imported; the smaller the amount the less the chance of carrying an infection; and inspection as well as post-entry quarantine, if necessary, will be simplified;

6) Material be carefully inspected on arrival and treated, either chemically or physically, as necessary;

7) An alternative suggestion would be only to introduce material via a third intermediate non-cassava-producing country or island. This would require the cultivation of this material for at least 1 year at the intermediate location before it was introduced into the receiving country;

8) Also the possible use of tissue culture techniques could considerably reduce the risk of disease and pest dissemination. However, it is not recommended, for the present time, that this technique should be used for exportation from those countries where African mosaic is present to those where it is absent, although it could possibly be used between countries within affected regions.

For all cassava growers and scientists, it is suggested: *1*) that care be taken in the selection of plantations and individual plants from which stakes or sexual seed are collected; *2*) that all tools and packing materials be disinfected and sterilized; *3*) that stakes or sexual seeds be chemically or physically treated before planting, packing, or transporting; and *4*) that stakes be handled with extreme care during cutting, treatment, packing, transporting, and planting.

The cassava collection of CIAT is free of dangerous pathogens transmissible through vegetative material. We are investigating preventive methods and effective disinfectants to prevent the dissemination of pests and pathogenic agents through material used for propagation.

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Potential Value of a Tissue Culture Technique for Producing Mosaic Symptom-Free Cassava Plants[1]

K.K. Kartha and O.L. Gamborg

Abstract

A procedure has been developed for regenerating complete plants from shoot apical meristems of cassava. The method was used to obtain symptom-free plants from stakes infected with the cassava mosaic disease of Indian and Nigerian origin. Meristem tips cultured on a mineral salt-sucrose-vitamin medium supplemented with a 5×10^{-7} M benzyladenine, 10^{-6} M naphthaleneacetic acid, 10^{-7} M gibberellic acid (GA_3) regenerated complete plants within 26 days. More than 90% of the meristem tips developed into complete plants out of which 60% were free of mosaic symptoms. In diseased stakes grown under higher temperature (35°C) for 30 days (16h/day at 4000 lux light intensity and 70% relative humidity), the mosaic symptoms completely disappeared. Symptoms reappeared when plants were transferred to a lower temperature (21°C). All plants regenerated from meristems of symptom-free cassava were healthy. Graft transmission carried out monthly confirmed the absence of symptoms of the causative agent in the plants regenerated by tissue culture techniques.

TISSUE culture denotes in a broader sense the in vitro culture of various plant parts under aseptic and defined nutritional and environmental conditions. Rapid technological advances have led to special procedures for the culture of meristems, embryos, pollen, cell suspensions, and plant protoplasts. The various systems are employed for specific objectives. Any living plant tissue can be cultured, and if the culture conditions are appropriate, the cells can be induced to divide and regenerate entire plants. Although the basic nutritional requirements for the growth of isolated plant cells or organs may be similar, variations do occur for different plant species and must be experimentally determined. However, in most cases a tissue culture medium consists of mineral salts, a carbon source, vitamins, and growth hormones.

Tissue culture techniques have applications (Murashige 1974) in: 1) genetic improvement of crops, 2) recovery of disease-free clones and preservation of valuable germ plasm, 3) rapid clonal multiplication of selected varieties, and 4) production of pharmaceuticals.

The present cropping pattern of intensive monoculture is encouraging the plant diseases to attain epidemic proportions, especially viral diseases, for which no suitable practical control measures are available. In a plant that has been systemically invaded by a virus, all cells are not uniformly infected and in most cases the shoot meristem cells are generally virus-free (Limasset and Cornuet 1949). This significant observation led Morel and Martin (1952) to the development of meristem culture techniques in order to produce virus-free plants. Since then, meristem culture alone or in combination with heat treatment has been successfully used to eliminate viral pathogens from a wide range of plant species (e.g. potato, dahlia, carnation, chrysanthemum, orchids; for a detailed review see Hollings 1965; Quak 1972).

Mosaic disease of cassava poses serious problems to the crop and is prevalent in most of the cassava-growing regions of the world (Menon and Raychaudhuri 1970), with the probable exception of Colombia (Lozano personal communication). Three types of cassava mosaic (Indian, Nigerian, and Brazilian or cassava common mosaic) have so far been reported and their mode of transmission studied (Costa 1940; Golding 1936; Menon and Raychaudhuri 1970;

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National Research Council of Canada, Prairie Regional Laboratory, Saskatoon, Saskatchewan S7N 0W9.

Storey and Nichols 1938). The Indian and Nigerian cassava mosaic diseases are identical with regard to the type of symptoms produced on susceptible cultivars, host range, and transmission, either by grafting or through the insect vector. Published reports so far indicate that no viral particles have been isolated from the diseased plants or conclusively demonstrated by electron microscopy. On the other hand, the Brazilian cassava common mosaic is of viral origin and mechanically transmissible to susceptible cultivars of cassava and other herbaceous hosts (Costa 1940; Kitajima et al. 1965).

Under terms of a contract with the International Development Research Centre we have been working for the past 2 years: (a) to develop a reproducible technique to regenerate entire plants from the shoot apical meristem of cassava, and (b) to employ the methods so developed in eliminating the mosaic disease in cassava plants.

Kartha et al. (1974) described the methodology to regenerate plants from the shoot apical meristem of cassava. This paper covers experimental procedures used to eliminate the cassava mosaic diseases of Indian and Nigerian origin by meristem culture techniques.

Materials and Methods

Stakes infected with the Indian and Nigerian cassava mosaic diseases were supplied by Drs M.R. Menon, Kerala Agricultural University, Vellayani, Trivandrum, and S.K. Hahn, International Institute of Tropical Agriculture, Ibadan, Nigeria. The diseased stakes containing dormant buds were cut in sections with two nodes each. The upper cut-ends were sealed with paraffin and the sections planted in pots of vermiculite, wetted with a Hoagland nutrient solution (Table 2) and incubated in growth chambers at 26°C, 18 h/day light (4000 lux, fluorescent lamps) and 70% relative humidity. Under these conditions the buds (sprouts) appeared in 4-5 days. Within 7 days, the buds were used for meristem culture.

The cassava plants grew poorly in the greenhouse in Saskatoon during winter months. The greenhouse was temperature-controlled at 21°C. Since all plants received additional lighting, it was obvious that the temperature in the greenhouse was too low for growing cassava. This was verified by the excellent growth of the 6-8 cultivars during summer months. Consistent vigourous growth with the production of deep green foliage was achieved in a growth chamber at 26°C, 18 h/day photoperiod (4000 lux from banks of cool white fluorescent lamps) and 70% relative humidity.

TABLE 1. Composition of culture medium for plant regeneration from shoot apical meristems of cassava.

A[a]	*Major elements*		
	Compound		*Amount/litre*
	NH_4NO_3		1650 mg
	KNO_3		1900 mg
	$MgSO_4 \cdot 7H_2O$		370 mg
	KH_2PO_4		170 mg
	EDTA, Ferric salt		40 mg
	$CaCl_2 \cdot 2H_2O$ *stock*: 15 g/100 ml		2.9 ml
B[b]	*Minor elements*	Stock solution mg/100 ml	
	H_3BO_3	620	
	$MnSO_4 \cdot 4H_2O$	2230	1 ml
	$ZnSO_4 \cdot 7H_2O$	860	
	$Na_2MoO_4 \cdot 2H_2O$	25	
	$CuSO_4 \cdot 5H_2O$	2.5	
	$CoCl_2 \cdot 6H_2O$	2.5	
	KI stock 75 mg/100 ml		1 ml
C[c]	*Vitamins* Stock mg/100 ml		
	Nicotinic acid	10 mg	
	Thiamine HCl	100 mg	
	Pyridoxine HCl	10 mg	10 mg
	m-inositol	1000 mg	
D	*Sucrose*		20 g
E	*Hormones*		
	Benzyladenine (BA) 5×10^{-7} M		
	Naphthalenacetic acid (NAA) 10^{-6} M		
	Gibberellic acid (GA_3) 10^{-7} M		
	pH 5.8 (adjust with 0.2 N KOH or 0.2 N HCl)		
	Difco Bacto Agar 0.6%		

(NB Use only glass distilled water)

[a] Data from Murashige and Skoog (1962).
[b] Data from Gamborg et al. (1968) and Gamborg (1975).

The meristem culture medium (Table 1) consisted of macro and micro elements according to Murashige and Skoog (1962), vitamins as in B5 medium (Gamborg et al. 1968) and 2% sucrose. Before adding Difco Bacto-Agar (0.6%) the pH of the medium was adjusted to 5.7 with 0.2 N KOH. Growth hormones such as benzyladenine (BA), naphthaleneacetic acid (NAA) and gibberellic acid (GA_3) were incorporated into the medium after the agar was dissolved at molar concentrations of 5×10^{-7}, 10^{-6}, and 10^{-7}, respectively. GA3 was a product of Kyowa Hakko Kogyo Co. Ltd., Tokyo, and supplied by Dr

J.D. Jones of Ottawa. The BA was of reagent grade (Calbiochem) and NAA was recrystalized before use. Aliquots of 2.5 ml of medium were individually dispensed into 10 × 2.5 cm pyrex test tubes, the tubes were plugged with absorbent cotton and autoclaved at 1.46 kg/cm^2 (20 psi) for 20 min. The medium was left to cool and solidify at ambient temperature.

TABLE 2. Composition of Hoagland nutrient solution.

Macronutrients	*mM*	*g/litre*
$Ca(NO_3)_2 \cdot 4H_2O$	4.0	.94
$MgSO_4 \cdot 7H_2O$	2.0	.52
KNO_3	6.0	.66
$NH_4H_2PO_4$	1.0	.12
Iron chelate "Sequestrene 330 Fe"[a]		.07
Micronutrients (stock solution)		*g/litre*
H_3BO_3		28
$MnSO_4 \cdot H_2O$		34
$CuSO_4 \cdot 5H_2O$		1.0
$ZnSO_4 \cdot 7H_2O$		2.2
$(NH_4)_6Mo_7O_{24} \cdot 4H_2O$		1.0
H_2SO_4 (conc)		5.0 ml

(0.1 ml of the micronutrients is mixed with 1 litre of the macronutrients and the pH adjusted to 6.7)

[a]Geigy Agricultural Chemical Corporation, Ardsley, N.Y., USA.

Dissection of the meristematic domes was carried out in a laminar flow cabinet (Envirco, Ontario) equipped with sterile air circulation. The shoot apices were sterilized by immersing in 70% ethanol for 1 min followed by three washings in sterile distilled water. Meristematic domes measuring approximately 0.2-0.5 mm were carefully removed from the shoot apices with razor blades chipped to form fine scalpels and mounted on steel holders. The dissection was performed under a Wild-M5 stereo microscope (Wild of Canada Ltd., Toronto) at ×50 magnification. The meristematic domes thus removed were planted on agar media and the tubes stoppered, sealed with Parafilm® and scotch tape and incubated in a growth cabinet (Model EF7 Controlled Environment) programmed to provide a light intensity of 3000 lux, a light and dark cycle of 16/8h, 26°C, and 70% relative humidity.

In other experiments, sections of diseased stakes were planted in vermiculite and grown in a growth cabinet programmed to provide 16 h/day photoperiod (4000 lux light intensity from banks of cool fluorescent lamps), 35°C (constant), and 70% relative humidity. After 30 days of growth, meristematic domes were isolated and cultured as mentioned above. Control experiments consisted of cuttings originating from the same diseased stakes but grown under greenhouse conditions (14 h/day photoperiod, 21°C, and 40-45% relative humidity).

Results

Regeneration of mosaic symptom-free plants by meristem tip culture Within 5-7 days, the diseased cuttings sprouted and the foliage showed typical mosaic symptoms. As the plants grew older, the symptoms became severe and caused crinkling, distortion, and reduction in size of leaf laminae (Fig. 1).

The response of the meristem tips to the culture conditions was noticeable within 3 days in the form of considerable swelling at the basal cut portion leading to the development of a callus. The shoot differentiation began within 7-10 days, followed by root development (Fig 2). Only explants exceeding 0.2 mm in length differentiated to form complete plants. Those less than 0.2 mm in length formed either callus or callus with roots. The regeneration potential (number of plantlets differentiated from the total number of meristem tips cultured) of meristem tips exceeding 0.2 mm was as high as 90-95% in both the Indian and Nigerian cultivars. The presence of leaf primordia on the meristem explants was not essential for plant regneration under our experimental conditions.

The data regarding the production of mosaic symptom-free plants are summarized in Table 3.

Within 26 days, the plantlets were formed and grew to 4-5 cm (Fig. 3). At this stage, they were transferred to pots containing vermiculite, grown either in a greenhouse or in a growth room at 26°C, 16 h/day photoperiod at 3000 lux light intensity and watered weekly with Hoagland's nutrient solution (Table 2). Visual observations were made for 6 months for any obvious symptoms.

Transmission experiments were conducted by grafting the scions from regenerated plants onto healthy but susceptible CIAT, Colombia, cultivars, namely, Llanera and Colombia #800 at monthly intervals for 6 months. Control experiments consisted of grafting scions from diseased plants. No visible symptoms were notice-

TABLE 3. Production of mosaic symptom-free cassava plants by meristem culture.

Cultivar	No. of meristems cultured	Meristem tip size (*mm*) [a]	No. of plants regenerated	No. of mosaic symptom-free plants obtained
Kalikalan (Indian)	150	$\leqslant 0.4$	135	70
Ogunjobi (Nigerian)	45	$\leqslant 0.4$	42	40

[a] The meristim tips exceeding 0.4 mm regenerated to form plants showing mosaic symptoms.

able on the stock plants grafted with healthy plants regenerated from meristems. On the other hand, the control plants using diseased scions exhibited typical mosaic symptoms on the newly formed axillary shoots of the stock plants within 21-28 days.

Regeneration of plants free from mosaic symptoms by heat treatment coupled with meristem tip culture Cuttings from diseased stakes of Kalikalan and Ogunjobi when grown at 35°C (constant), 16 h/day photoperiod (4000 lux, fluorescent lamps) and 70% relative humidity, exhibited vigourous growth as compared to the control plants grown under greenhouse conditions (21°C). Masking of mosaic symptoms on the young leaves was apparent from day 15 and no symptoms were visible on the new leaves produced by day 30 (Fig. 4b). The control plants of the same age derived from the same cutting grown at 21°C developed severe mosaic symptoms with extensive distortion and reduction in size of leaf laminae (Fig. 4a). In the plants with foliage free of mosaic symptoms, typical mosaic symptoms appeared within 7-10 days, when they were transferred from the 35°C growth cabinet to the greenhouse at 21°C.

Meristems were cultured from plants grown at 35°C for 30 days (with symptom-free leaves) while still being maintained under growth-cabinet conditions (Table 4).

Transmission experiments carried out as described above showed no sign of mosaic disease agent being present in the regenerated plants (Fig. 5). However, in the absence of the white fly vector *Bemisia* sp. transmission studies were not done. Transmission experiments were not attempted on other herbaceous hosts of cassava mosaic disease.

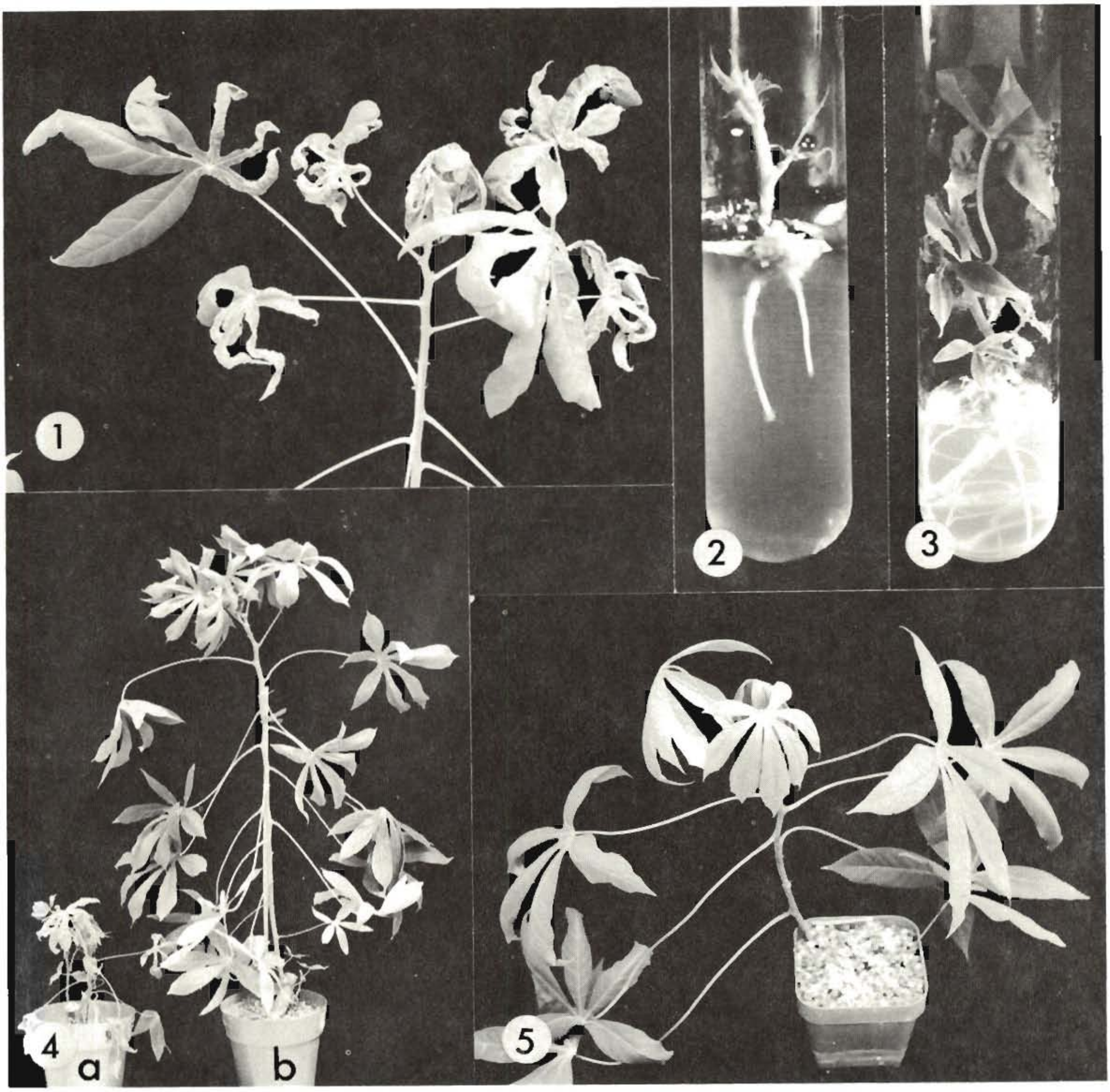
Discussion and Conclusion

The experiments clearly indicate that symptoms of the cassava mosaic disease prevalent in India and Nigeria could be eliminated by meristem culture alone or coupled with heat therapy. The success and frequency of producing symptom-free plants appear to be governed by the size of the meristem tip (maximum size 0.4 mm). Apparently the cassava mosaic disease agent is present in shoot apical regions of a diseased plant below 0.4 mm. However, when the diseased stakes were grown under a higher temperature (35°C), masking of the symptoms leading to their total disappearance was observed, and meristem tips up to 0.8 mm were free of the pathogen. The higher temperature apparently favoured plant growth and may have retarded invasion and multiplication of the causative agent. Plant hormonal balance may

TABLE 4. Heat treatment coupled with meristem tip culture in the production of cassava plants free from mosaic symptoms.

Cultivar	No. of meristems cultured	Meristem tip size [a]	No. of plants regenerated	No. of plants free of mosaic symptoms obtained
Kalikalan (Indian)	50	$\leqslant 0.8$	45	45
Ogunjobi (Nigerian)	50	$\leqslant 0.8$	46	46

[a] Meristem tips exceeding 0.8 mm regenerated to form plants showing mosaic symptoms.



A recently developed technique for growing cassava in tissue culture may offer a new opportunity for producing disease-free material. Fig. 1: an adult cassava plant exhibiting typical mosaic symptoms; Fig. 2: shoot and root formation from the cultural meristem; Fig. 3; a 5-week-old mosaic symptom-free plant regenerated from meristem; Fig. 4; cuttings from diseased plant grown in a greenhouse at 21°C (a) and under growth cabinet conditions at 35°C (b) for 30 days (note the disappearance of mosaic symptoms and increased vegetative growth in "b"); Fig. 5: 3-month-old symptom-free plant regenerated by culturing shoot apical meristems from mosaic-diseased cassava.

be a determining factor for stimulating plant growth and providing adverse conditions for the multiplication and invasion by the pathogen.

The disappearance of symptoms on plants grown at 35°C does not appear to be the result of inactivation of the pathogen, since the symptoms reappeared on the foliage after exposure to a lower temperature. Chant (1959) reported that the cassava mosaic "virus" had been inactivated from the Nigerian cassava heated at 35-39°C for periods of 28-42 days. He obtained four plants which remained healthy after 42 days at 39°C out of 18 surviving plants, and the rest were infected. In our experience cassava plants grown above a temperature of 36-37°C for periods exceeding 20 days develop spindly growth and premature senescence. Moreover, the regeneration potential of meristems from such plants was as low as 2-5%. Our results, therefore, suggest that the causative agent of cassava mosaic disease present in Indian and Nigerian plants cannot be inactivated by thermotherapy alone but, coupled with meristem tip culture, it is effective in completely eliminating symptoms of the disease.

The mosaic symptom-free plants produced by meristem culture techniques are not immune to reinfection by the same or other causative agents, although the meristem technique makes it possible to produce symptom-free plants and provide a foundation stock. This stock can be propagated in an area fully protected against reinfection hazards and only the progeny propagated from it should be exposed to field conditions. The tissue culture operations can be expanded to any desired capacity. The most efficient operation will probably require that the tissue culture facility be augmented with a unit for extensive vegetative propagation (Wholey and Cock 1973).

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A Suggested Method for Improving the Information Base for Establishing Priorities in Cassava Research

Per Pinstrup-Andersen and Rafael O. Díaz

PRIORITIES in applied agricultural research are frequently established on the basis of very limited information about existing problems and their relative economic importance in the production process. The communication between the farm sector and the research institute is often poor, and the demands at the farm level for problem-solving research frequently are not well known to the research manager.[1] Farmers in most developing countries, with the possible exception of large commercial farmers and members of efficient producer associations, have great difficulty communicating their needs to the research institutes because of institutional and social barriers. As a result, some research may be irrelevant to the actual farm problems and results may not be adopted.

Low rates of adoption of a new technology are frequently blamed on ineffective extension services. Although they may be partly at fault, certainly one of the main reasons for the low adoption rate is that new technology does not always meet the most urgent on-farm needs and farmer preferences. A continuous flow of information to the research manager on the potential gains in production, productivity, and risks in various research activities (e.g. developing resistance to diseases and insects, changing cultural practices, changing plant types, changing plant response to nutrients, etc.) will help ensure that new technology corresponds with the farmers' needs and preferences. This, in turn, will accelerate adoption and increase research payoff.[2]

Such an information flow may consist of a continuous feedback of information from the farmer through the extension service to the research institutions. Direct contact between researchers and farmers through meetings, farm visits, etc., would also be effective. To complement these we are suggesting a third method. This method combines agroeconomic analyses and agrobiological experiments.

This paper presents the methodology used to carry out the agroeconomic analysis and discusses the experience gained from the empirical testing of the methodology for cassava in Colombia with illustrations of the kind of information obtained.

Centro Internacional de Agricultura Tropical, Apartado Aéreo 67-13, Cali, Colombia.

[1] The term "research manager" is used to indicate the person or group of persons making the decision on research priorities. Depending on the research organization and the level in the research process at which priorities need to be established, the research manager may be the individual scientist, a team of scientists, a research director, or any other person or group of persons in the research system.

[2] Other aspects of resource allocation in agricultural research are discussed in: Pinstrup-Andersen, Per. Allocation of Resources in Applied Agricultural Research in Latin America — Preliminary Approach. Paper prepared for the Regional Seminar on Socio-economic Aspects of Agricultural Research, IICA, Maracay, Venezuela, April 10-13, 1973.

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Agroeconomic Analysis

The agroeconomic analysis attempts to transmit to the research manager the farm level demand for applied agricultural research through the establishment of a direct link between the farm and the research institute. The analysis focusses on four principal aspects: 1) describing the production process, 2) identifying factors limiting production and productivity, 3) estimating the relative importance of each of these factors, and 4) obtaining indications of the technology characteristics preferred by the farmer.

In addition to serving the needs of research managers, the information generated by the agroeconomic analyses is expected to be useful for establishing or reviewing public policy on such issues as agricultural extension, credit, and prices (Fig. 1). Finally, the information may be useful to producer associations and individual farmers. However, the primary purpose of the surveys is to supply information for establishing research priorities.

The basic framework underlying the choice of data to be collected is shown in Fig. 2. Attempts are made to describe certain key aspects of the structure, conduct and performance of the production process, the farmer objectives, and the interaction among these factors. Emphasis is placed on identifying the principal factors limiting production and productivity and estimating the implications of removing these factors.

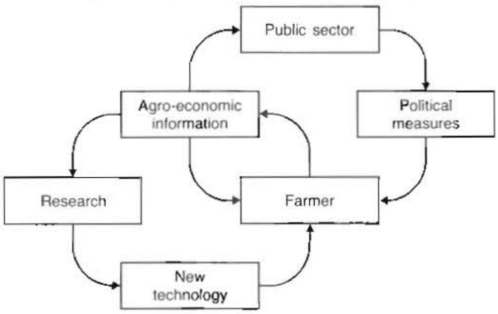

Fig. 1. The expected utility of the agroeconomic study.

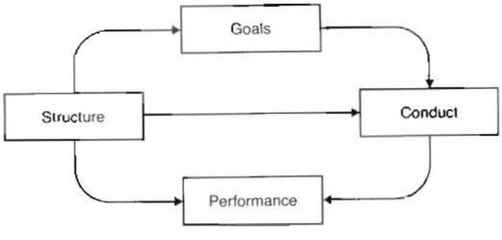

Fig. 2. Basic model underlying choice of data to be collected.

Process Structure

The structure of the production process refers to the process characteristics determined by factors external to the process itself. The structure represents the constraints within which the process operates. Some of the constraints may be modified or removed by the farmer while others are beyond his control. Figure 3 illustrates the structural factors described by the agroeconomic surveys. Given the purpose of the survey, major emphasis is placed on agrobiological and ecological factors.

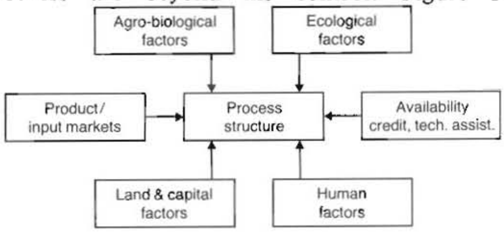

Fig. 3. Factors determining the structure of the production process.

Most of the data related to the agrobiological factors are obtained from direct observation in the farmers' fields. The occurrence and severity of disease and insect damage, mineral deficiencies, and weed occurrence are noted. Furthermore, altitude, soil quality (by means of soil tests), availability of water, plant type, and general plant development are described. The farmer's perception of the agrobiological problems is compared to the field observations. In addition, data are obtained from the farmers on product and input prices and their fluctuations; availability of commercial inputs, labour, credit, and technical assistance; land tenure, farm size, capital, and certain characteristics of the farmer and his family.

Process Conduct

The conduct describes the action resulting from the farmer's decisions with respect to the production process. Data are obtained on 1) use of the land controlled by the farmer; 2) crops found in the production process studied; 3) planting, cultural, and harvesting practices; 4) use of inputs such as fertilizers and insecticides as well as credit and technical assistance; and 5) the utilization of the products produced by the process studied (Fig. 4). Emphasis is placed on

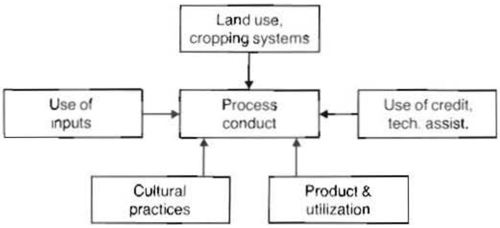

Fig. 4. Factors expressing the conduct of the production process.

analyzing the relationship between structure and objectives on the one hand and conduct on the other, to determine the major production limiting factors.

Process Performance

The performance measures the outcomes or results of the production process in terms of established goals. The analysis obtains data on yields, production, costs, labour absorption,

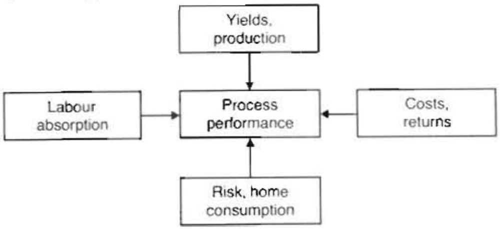

Fig. 5. Factors expressing the performance of the production process.

home consumption, yield variation (risk), and gross and net revenues (Fig. 5).

Farmers' Objectives

Attempts are made to describe the farmer's goals and the relative importance of incomes, cash flow, risk, and availability of products for home consumption in his objective function to help identify technology with expected high rate of adoption. This work includes the collection of data on reasons why various types of new technology were or were not adopted and factors underlying the choice of cropping systems.

Data-Gathering Mechanism

Primary data are obtained by a small specialized team of agronomists and economists, from a panel of farms expected to be representative of the farms for which agrobiological research is intended. The field team makes periodic visits (normally three or four) to each farm during a complete crop cycle. About half of the time on the farm is spent in the field collecting data on agrobiological issues (by direct observation), while the other half is used to interview the farmer.

Before the farm visits are initiated the field team receives extensive training in diagnosing farm-level production problems. Training of the field team is one of the most critical issues in assuring high quality data from the agroeconomic survey. Making a correct diagnosis in the field (e.g. distinguishing among the symptoms of certain diseases, insect damage, mineral deficiencies, etc.) in most cases requires considerable expertise. Hence, direct participation of a highly qualified multidisciplinary research team in the training and field execution phases is essential to the success of the survey. The field teams working on the ongoing CIAT agroeconomic surveys have received 3-4 months of such presurvey training in direct contact with the scientists from the relevant disciplines.

Agrobiological Experiments

The agroeconomic analysis provides an estimate of the area affected by each of the problems identified. Furthermore, it gives an indication of the yield-depressing effect. However, it is frequently difficult to accurately estimate the yield impact from survey data, so controlled experiments are carried out to help quantify the impact of the problems on yield.

Data Analysis

The data obtained from the agroeconomic survey and the related experiments are analyzed for the general purpose of 1) describing the structure, conduct, and performance of the production process under study, and 2) estimating the impact of changing process structure and conduct on performance. In addition to aggregating the data to present a description of the process, attempts are made to estimate the economic loss caused by each of the agro-biological and ecological factors. These include diseases, insects, weeds, soil deficiencies, and adverse rainfall conditions and the implications of changing these factors. Furthermore, estimation is made of 1) production costs and labour absorption by production activity, 2) net returns to the process for each of the principal cropping systems, 3) the contribution of each of the principal resources to net returns, and 4) the factors influencing the farmer decision-making on adoption of new technology and choice of cropping system.

On the basis of the data from the agroeconomic analysis attempts are made to estimate relative benefit/cost relationships for alternative lines of research. The estimates are difficult to make with any degree of confidence.

Illustration of Empirical Results

Projects are currently under way in Colombia to field test the above methodology for maize, cassava, and beans. While the information obtained from these empirical studies is expected to be useful to Colombian national institutions and CIAT, the primary purpose of the work is to develop and test a simple methodology for use by national research agencies in Latin America and elsewhere. The purpose of this section is to present preliminary results from the agro-economic analysis of cassava production in Colombia to illustrate the kind of information obtained. The data collection is not yet completed, hence, only limited analysis has been done.

The agroeconomic analysis of the cassava production process in Colombia is based on the collection of primary data from personal visits to approximately 300 cassava producers located in five regions of Colombia (Fig. 6). Each farm is visited three times during the growing season by a team of two agronomists and an agricultural economist previously trained in identifying agrobiological problems in cassava and carrying out farm interviews. The growing season for cassava in Colombia is around 12 months except in one zone (North Coast Region) where it is 8-10 months. The first visit is made less than 4 months after planting and the last right after harvest.

The selection of zones was based on their contribution to the total national cassava produc-

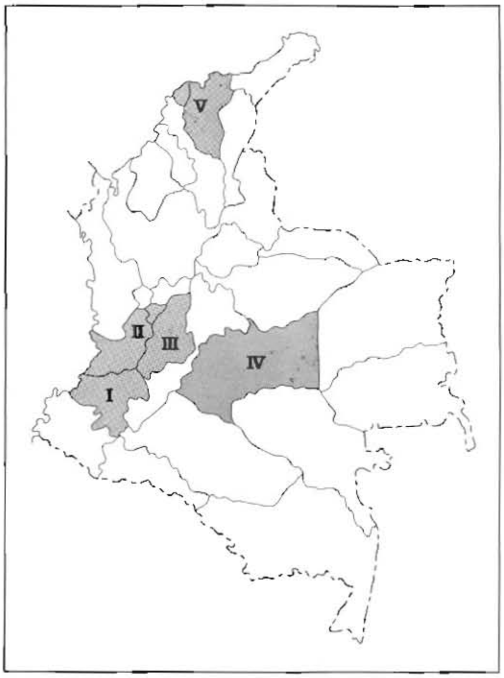

Fig. 6. Locations of the five zones included in the agroeconomic analysis of cassava production in Colombia.

tion and their ability to represent the characteristics of the various cassava-producing regions of the country.

Table 1 shows the altitude, farm size, and land use characteristics of the sample farms. The altitude of the farms varies from over 1000 m in zones I and II to almost sea level in zone V. A large portion of the land is idle or in pasture, hence the cultivated area per farm is small. Although a few of the farms had large cassava plantations, the average was about 5 ha. The farms visited had, on the average, two fields with cassava. The importance of other crops on the sample farms varied with location. Coffee and plantain, in most cases intercropped, were the most important crops in zones I, II, and III, and sugar cane, maize, and banana were important in certain zones.

Table 2 shows the most common cropping systems used on the sample farms, and field size and plant population for each system. More than 14 different crop combinations were identified on the first visit. Over 50% of the farmers grew cassava alone while about 25% grew cassava intercropped with maize. About 60% of the area was planted with cassava alone. Although field size varied greatly with cropping

TABLE 1. Altitude, farm size and land use on sample farms.

	Zone I	II	III	IV	V	Simple average
Altitude of farm (*m*)	1254	1187	886	396	33	761
Total farm size (*ha*)	7.2	37.5	16.5	61.3	18.0	25.9
Area in crops (*ha*)	3.5	18.3	4.7	10.9	8.4	9.9
Area in cassava (*ha*)	2.9	6.4	2.0	9.4	5.3	5.2
Area in pasture and unused land (*ha*)	3.7	19.2	11.8	50.4	9.6	16.0
Number of cassava lots/farm	2.16	1.91	2.16	1.98	1.59	1.96
Size of cassava lot observed (*ha*)	1.30	3.35	0.90	3.37	2.16	2.22
Crops other than cassava (*% of farms*)						
Coffee	32.4	61.4	31.6	10.0	0.0	28.7
Plantain	18.9	54.5	5.3	10.0	4.5	22.0
Maize	2.7	11.4	15.8	15.0	4.5	8.5
Sugar cane	5.4	0.0	26.3	0.0	0.0	4.3
Banana	2.7	0.0	0.0	0.0	6.8	2.4
Other crops	0.0	9.1	5.3	10.0	18.2	9.1

system, additional data analysis is needed to determine the possible relationship between these two variables.

The plant population of cassava was similar whether grown alone or intercropped. However, when grown with two or more crops, the cassava plant population diminishes. A comparative economic analysis of various cropping systems for cassava, including the factors determining the farmer's choice of system, has been initiated.

The occurrence of insects, insect damage, and diseases in cassava was estimated on the basis of direct field observations. The final results from the first visit and preliminary results from the second and third visits are shown in Tables 3-6.

Thrips was the insect most frequently found, followed by gall midge and white fly (*Bemisia* sp, Table 3). It appears that the occurrence of these insects and the visible damage they cause is less frequent in crops more than 8 months old. This is not the case, however, for other insects including white fly and mites. One explanation is that the crop in many cases outgrows the visual damage caused by the initial attacks. However, data are not yet available to determine whether the attacks had any significant impact on yields.

The occurrence of each of the major insects varies considerably between zones (Table 4). For example, fruit fly (in stems) was found on 76% of the farms in zone II while it was of little importance in the other zones. Leaf hopper was important only in zone V and white fly (*Bemisia*) was found on 70% of the farms in Cauca, Magdalena, and Atlantico (zones I and V) and much less important in the other three zones.

The visible damage caused by diseases in cassava was most pronounced between 4 and 8 months. The diseases most frequently found were white leaf spot, *Phoma* leaf spot, brown leaf spot, powdery mildew, and *Cercospora* leaf blight (Table 5). As in the case of insects, it appears that the cassava plant in some cases is capable of outgrowing the disease symptoms. However, for most diseases the proportion of the field affected increases with the age of the

TABLE 2. Cropping systems, lot sizes, and plant population.

Cropping system	Percent of farms	Lot size (*ha*)	Percent of area	Plant population (No. of plants/ha) Cassava	2nd crop	3rd crop
Cassava alone	60.0	2.5	69.3	9811	–	–
Cassava – Maize	24.5	1.4	15.8	9421	5578	–
Cassava – Plantain	4.1	3.6	6.8	12172	574	–
Cassava – Beans	3.4	2.7	4.2	9455	2127	–
Cassava – Maize – Beans	2.2	0.6	0.6	8988	5113	7813
Cassava – Maize – Plantain	1.3	2.0	1.2	7617	3583	833
Cassava – Maize – Sesame	1.0	0.6	0.3	7333	4133	4283
Cassava with other crops	2.3	1.7	1.8	7386	–	–

TABLE 3. Preliminary data on insect occurrence in cassava.

Insect	First visit (305 farms) % of farms	% of lot	Intensity[a]	Second visit (248 farms) % of farms	% of lot	Intensity	Third visit (162 farms) % of farms	% of lot	Intensity
Thrips	80	81	2	84	42	2	46	42	2
Gall midge	51	22	2	54	16	1	21	18	1
White fly (*Bemisia*)	44	27	2	41	37	2	21	15	2
Shoot fly	17	25	3	16	16	2	1	10	1
Leaf cutter ants	14	35	4	12	14	2	10	25	1
Leaf hoppers	13	16	2	4	16	2	0	–	–
Fruit fly (in stems)	12	26	2	24	37	2	9	37	1
Horn worm	7	18	2	2	21	2	2	12	1
White fly	6	12	2	16	23	1	19	45	2
Chrysome lids	4	12	1	4	15	2	0	–	–
Tingids	4	23	2	8	19	2	4	16	1
Mites	2	4	2	25	41	2	27	60	3
Termites	1	37	2	0	–	–	2	28	1
Ants	1	10	2	2	14	1	0	–	–
Cutworms	1	45	1	0	–	–	0	–	–
Stemborers (lepidopterous)	1	15	1	0	30	2	0	–	–
Scale insects	–	–	–	0	–	–	1	35	2
Stemborers (coleopterous)	–	–	–	0	–	–	1	5	1

a Intensity of attack using scale of 1–4 with 1 being low and 4 high.

crop. One possible conclusion might be that while lighter attacks tend to be overcome by plant growth, the somewhat more serious attacks continue to spread in the field. The relationship between rainfall conditions and disease spread will be analyzed as more data are collected.

The occurrence of cassava disease also varies greatly between zones. *Phoma* leaf spot, the disease most frequently found during the second visit (in plantations 4-8 months old), was found on about 70% of the farms in Cauca, Valle, and Quindio (zones I and II) and only 30-40% of the farms in the other three zones (Table 6). Superelongation, while important in four zones, was found on two-thirds of the farms in Tolima (zone III). Likewise, the occurrence of cassava bacterial blight and white leaf spot differed greatly between zones.

TABLE 4. Distribution of major insect occurrence among zones, second visit (preliminary data from 248 farms, in % of farms).

Insect	Zone I	II	III	IV	V
Thrips	61	89	100	100	83
Gall midge	25	46	68	68	85
White fly (*Bemisia* sp.)	70	10	24	26	71
Shoot fly	8	32	5	38	0
Leaf cutter ants	20	6	32	21	2
Leaf hoppers	2	2	0	0	15
Fruit fly (in stems)	7	76	3	6	8
Horn worm	0	2	0	0	10
White fly	46	5	16	0	4
Chrysome lids	5	6	0	0	6
Tingids	15	3	13	12	0
Mites	7	8	38	15	44

During the first visits, 92 weeds were identified. Table 7 shows the ten most common weeds. *Pteridium candatum* was found on 25% of the sample farms but the plant density was relatively low. It was most frequently found in zone III (79% of all farms), but not in zone V.

Other agrobiological problems in cassava production assessed by the field team include water supply. Excess water was a severe problem in Valle and Quindio (zone II) while water scarcity reduced yields in Magdalena and Atlantico (zone V).

Once the data collection is completed, attempts will be made to estimate the relative economic loss caused by each of the major insects, diseases, weeds, and other agrobiological problems, in collaboration with the respective biological scientists within the cassava pro-

TABLE 5. Preliminary data on disease occurrence in cassava.

Disease	First visit (305 farms)			Second visit (248 farms)			Third visit (162 farms)		
	% of farms	% of lot	Intensity[a]	% of farms	% of lot	Intensity	% of farms	% of lot	Intensity
Brown leaf spot	34	22	2	54	33	2	35	36	2
White leaf spot	28	33	2	59	41	2	36	54	2
Cassava ash disease	19	40	2	43	42	2	20	57	2
Cercospora leaf blight	15	17	2	23	26	1	7	40	1
Phoma leaf spot	15	20	2	54	33	2	43	36	2
Superelongation	6	23	3	12	45	4	1	48	2
Cassava bacterial blight	5	27	2	13	38	3	9	45	3
Root rotting	1	43	3	1	15	3	–	–	–
Leaf sooty mold	1	10	1	2	42	3	2	27	1
Frog skin – root disease	–	–	–	–	–	–	4	–	–

a Intensity of attack using a scale of 1–4 with 1 low and 4 high.

gram.[3] Such estimates are expected to be useful to the cassava program in establishing and reviewing priorities among and within disciplines.

The distribution of production costs and labour requirements among production activities is another factor likely to provide guidelines for research resource allocation. Table 8 shows the estimated labour requirements by production activity and the percentage distribution of labour requirements and available costs.[4] Weeding was the most labour-consuming activity (and accounted for the highest percentage of variable costs), followed by harvesting/packing, land preparation, and planting.

The data reported in Table 8 suggest that high priority might be placed on improving the efficiency of weeding, harvesting/planting, and land preparation, e.g. estimating the impact of alternative degrees of land preparation and weeding on yields and economic net return, and the impact of alternative methods applied in these activities and harvesting/packing.

The potential impact of the development and adoption of mechanical, chemical, and biological technology on labour use in cassava production was estimated for various adoption rates. Extensive mechanization and/or herbicide use was assumed to have a significant negative impact on labour demand, while biological technology is expected to increase labour demand slightly.[5] The impact of the various types of technology on costs would depend on existing relative prices, hence may differ between localities.

Before such data are used to help establish research priorities, the objectives of the society

TABLE 6. Distribution of major disease occurrence on second visit to 248 farms (in % of farms).

Disease	Zone I	II	III	IV	V
Brown leaf spot	28	32	79	68	83
White leaf spot	71	95	28	9	54
Cassava ash disease	43	57	84	15	10
Cercospora leaf blight	39	8	40	18	14
Phoma leaf spot	72	71	34	32	42
Superelongation	2	0	66	9	0
Cassava bacterial blight	2	0	11	24	37
Root rotting	2	3	0	0	0

[3]The data collection extends over a 2-year period to cover two complete growing seasons and most of the data analysis cannot be performed until a complete data set is obtained in mid 1975.

[4]Since the data collection within the agroeconomic survey is not sufficiently advanced to provide estimates of labour and cost distribution, the data presented in Table 8 are taken from prior work (Rafael O. Díaz, Per Pinstrup-Andersen, and Rubén Dario Estrada. *Costs and Use of Inputs in Cassava Production in Colombia: A Brief Description.* CIAT, EE-No.5, September 1974).

[5]The quantitative results of the analysis are reported in Per Pinstrup-Andersen and Rafael O. Díaz. *Present and Potential Labor Use in Cassava Production in Colombia.* Paper presented at the third International Symposium on Tropical Root Crops, Ibadan, Nigeria, 2-9 December, 1973.

TABLE 7. The ten most important weeds in cassava in terms of proportion of sample farms where they occurred (first visit).

Weed	% of farms	Weed density (plants/ha)
Pteridium caudatum	24	78,000
Sida acuta	18	90,000
Commelina difusa	17	136,000
Bidenes pilosa	16	102,000
Melinis minutiflora	14	134,000
Portulaca oleracea	12	168,000
Cyperus ferax	10	148,000
Rychardia scabra	10	84,000
Cyperus rotundus	10	188,000
Drymaria cordata	9	234,000

for which the research is intended must be clearly defined. Social and private objectives may conflict (e.g. the social objective of creating productive employment may conflict with private objectives of maximizing profits). Chemical weed control, for example, may increase net returns to the producer but reduce employment. The impact of new technology on net returns depends, at least in part, on relative factor prices, which in turn may be influenced by public policy. It is important that possible conflicts between social and private objectives, as well as government's ability and desire to introduce corrective and facilitating policy measures, be fully understood before research priorities are established. This will help ensure that the research significantly contributes to social and economic development goals.

The agroeconomic survey also seeks information on a number of other issues expected to be useful for the cassava program in allocating its research resources.

Training Benefits

This work also provides a valuable training opportunity for young agronomists and economists interested in production. The extensive initial training along with the experience gained while carrying out the surveys produce professionals knowledgeable of farm-level production limitations and the possible ways to remove these limitations. These professionals in their future activities will hopefully provide a close link between research and farm-level problems.

Conclusions

A very large number of farm surveys have been carried out in the past, so our survey is not entirely unique. However, certain aspects of the work tend to distinguish it from traditional farm surveys and will hopefully make it more useful for establishing priorities in applied agricultural research. These aspects are: 1) a considerable proportion of the data are obtained from direct field observations made by agronomists previously trained for this job; 2) each farm is visited periodically during a complete growing season; 3) the work is multidisciplinary in nature and involves direct participation by professionals from all the relevant disciplines; and 4) The work is specifically focussed on providing information needed to establish research priorities. Although the information may be useful for other purposes, such utility is considered secondary.

TABLE 8. Distribution of labour requirements and variable costs among cassava production activities in Colombia.

	Labour requirements				
	Mechanical land preparation Man-days/ha	%	Manual land preparation Man-days/ha	%	Variable costs (%)
Land preparation	–	–	25.0	23.6	23
Planting	9.1	10.4	10.8	10.2	8
Replanting	0.3	0.3	0.6	0.6	1
Weeding	46.8	53.4	43.7	41.2	36
Fertilizers and application	0.5	0.6	0.3	0.3	1
Insecticides and application	0.3	0.3	0.6	0.6	1
Harvesting and packing	30.7	35.0	24.9	23.5	24
Seed	–	–	–	–	6

[a] Source: Rafael O. Diaz, Per Pinstrup-Andersen and Rubén Dario Estrada. *Costs and use of inputs in cassava production in Colombia. a brief description.* CIAT, Series EE No. 5 September 1974.

It is too early to evaluate the contribution of the above work to research resource allocation. However, the direct participation of the CIAT agricultural production scientists in project planning and training of field agronomists, and the preliminary project findings, have been of some value to the scientists in planning their future research.

The methodology and experience gained from the work will be made available to interested national research agencies upon request. Furthermore, CIAT will consider requests for technical assistance for projects of this type. Currently, a collaborative project with INIAP, Ecuador, for cassava is being planned. The possibility of carrying out projects for cassava in Brazil and Thailand are being discussed, and funds have been assured to provide technical assistance for two similar projects for beans in Latin America.

Cultivars which perform well in the regional trials are then distributed to selected farmers for commercial scale evaluation.

Proposed Structure of an International Cooperative Network for Evaluation of Promising Cassava Materials

Julio Cesar Toro and David Franklin

THE bases for the formation of an international cooperative cassava testing network are discussed. These points are primarily based on first-hand experience gained from the first group of regional trials in Colombia. This country offers an ideal range of climate and soil conditions for the rigourous evaluation of varieties. Suggestions are made on how such a network could be structured.

Firm recommendations on such structure are expected from this workshop, and the analysis of our experience from the first group of regional trials being undertaken in Colombia. These trials will be harvested in July 1975.

We feel that the international testing network for cassava should be highly structured, as was the one for wheat. It is probably not possible to emulate, exactly, the successful strategy followed by the ICA-CIAT rice program. Nevertheless, we believe that the experience in rice is useful.

It is worthwhile to compare the current situation in cassava with that of rice to clearly define the problem:

	Rice	*Cassava*
1)	History of prior research for over 10 years	Little background information, research for 2 years.
2)	Two cropping cycles per year	One cropping cycle per year.
3)	Existing infrastructure of National and International Trainees and Collaborators	Doesn't exist
4)	Four experiment stations	One
5)	Promotion support from the Rice Growers Federation in Colombia	Cassava Growers Federation doesn't exist.
6)	Rice is a high prestige crop for commercial farmers	Low prestige crop, until now principally for subsistence farmers
7)	Close integration ICA-CIAT-RICE-GROWERS FEDERATION	ICA-CIAT COFFEE GROWERS FEDERATION
8)	The technological package is based on modern factors of production	No
9)	The new materials tested had excellent controls IR 8, CICA 4, CICA 6 to be tested against	Such materials do not exist. The promising materials would be tested against the local best variety
10)	Seed propagated	Propagated by vegetative means.

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Methodology of the Trials

It is assumed that the breeding program will release five different elite materials yearly for testing by the agronomy unit. These materials would be multiplied using the rapid propagation scheme and would be ready for regional trials the following year. The first promising crosses would appear in 1977.

In regional trials, the level of technology should be uniform according to recommendations of the various sections of the CIAT Cassava Program (see Appendix, Guidelines for the Colombian Regional Trials).

Each year the materials showing the best behaviour in a given zone would be distributed to farmers after testing and evaluation. The distribution would be done through field days, after each regional trial.

In Colombia, the field days and the regional trials would be done in collaboration with ICA and the Coffee Growers Federation. These would be held on a continuing basis and provide the additional benefit of promising elite materials replacing the local varieties, thereby obtaining immediate or near-term yield and production increases. Farmers do not have better materials because they have not had enough material to select from in the past. Since CIAT manages the largest collection of cassava germ plasm the possibilities of finding superior varieties for each zone are very promising.

Infrastructure

We believe that international trials must be carried out by a network of collaborators trained at CIAT for that purpose. This network would be the principal base of support for the international trials and the dissemination of varieties and technology throughout the world.

Proposed Strategies

We propose the following two widely different strategies for discussion. The first strategy, which is conservative, would permit the testing of the same materials over three years without eliminating any materials until the end of the third year. Decision over their naming as a variety would be based on excellence of performance throughout ecological zones during the three years.

The second strategy would only select for further testing those materials which have been definitely superior in that year's trials, discarding any material that does not show excellent performance the first time. Materials passing this rigid test would become candidates to be named as varieties.

The main problem with the first strategy is that it accumulates large numbers of materials in a very short time. However, one would expect that with the second strategy the number of materials to be tested each year would remain more or less the same. This latter strategy would probably also lead to fewer named varieties being released.

Cassava Germ Plasm Collection and Advanced Genetic Material at CIAT

Kazuo Kawano

CASSAVA originated in the American tropics. There is no evidence of this crop being transported to Asia or Africa before the age of the conquistadores, so we assume the majority of varietal diversification occurred in Latin America. The physiological features of cassava would indicate that cultivation originated in the marginal area between the tropical rain forest and the savanna. No edible cassava is found in the wild, and little modern technology has been applied to its genetic improvement. Thus the existing cassava germ plasm represents an intensive human intervention, without significant scientific methods, for the evolution of crop species.

Collection

Systematic collection of cassava germ plasm was already underway when CIAT's cassava research program started. Approximately 2700 clones of cultivated cassava were collected from Colombia, Venezuela, Ecuador, Mexico, Panama, Puerto Rico, Brazil, and Peru.

Most of the Peruvian collection was eliminated because of the presence of the Brazilian mosaic virus. A significant portion of the collections from Colombia, Panama, and Puerto Rico were lost because of salt spots in the field and an outbreak of bacterial blight (CBB) during the maintenance period. The total number of entries now maintained is a little more than 2200 (Table 1).

The number of Brazilian collections is small considering the expected great variability of cassava in this country. This deficiency occurs because of plant quarantine regulations. However, a continuous effort is made to introduce more genetic variation from Brazil in the form of true seeds. Nevertheless, the phenotypic variability in the CIAT germ plasm field is vast.

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The collection was made right in the centre of origin and diversification of the species. Cassava is highly heterozygous, and nobody has fully exploited the existing genetic variability of the species. We believe the CIAT cassava germ plasm is a highly promising source of genetic variation with which to start a breeding program. We do not intend to include wild species in our breeding work until we study a major part of genetic variability within the species. Wild species will only be used when we are certain that they have useful characters.

TABLE 1. Entries of cultivated cassava collection in the CIAT collection.

Country of origin	No. of clones maintained at present
Colombia	1682
Venezuela	266
Ecuador	133
Mexico	66
Panama	21
Brazil	17
Costa Rica	16
Puerto Rico	15
Perú	2
Total:	2218

Evaluation

Agronomic evaluation of approximately 2000 collections has just been completed at CIAT, which has highly fertile soil. The agronomic traits observed in the evaluation are listed in Table 2. Throughout the evaluation period there was no prolonged dry season, no heavy rainfall, or extreme temperature for normal cassava growth. The CIAT farm is kept free of two of the most destructive diseases, CBB and superelongation. Thus, yield data from the evaluation may well represent yielding ability of each genotype under nearly ideal growing conditions for cassava.

TABLE 2. List of characteristics recorded in germ plasm evaluation.

Growing period (months)	Agronomic characteristics
0-3	Germination, vegetative vigour, flowering
4-6	Thrips, flowering
6	Root yield, top weight, harvest index, height, No. of total and commercial roots, root specific gravity
6-10	Branching habit, leaf size, leaf retention, flowering
10	Root yield, top weight, harvest index, height, No. of total and commercial roots, root specific gravity, ease of harvest, root length, root stalk length, HCN and N content, root perishability

A great genetic variability was observed in nearly all the traits evaluated. A summary of the evaluation is presented in the 1974 Annual Report of CIAT. Two hundred and thirty collections were selected on the basis of harvest index, root yield, and total plant weight, with an additional effort to include as much genetic diversity as possible. These are being further evaluated in advanced yield trial at CIAT and in observational yield trials at Carimagua, Llanos Orientales, and Caribia, Costa Atlántica. The trial in Carimagua is expected to give selection opportunity for poor acid soils with a prolonged dry season, and the other, in Caribia, a selection under high temperatures. These collections form the basis for obtaining higher-yielding capacity with wide adaptability.

Advanced Material

The present objective of hybridization is to upgrade primarily the harvest index of populations without losing overall heterozygousity since the inheritance of harvest index is largely controlled by the additive gene effect. Hybridization of cassava by hand pollination is easy. During 1974, approximately 35,000 F_1 seeds of about 250 cross-combinations were obtained out of about 30,000 female flowers by hand-pollination by three field labourers. These crosses were done mainly among the selected genotypes for higher-yielding capacity. Sources of resistance to CBB, superelongation disease, *Phoma* leaf spot, and *Cercospora* leaf spot were found by the pathology group. Genes for resistance to important diseases are being added gradually. Characteristics of some frequently used genotypes in hybridization and their results are presented in CIAT's 1974 Annual Report.

Since cassava is a highly heterozygous plant, we need to produce a large number of F_1 seeds per cross combination. Yet we sometimes produce more than 1000 F_1 seeds in a single cross. The number of F_1 seeds per cross and total number of F_1 seeds being produced is too large for evaluation by CIAT.

An example is a cross between M Colombia 113 and M Mexico 55, of which we have obtained more than 1500 F_1 seeds. M Colombia 113 is a vigourous-growing type adapted to the relatively high land of Colombia with an excellent leaf area retention after 6 months of planting. M Mexico 55 comes from lowland Mexico and has high harvest index. We are looking for a new type that yields well not only on the CIAT farm but also in Costa Atlántica and Llanos Orientales of Colombia and outside Colombia. We hope to be able to produce a large quantity of F_1 seeds that can be distributed to workers interested in testing in their own environment.

A brief summary of our recent hybridization work is presented in the 1974 Annual Report of CIAT.

Material Exchange

The CIAT cassava breeding program is ready to send various types of genetic materials to cassava breeders outside CIAT upon request. Material exchange in the form of stakes is risky and bulky, so we prefer to exchange true seeds.

Since proper evaluation of large amounts of germ plasm requires considerable work, we have so far only sent general germ plasm material to other international programs. Approximately 15,000 open-pollinated seeds from 203 germ plasm collections were sent to the IITA program in Nigeria. Of course other cassava breeders in Africa may request general germ plasm material from IITA.

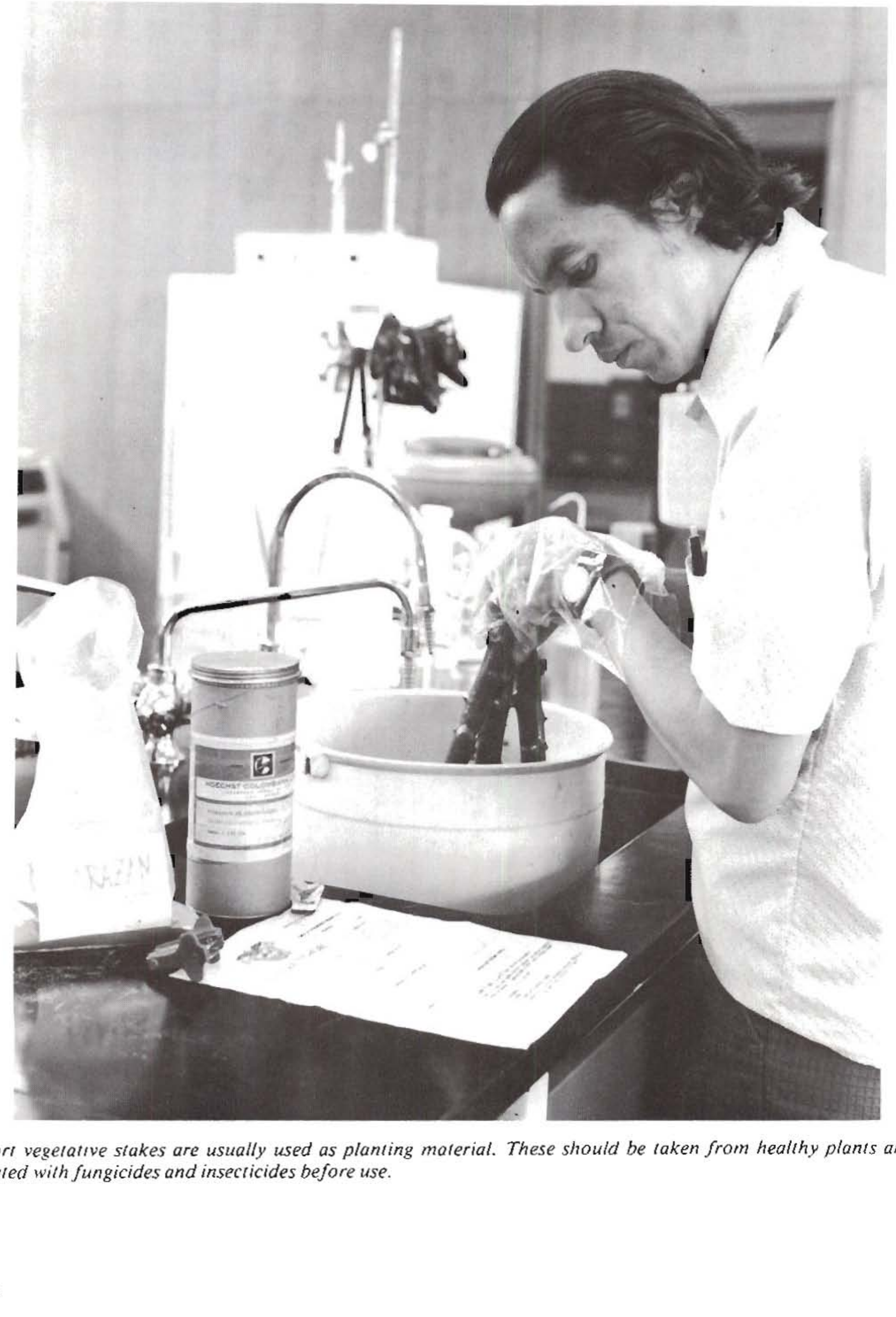
So far we have distributed some 5000 F_1 seeds, from such crosses as M Colombia 113 × M Mex 55, M Colombia 22 × M Colombia 647, and M Colombia 22 × M Venezuela 318, to 12 interested breeder-agronomists in Brazil and IITA and to a CIAT trainee from Africa. How significantly better these materials are than indigenous materials or simple open-pollinated progenies of germ plasm is a matter of hope rather than a scientific fact at present. Nevertheless, the level of our advanced material will be improved year by year. We hope that some of the recipients of these materials will do a proper evaluation on the materials and send us their best selection or information. We believe this is the best way to obtain wide adaptability.

Handling Genetic Material

Some of the recent findings on the genetic nature of cassava plants are: 1) highly heterozygous; 2) high occurrence of self-pollination; 3) extreme degree of inbreeding depression; 4) highly heritable nature of harvest index; and 5) high correlation between yield data with seedling plants and those with stake-planted plants.

The high occurrence of self-pollination and sensitiveness to inbreeding of cassava should be taken into consideration when exchange of seeds is planned. Any open-pollinated seed collected in pure stand is almost certainly a result of self-pollination. Even in a genetically mixed population, outcrossing of profusely flowering type seldom exceeds 50%. The plants from self-pollination are unlikely to grow normally and hence fail to produce flowers necessary to ensure further hybridization with other genotypes. Thus in preparing seeds for exchange, special care should be taken so as to decrease the proportion of self-pollination.

The very high correlation between seedling and stake-planted performances eliminates the long period necessary for each seedling plant to produce enough stakes to be planted for proper field evaluation. This is especially true when the seedlings are given enough space for maximum yield without significant intergenotypic competition. Breeders are, therefore, able to save considerable time and space, and evaluate large numbers of genotypes. A detailed description can be found in the 1974 Annual Report of CIAT.



Short vegetative stakes are usually used as planting material. These should be taken from healthy plants and treated with fungicides and insecticides before use.

Summary of General Discussion and Conclusions of the Workshop

1 Cassava originated in the American tropics and has only been transported to Africa and Asia in the last 400 years. It is assumed that the majority of varietal diversification occurs in Latin America, which is free from cassava mosaic disease, one of the major diseases of the crop.

2 Cassava is highly heterozygous but is frequently self-pollinated. This latter fact, plus the extreme degree of inbreeding depression shown by the plant, should be taken into consideration when seeds are to be considered as material for germ plasm exchange. Any open pollinated seed collected in a pure stand is almost certainly a result of self-pollination. Even in genetically mixed populations the percentage of outcrossing of profusely flowering types seldom exceeds 50%. Plants from self-pollinated seed are unlikely to grow normally and hence fail to produce flowers necessary for further hybridization. Hence in the preparation of seeds for exchange, special care is required to reduce the level of self-pollination.

3 Genetic variation in material for testing can be reduced by the use of stakes, the normal planting material. The new rapid propagation technique developed by CIAT and the tissue culture method of the NRC Saskatoon Laboratory offer opportunities for the rapid bulking up of vegetative material. However, the risk of disease transmission is much higher when using stakes.

4 There is a very high correlation between the performance of plants grown from seeds and stakes and this can be used to facilitate early screening of seed material, especially if the seeds are widely spaced so that their yield potential can be expressed free from intergenotypic competition.

5 Cassava has not figured prominently as a crop that has played a significant role in the international exchange of germ plasm in past years. It is currently the subject of intensive breeding programs in several locations and there is considerable interest in the international exchange of both seeds and stakes.

6 Plant quarantine regulations relating to cassava importations vary from being extremely strict to completely absent. As a result, several recent importations of stakes either have, or could have, led to the introduction of new pests and diseases.

7 The workshop drew up a list of suggested guidelines relating to the international movement of cassava planting materials, and recommended that these be circulated to national plant quarantine authorities in cassava-producing countries and to international organizations involved in phytosanitary activities.

8 It was recognized that these guidelines were intended to supplement existing quarantine regulations and to provide a service to quarantine authorities. It was suggested that CIAT and IITA could provide two supplementary services. The first would be to devote some priority in their programs to the organization and operation of short courses on the early recognition of diseases and pests of cassava. Secondly, it was recommended that the manual on disorders of cassava, which CIAT staff are preparing, should include colour photographs of the symptoms of early stages of important diseases so that they are recognizable by the nonspecialist.

9 The suggested guidelines for the international movement of both vegetative propagating material and true seed are appended to this report as Annex 1.

10 The workshop also considered two additional proposals connected with quarantine activities. The first of these related to the establishment of a quarantine station in a non-cassava-producing country or island which would act as an intermediate station in the transfer of cassava germ plasm from one country to another. Whilst this proposal received general support it was recognized that its implementation would be costly and perhaps represented an issue that was best dealt with within the framework of activities of the Germ Plasm Conservation Group of the Consultative Group on International Agricultural Research.

11 The second additional proposal put forward was to examine the possible future use of the tissue culture technique as an alternative to an intermediate quarantine station. No firm recommendation was made on this proposal since experience to date with the tissue culture technique was confined largely to one laboratory and the value of the technique in producing material free from cassava mosaic disease was not yet established. Nevertheless, the potential of this technique appeared very promising and a number of participants expressed interest in working with it in their laboratories.

12 The country statements presented during the first day of the workshop indicated that the germ plasm currently in use throughout the world appeared to possess a wide range of characteristics and sizeable differences were reported for such important factors as yield, starch content, and HCN level. There was a widespread interest not only in introducing germ plasm from other sources, especially material originating from the large collections at CIAT and IITA but also in establishing a standardized system for comparing promising cultivars under a wide range of ecological conditions. It was anticipated that the development of guidelines for adaptation testing would also assist cassava breeders in producing material for specific locations.

13 The workshop considered and approved a set of suggested guidelines for the design of trials for the agronomic evaluation of promising cassava cultivars which had already undergone preliminary yield trials at the centres where they were developed, and were considered suitable for testing under a broad range of ecological conditions. Because of the large land area involved in field trials with cassava, it was suggested that unless soil conditions were extremely uniform it would be desirable to limit the number of entries to these trials to 12 per location.

14 The Suggested Guidelines for The Design of Agronomic Trials for Evaluating Promising Cassava Cultivars is included in this report as Annex 2.

15 At the present time there are no standard methods for interpreting the results of evaluation trials with cassava germ plasm, and a large number of characteristics are being recorded in different collections. Because neither these characteristics nor the units they are measured in are standardized, it is often difficult to compare the results of evaluations at different locations.

16 Whilst recognizing that the objectives of germ plasm evaluation would necessarily differ from country to country according to local requirements such as utilization and consumer preferences, the workshop felt that there would be considerable merit in drawing up a list of guidelines for data which should be recorded in evaluation trials.

17 Approximately 30 characteristics were identified as being desirable ones from which data should be recorded. In Annex 3 these characteristics are listed and categorized at three levels of priority. A preliminary definition of each characteristic was made by the CIAT team subsequent to the workshop. These definitions are included in Annex 3 although they were not discussed in detail at the workshop and undoubtedly justify further examination.

18 After discussing the design and evaluation of agronomic trials the workshop examined alternative strategies for varietal selection based on the results of the trials. There was a strong consensus in favour of a rigid selection procedure which discarded in a definitive way any material which did not perform well in its first year in field trials. This procedure would allow about five new entries per year to a twelve entry trial. Material which had a superior performance for three consecutive years under trial would become eligible for naming as a "variety."

19 The workshop did not consider the description, formal release, and local multiplication of new cultivars, since these matters were considered issues for national rather than international consideration.

ANNEX 1*

Suggested Guidelines Relating to the International Movement of Cassava Planting Materials

A. *General*

1. These guidelines are presented as a suggested supplement to existing quarantine regulations of recipient countries. Their implementation is the joint responsibility of the donor and the recipient country.
2. It is recommended that at all times the smallest amount of planting material be imported; the smaller the amount the less chance of its carrying infection, and the greater the ease of inspection and post-entry quarantine.

B. *The Movement of Vegetative Propagating Material*

1. Cassava material should not be imported from countries where cassava African mosaic disease and brown streak virus of cassava exist into countries free from these diseases.**
2. For importations from all other countries the following procedures are recommended:
   a) *in the donor country:*
      (i) material for export should be selected only from sources which are free from symptoms of: all virus and virus-like diseases
      stem borers
      mycoplasma
      cassava bacterial blight
      superelongation
      (ii) material for export should be treated with a combination of an effective fungicide and insecticide. For this purpose the fungicides*** Thiram (25 g a.i/litre) and Chloroneb (20 g a.i/litre) and the insecticides*** Methamidophos (0.8 g a.i/litre) and Carbofuran (1.2 g a.i/litre) have been found satisfactory although these chemicals are not exclusive
      (iii) material for export should be handled with extreme care and all tools and packing material should be either heat or chemically sterilized before contact with the material to be exported
   b) *in the recipient country:*
      (i) any material which on arrival shows evidence of pests or diseases should be destroyed immediately by burning
      (ii) on arrival the material should be retreated with insecticide and fungicide as described in paragraph 2(a)(ii)
      (iii) the imported material should be planted in an isolation area and be subjected to regular and careful inspection for a period of one year
      (iv) if at any time the imported material shows evidence of pests or diseases hitherto unknown in the country it should be destroyed by burning

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*This annex was drafted by Drs A Bellotti, C. Lozano and A. van Schoohoven (CIAT), E. Terry (IITA), and R. Booth (TPI) and subsequently modified by the Workshop.

**The distribution of these two diseases has not yet been mapped, however, cassava mosaic disease has only been reported from India and the African content, and brown streak is only known in small areas of East Africa.

***For chemical nomenclature see 1972 Ed. Pesticide Manual, Published by the British Crop Protection Council.

3. In addition to the above general recommendations:
   a) material being exported from a country where superelongation is known to be present should receive a hot water dip (50°C for 30 min) before despatch
   b) countries without cassava bacterial blight (CBB) importing material from countries where CBB is present should undertake shoot tip indexing within 20 days of germination

C. *The Movement of True Seeds*
   a) *In the donor country:*
      (i) Seed for export should be selected only from plants free from symptoms of:
         all virus and virus-like diseases
         superelongation
         mycoplasma
         cassava bacterial blight
      (ii) the best quality seed should be selected visually
      (iii) seed should be dusted with a fungicide (e.g. Thiram) and an insecticide (e.g. Malathion) powder at the manufacturers recommended level prior to shipment
      (iv) seed should be handled carefully and all handling and packing materials should be disinfected and sterilized before use
   b) *In the recipient country:*
      (i) seed which is pest-infested or obviously diseased should be destroyed on arrival
      (ii) imported seed should be planted in an isolation area and be subjected to regular and careful inspection for a period of one year
      (iii) if at any time the plants originating from imported seed show evidence of pests or diseases hitherto unknown to the country they should be destroyed by burning.

ANNEX 2*

Suggested Guidelines for the Design of Agronomic Trials For Evaluating Promising Cassava Cultivars

These guidelines are intended for the field evaluation of promising material that has already undergone preliminary yield trials.

1. *Design*
   The trials should be planted in randomized blocks with a minimum of four replications.

2. *Size of the Plot*
   Plots located at the end of each block will have 9 × 8 = 72 plants and those located in the middle will have 8 × 8 = 64 plants. In other words, the plots at the corners will have one more row than those in the middle (see Fig. 1).
   In both cases, the area occupied by the middle 24 plants will be harvested from each plot. If plants are missing at harvest they should not be replaced by border plants. The number missing should be noted.

3. *Land Preparation*
   This should be done according to best practices available to farmers in the region.

4. *Cuttings Required*
   For those varieties planted at the ends of each block an additional eight cuttings will be required for each replication.

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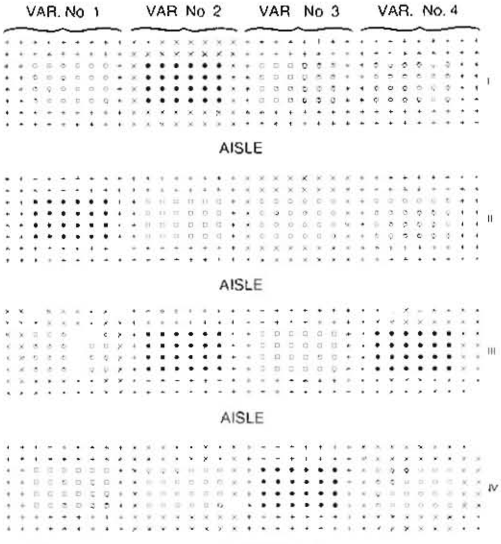
*This Annex was drafted by Drs J.C. Toro and J. Cock of CIAT and subsequently modified by the Workshop.



CASSAVA PLANTS TO BE HARVESTED

An additional 10-15% of cuttings of each variety should be prepared so as to be able to replant each block to a full stand in those cases where germination is not complete.

Blocks with less than 80% germination should be discarded. Where replanting is carried out it should be performed within 5 weeks of the original planting date.

To take care of all unforeseen situations, a minimum of 320 cuttings of each variety should be available for each trial.

The stakes used for planting should be from plants 8-18 months old and should have been grown for this period in the region where the trial is being carried out.

5. *Planting System*

Cuttings 25 cm long should be planted with a distance of 1 m between rows. Plant density will depend on soil type, etc., but should be between 10,000 and 20,000 plants/ha.

6. *Weed Control*

Weed control should be according to local practice.

7. *Insect Control*

a) *In the soil:* To control pests attacking the cuttings and hindering germination and good development of the seedlings during the initial stage of growth, from 3 to 5 litres/ha of "toxaphene" DDT 40-20 should be applied to the soil without incorporation.

b) *On the aerial parts:* To control the hornworm when very severe attacks are noticed, a contact insecticide should be used. Other insects should not be controlled as resistance to these is a varietal characteristic.

8. *Disease Control*

In order to avoid decay of the cuttings and postemergence death of seedlings, the cuttings should be dipped in a 5% solution of *arasan* (Thiram) for 3 min before planting. Planting material infected with CBB or superelongation disease should not be used.

9. *Fertilization*

Fertilization should be carried out according to the prevailing local practices with cassava. Since in many areas the crop is not fertilized it is also desirable, where resources permit, to use a fertilizer level based on agronomic recommendations in addition to the prevailing local practice.

10. *Visits Required*

A minimum of eight visits to each trial will be required as follows:

1. To select the site
2. To plant
3. After 20-25 days to replant.
4. After 2 months to observe weeds and plan weedings, if necessary.
5. After 3 months to observe diseases.
6. After 4 months to observe diseases and weeds.
7. After 6 or 7 months to observe diseases and weeds.

8. To harvest the crop.

11. *Collection of Data*
The most important data to be collected from the trial are the same as those listed in Annex 3.
In addition, the trial should record the land preparation, weed control and fertilizer practices adopted, the planting density, the number of plants germinating, replanted, and harvested.
A standard soils analysis should be carried out and climatic data obtained from the nearest meteorological station.

12. *Analysis of Data*
Data should be analyzed using standard techniques for randomized block designs. An overall analysis of the results will be made by CIAT in collaborative trials.
Pending the establishment of an international check cultivar it is suggested that collaborative trials should use both a local and a CIAT cultivar as controls.

ANNEX 3*

Suggested Criteria to Record for Evaluating Cassava Germ Plasm

A. *Indispensable*

1) Accession number
2) Accession origin
3) Root yield (for stated length of growth cycle)
4) Harvest Index (per unit time and planting density)
5) Whole root cyanide content
6) Whole root starch content
7) Ease of harvest
8) Cassava mosaic disease incidence/resistance**
9) Cassava bacterial blight incidence/resistance**

B. *Highly Valuable*

1) Germination
2) Vegetative vigour
3) Plant height
4) Branching habit
5) Leaf area retention
6) Percentage of roots that are commercial
7) Root perishability
8) Earliness
9) Consumer acceptability (food, feed, starch)
10) Incidence/resistance to superelongation
10) Incidence/resistance to thrips
12) Incidence/resistance to spidermites
13) Incidence/resistance to *Phoma*
14) Incidence/resistance to *Cercospora*
15) Incidence/resistance to stemborer
16) Incidence/resistance to shootfly

*This Annex is based on a survey conducted by Dr K. Kawano of CIAT.

**When specific screening for diseases is carried out resistance levels can be recorded. In other cases observations showing presence or absence of the disease can be noted.

C *Valuable*

1) Crude protein content (N × 6.25)
2) No. of roots
3) Root shape and colour
4) Flowering habit

Definition of Evaluation Criteria

(These definitions are tentative and are intended to serve as a basis for discussion. It is proposed that this subject be given a more detailed treatment at the Fourth International Symposium on Tropical Root Crops in August 1976.)

A1 Accession Number
name of institution and serial number of accession

A2 Accession Origin
country and specific location (if known). If from another collection cross-reference to accession number in that collection

A3 Root Yield per Unit Time
yield (small plots) in kilograms per plant
yield (replicated trials) in kilograms per hectare
time — months to nearest 30 days

A4 Harvest Index (per unit of time and planting density)

$$\text{Harvest index} - \frac{\text{fresh root weight}}{\text{total fresh plant weight}}$$

Time — to nearest 30 days
Planting density — plants per hectare

A5 Whole Root Cyanide Content
Using picric acid paper — subjective visual assessment 1 (very low) to 5 (very high). 0 (no cyanide) not yet encountered. Scale 1 is generally <30 ppm, Scale 5 is >150 ppm

A6 Whole Root Starch Content
Best expressed by stating specific gravity or dry matter content. For specific gravity there are also conversion tables available

A7 Ease of Movement
Subjective evaluation — difficult (needs extensive digging)
— normal (needs easing with spade)
— easy (pulled by hand alone)

A8 Cassava Mosaic Disease Resistance

A9 Contagious Bacterial Blight Resistance
Subjective scale
0 resistance
1 moderately resistant
2 tolerant
3 susceptible
4 very susceptible
5 completely susceptible

B1 Germination
Percent emergence 30 days after planting
Quantitative linear scale 0-10
0 = no germination
10 = 100% germination

B2 Vegetative Vigour
Subjective assessment of vigour 3 months after planting
1 very weak
2 weak
3 average
4 rigourous
5 very rigourous

B3 Plant Height
Height in metres at harvest time (using harvest age as in harvest index A4) unless plant age otherwise specified

B4 Branching Habit
Subjective assessment at harvest

1 no branches
2 slight branching
3 moderate branching
4 heavy branching
5 very heavily branched

B5 Leaf Area Retention

Subjective assessment at harvest

1 very low
2 low
3 average
4 good
5 very good

B6 Percentage of Roots that are Commercial

Subjective decision only to be applied unless the market demands a *minimal* size

B7 Root Perishability

The state of the roots 15 days after harvest

1 very poor
2 poor
3 average
4 good
5 very good

B8 Earliness

The ratio of the yield of an early harvest to the yield of a late harvest

i.e. $\frac{\text{early yield}}{\text{late yield}}$

It should be expressed as an index specifying the plant ages at harvest (at CIAT 6 months and 10 months are the ages used and large seasonal differences are not apparent but this may not be the case in other environments where alternative plant ages may be preferred)

B9 Consumer Acceptability

A subjective assessment dependent entirely on local conditions. The consumer market (e.g. food, feed, starch) should be recorded — acceptability can be graded 1-5:

1 very poor
2 poor
3 average
4 good
5 very good

B10-
B16 Disease and Insect Resistance

These should be graded on the same subjective scale as A8 and A9

0 resistant
1 moderately resistant
2 tolerant
3 susceptible
4 very susceptible
5 completely susceptible

C1 Crude Protein Content

Express this as nitrogen percentage $\times 6.25$ based on the dry matter of *peeled* roots

C2 Number of Roots

Record the number of thickened roots per plant

C3 Root Shape and Colour

Record 1) colour of a) outer skin — white or brown
b) inner skin — white, pink, yellow
2) root shape a) conical, cylindrical, regular
b) compact or extensive

C4 Flowering Habit

Record 1) whether plant is male sterile or not
2) months from planting to flowering