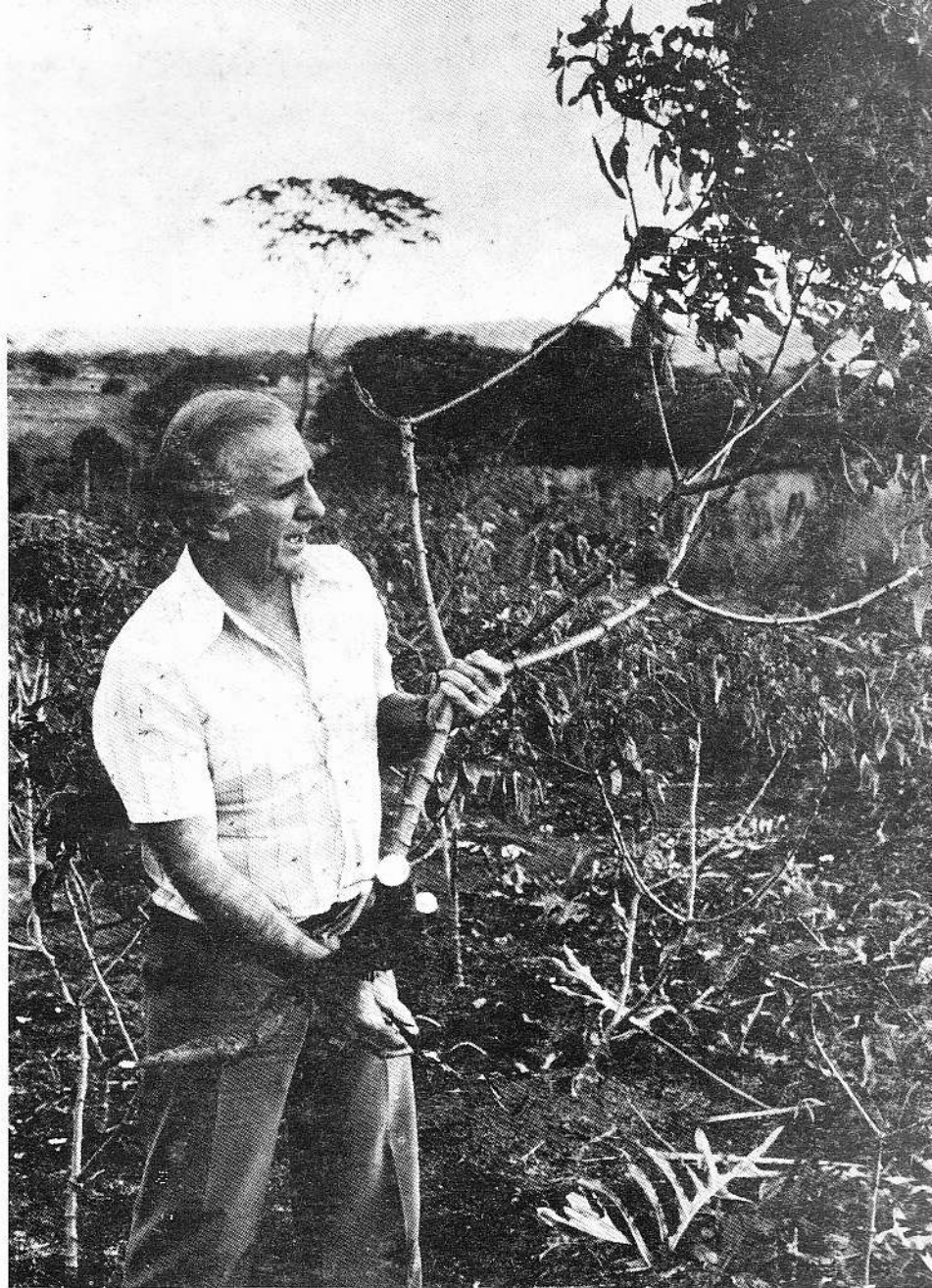




GENETIC RESOURCES OF CASSAVA AND WILD RELATIVES

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INTERNATIONAL BOARD FOR PLANT GENETIC RESOURCES

GENETIC RESOURCES OF CASSAVA AND WILD RELATIVES

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IBPGR Secretariat

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INTRODUCTION

The IBPGR sponsored two complementary working groups on cassava; the first one in 1981 at CIAT, Cali, Colombia and the second in 1982 at IBPGR Headquarters at FAO, Rome. The primary objectives of these working groups were to: review the major existing collections of cassava; advise on known genetic erosion; identify priorities for collection; advise on collection procedures; advise the IBPGR on potential depositories for international designation; advise on storage and maintenance procedures; identify any quarantine problems affecting the transfer of material; and to agree on a list of descriptors.

In addition the Board provided a consultancy to Dr. Patiño, under the guidance of CIAT, to more clearly define areas of priority and strategies for the collection of cassava and wild Manihot spp. in their centre of diversity. His report was discussed and endorsed by the second working group.

The participants of the working groups are listed in Appendix I and their recommendations to the IBPGR, CIAT, IITA and other international and national organizations, as well as to experts on cassava, are outlined throughout the Report.

The present document summarizes the information provided by the members of both working groups, Dr. Patiño's report and comments from other experts consulted. The IBPGR endorsed this report at its 1982 meeting.

1. BACKGROUND

1.1 Current World Importance

Cassava is one of the most important food energy crops in developing countries. It provides more than 50% of the caloric requirements for over 420 million people in 26 tropical countries (Hahn 1979). Most cassava is produced by small farmers cultivating marginal soils, making it an important component of the diet among a major segment of the rural poor. Further, cassava has played a vital role in alleviating famine conditions, because it provides a sustained food supply when other crops fail under drought.

The greatest part of world production is for human consumption. The starchy roots are eaten fresh (after cooking) or dried and milled for flour. It is also used to produce starch for food and is also used in paper and fabric manufacture. Leaves are preferred vegetables in central African diets and in Thailand and southern Brazil cassava is also grown for animal feed. The possibility of cassava cultivation for fuel-alcohol production is being extensively investigated in Brazil. World production data of cassava for human consumption is given in Table 1. These data are based on market production and consequently are an underestimate of the importance of the crop; the data do not include the large amount of cassava grown for home consumption. Table 1 indicates the increasing importance of cassava cultivation throughout the world, but also demonstrates the decreasing mean per hectare yields in many areas.

Table 1. Cassava production in 1969-71 and 1979-81 (Averages)

Area	Yield (t/ha)		Area (million ha)		Production (million t)	
	1969-71	1980	1969-71	1980	1969-71	1980
Africa	6.64	6.25	5.79	7.33	38.41	46.44
Asia	9.29	11.83	2.47	3.80	22.94	43.97
South America	13.87	11.73	2.48	2.59	34.45	29.93
Others	7.44	6.94	0.13	0.18	.97	1.25
World	8.89	8.77	10.88	13.84	96.76	121.47

(Source: FAO Production Yearbook Nos. 33, 34 and 35)

Work on the genetic improvement of cassava has already produced varieties with greatly increased yields under low technology cultivation. Improved varieties developed at both the International Institute for Tropical Agriculture (IITA) in Nigeria and Centro Internacional de Agricultura Tropical (CIAT) in Colombia have yields of 25 to 30 t/ha under improved low technology conditions compared to yields of 15 t/ha with traditional varieties grown under the same conditions. A yield potential of 80 t/ha for new varieties grown under advanced cultural conditions has been demonstrated at CIAT.

1.2 History

The early history of cassava is still mainly conjecture. It is apparent, however, that it is one of the older cultivated crops; it is reported to have been cultivated in northern Amazonia more than a thousand years ago and introduced to the Caribbean and Central America in the eleventh century. Cassava was introduced to the west coast of Africa in the latter part of the sixteenth century (Jones 1959), to the east coast of Africa in the eighteenth century, and to India in the early nineteenth century.

1.3 Nutritional Value

The nutritional value of cassava's storage roots is primarily caloric; its protein, mineral and vitamin content being generally low (Table 2). The energy content of cassava roots, measured on a dry weight basis, is similar to that of rice, maize and sweet potato, but its yield of Kcal/ha is significantly greater than these crops. All roots so far examined contain varying concentrations of a cyanogenic glucoside which, upon autolysis, releases gaseous HCN. For this reason the roots require some preparation such as cooking, fermenting or milling and toasting before consumption. Cassava leaves, which are commonly eaten in parts of Africa, have about 30% protein content (by dry weight).

Table 2. Composition of some vegetables, compared with pulses and starchy foods*

Product	Per 100 g of edible portion										
	Dry matter g	Energy Kcal	Protein g	Fibre g	Calcium mg	Iron mg	Carotene mg	Thiamine mg	Riboflavine mg	Niacin mg	Vitamin C mg
Starchy basic food											
Maize	88	362	9.5	1.5	12	2.5	0	0.35	0.13	2.0	0
Rice	88	354	8.0	0.5	10	2.0	0	0.25	0.05	2.0	0
Cassava	40	153	0.7	1.0	25	1.0	0	0.07	0.03	0.7	30
Sweet potato	30	114	1.5	1.0	25	1.0	0.06	0.10	0.04	0.7	30
Pulses											
Groundnut	55	332	15.0	1.5	30	1.5	0	0.50	0.10	10.0	10
Cowpea	90	340	22.0	4.0	90	5.0	0.01	0.90	0.15	2.0	0
Vegetables											
Dark green leaves	15	48	5.0	1.5	250	4.0	1.80	0.10	0.30	1.5	100
Tomato	6	20	1.0	0.6	5	0.4	0.15	0.06	0.04	0.7	25
Okra	10	33	2.0	1.0	70	1.0	0.09	0.10	0.10	1.0	25
Green beans in pod	10	34	2.0	1.0	50	1.4	0.12	0.08	0.12	0.5	20
Cassava leaves	19	60	6.9	2.1	144	2.8	8.30	0.16	0.32	1.8	82
Daily requirements**		2,530	46.0	-	500	9	1.50	1.00	1.50	17.0	30

* From Tropical Vegetables and their Genetic Resources, Grubben (1977): IBPGR

** Requirements for an adult man (55 kg) from FAO/WHO standards for East Asia; protein biol. val. 60%

1.4 Taxonomy, Ecology and Breeding Potential

The genus Manihot occurs endemically only in the western hemisphere (between southwestern USA and Argentina). Ninety-eight species of Manihot with centres of diversity in southern Mexico and northeastern to central Brazil have been described. The North and South American groups of species are remarkably disjunct; only a few examples of individual species are found in both centres.

Manihot species are all somewhat sporadic in their distribution and never become dominant in the local vegetation. Although most species are found in relatively dry regions, a few are typically found in rainforest regions. Most species seem to be heliophytes, and many are "weedy" types capable of invasion into open areas. All of the species are frost-sensitive with M. grahamii and M. anisophylla appearing to have some tolerance to seasonal low temperatures. The altitudinal limit of Manihot spp. in the tropics is approximately 2,000 m. The species of Manihot are perennial and vary in growth pattern from nearly acaulescent subshrubs to small trees with trunk diameters of 25 cm and heights of 10 to 12 m.

M. esculenta, which is not found in the wild state, is the only species widely used as a crop and M. glaziovii is used to a limited extent for rubber extraction. All of the wild species examined until now have 36 chromosomes and they are fairly compatible in crosses to M. esculenta. It is therefore to be concluded that all compatible species could be regarded as having a common genepool with M. esculenta and consequently have a high potential in cassava breeding programmes. M. glaziovii has already been used as a source of resistance to African mosaic disease for M. esculenta. There are eight other species (M. tristis, M. aesculifolia, M. angustiloba, M. anomala subsp. glabrata, M. brachyloba, M. carthagensis, M. leptophylla, M. subspicata) which may be interesting because they also form starchy storage roots and they are adapted to very different edapho-climatic areas, ranging from tropical rainforest to dry savannah. One of these species, M. tristis subsp. saxicola has been reported to produce a hybrid with M. esculenta containing a 12% protein content in its roots.

Wild Manihot can also provide genes for low cyanide content and for African cassava mosaic diseases (CMD) resistance. For some other characteristics, such as resistance to cassava bacterial blight (CBB) or high starch content in which a certain source of genes has been found, identification of more diverse sources is highly desirable. As more characteristics are evaluated, the same tendency is likely to appear and therefore the availability of a broader genetic base of cassava should be stressed.

Cultivated cassava is normally vegetatively propagated by stem cuttings, and traditionally superior genotypes have been maintained as clones. Most wild species appear to be seed propagated. Manihot esculenta and apparently all of the wild Manihot species are outcrossing, and they suffer severe inbreeding depression when they are self-pollinated.

2. MAJOR WORLD CASSAVA GERMPLASM PROGRAMMES

The major cassava research programmes were discussed during either the first or second working group and summary presentations were given on the status of research on cassava genetic resources in CIAT, IITA, Empresa Brasileira de Pesquisas Agropecuarias (EMBRAPA) and Southeast Asia (Appendix II).

Because these productive and promising programmes are relatively new the spread of new cultivars has been limited and they have not yet substituted much of the old material. It is thus an important time to conduct a coordinated and systematic collection of cassava

before the large scale replacement of local cultivars occurs.

3. REVIEW OF MAJOR EXTANT COLLECTIONS

Table 3 shows important features of the major collections of cassava. More detailed information on these and other collections is available in the IBPGR publication: "Directory of Germplasm Collections: 2. Root Crops". Some modifications and additions to this directory were recommended by the IBPGR working groups and these amendments will be incorporated in the next edition of the publication.

The areas in Latin America represented in the collections maintained in national and/or international centres, as well as the number of samples held from each area, are presented in Figure 1 and the cassava accessions maintained only at CIAT are presented in Figure 2.

4. GENETIC DIVERSITY, GENETIC EROSION AND COLLECTION PRIORITIES IN LATIN AMERICA

The information contained under this heading is based on highly subjective criteria relying mainly on the experience of Dr. Patiño in observing cassava throughout Latin America, of the members of the working group and of other scientists consulted.

4.1 Cultivated Cassava (*Manihot esculenta*)

4.1.1 Areas of genetic diversity

Areas of primary, secondary and tertiary diversity are illustrated in Figure 3.

(a) Areas of primary diversity are zones where cassava is widely cultivated and is a traditional crop. Farmers often grow simultaneously several different clones and across relatively small distances varieties change considerably.

Three principal regions are defined as having primary diversity. The first is a large area including parts of northeast, east-central, southeast and southern Brazil as well as Paraguay. This zone includes some of the most intensive cassava-producing areas of the world. A second region covers southern Venezuela, eastern Colombia and northern Brazil, extending south to the Amazon river and north along the Orinoco river. Although this part of the region is sparsely populated, cassava is a crop of primary importance in inhabited areas. Because cultivated areas may be widely separated, with limited communication, a myriad of different genotypes has evolved throughout the area. Nevertheless, much of this area has not been studied, so the estimates of genetic diversity can only be tentative. The area of diversity extends throughout much of Colombia, including the highly diverse ecological regions of the plains, tropical rainforest and Andean zone. The third area of primary diversity is centered in Nicaragua and extends south to Panama and north into Honduras. This region is also one of traditional cassava culture in small plots. In addition, this is an edapho-climatically diverse region which has lent an additional evolutionary force to the diversification of cassava germplasm.

(b) Areas of secondary diversity are those areas where cassava is grown as an important or moderately important crop but appears to be less genetically variable. This may be due to (i) rather wide distribution of only a few clones or (ii) to only moderate importance of the crop. Bolivia, a large part of the Amazon basin, southern Mexico and north-east Brazil fall in this category.

Table 3. Important features of the major collections of cassava

Collection	Details of samples	Geographical Representation	Maintenance	Availability for Exchange	Quarantine Restrictions	Documentation & Evaluation
ARGENTINA						
Dop. Prod. Vegetal Univ. Nac. del Nordeste Sargento Cabral 213 3400 Corrientes	250 cvs	S. America	Plants	Yes		
Est. Exp. Agr. El Colorado INTA R.E. Druetta C.C. 5 El Colorado, Formosa	360 cvs					
BRAZIL						
Sub-Est. Exp. do Rio do Sul Itajai EMPASC C.P. D20 88.000-Florianópolis-S.C.	200 cvs	S. Brazil	Plants	Stakes		Agronomic, disease resistance and environmental stress
Est. Exp. do Taquuari IPAGRO Rua Goncalves D., 570 90.000-Porto Alegre-R.S	250 cvs	S. Brazil	Plants	Stakes		For productivity, disease resistance and environmental stress
Inst. Agron. de Campinas(IAC) N.C. Schmidt C.P. 28 13.100-Campinas-S.P.	200 cvs	S.E. Brazil	Plants	Stakes		Agronomic characters
Escola. Sup. de Agron. de Lavras J. Vieira C.P. 37 37.200-Lavras-M.G.	300 cvs	Minas Gerais & S. Paulo (Brazil)	Plants	Stakes		Agronomic characters
UEPAE de Manaus EMBRAPA L.A. Silva Melo, C.P. 455 69.000-Manaus-AM.	110 cvs	N Brazil	Plants	Stakes		Agronomic characters
CNPME, EMBRAPA S. de Oliveira e Silva C.P. 7 44.380-Cruz das Almas-BA.	750 cvs 12 species of wild <u>Manihot</u>	Brazil & Colombia	Plants	Stakes, meristem cultures and limited no. of plants		
Univ. Fed. de Viçosa A.J. de Silveira 36.570-Viçosa-M.G.	150 cvs	Brazil & Colombia	Plants	Stakes	No	Some agronomic characters
Departamento de Agronomia Univ. de Brasília 70.910-Brasília-O.F	21 species of wild <u>Manihot</u>	Brazil	Seed	Plants Seeds		Agronomic and nutritional characters
COLOMBIA						
CIAT C. Hershey Apartado 6713 Cali	2,600 cvs 7 species of wild <u>Manihot</u>	Throughout Latin America (see Fig. 2), Malaysia & Thailand	Plants, meristem culture and some seeds	Yes	Only in vitro & true seeds can enter country	Agronomic characters, pest & disease resistance, availability and HCN content. Data computerized
Cen. Nac. de Inv. Agro. Palmira ICA E. Lozada A.A. 233 Palmira	360 cvs					
COSTA RICA						
CATIE H. Heinze Apartado 74 Turrialba	153 cvs	Mostly Costa Rica	Plants	Stakes		Catalogue available from CATIE
CUBA						
CEMSA A. Rodriguez N. Apartado 6 Santo Domingo Villa Clara	176 cvs	Mostly Cuba				

Table 3. Important features of the major collections of cassava (cont.)

Collection	Details of samples	Geographical Representation	Maintenance	Availability for Exchange	Quarantine Restrictions	Documentation & Evaluation
INDIA						
Central Tuber Crops Research Institute V.M. Nayar Trivandrum 695017 Kerala	1,279 cvs	Mostly India; also S.E. Asia, S. America Africa	Plants	Yes	Permit needed	
INDONESIA						
Sukamandi Res. Inst. for Food Crops B.H. Siwi Subang W. Java	700 cvs	Mostly Indonesia	Plants	Yes	Permit needed	
MEXICO						
Campo Agr. Exp. Cotaxtla CIAGOC-INIA G.A. Galindo R. A.P. 429 Veracruz	266 cvs	Mexico, Colombia & other Central & South American countries	Plants	Yes		
NIGERIA						
IITA N.Q. Ng P.M.B. 5320 Ibadan	1,286 cvs	East & West Africa, Venezuela, Colombia & Brazil		Seeds & meristem culture	Strictly observed	Agricultural & nutritional characters; pest & disease resistance
National Cassava Centre Nat. Root Crops Res. Ins. N. Ukpa P.M.B. 1006 Umushia, Imo State	1,060 cvs	Mostly Nigeria	Plants & Seeds	Seeds	Only seed can enter the country	Agronomic & nutritional characters, pest & disease resistance
PERU						
Est. Exp. La Molina INIA D. Acha de Zapata Apartado 2791 La Molina Lima	294 cvs	Andean region, Brazil & Paraguay	Plants		Certificate needed	
PHILIPPINES						
Philippine Root Crops Research & Training Center M. Villanueva Visaya State Coll. of Agr. Baybay, Leyte 7127	322 cvs	S.E. Asia & South America	Plants			Several characters
THAILAND						
Root Crop Branch S. Sinthuprama Field Crop Division Dept. of Agriculture Bangkhen, Bangkok 10900	350 cvs	S.E. Asia & Latin America	Plants	Yes	Imports from India, Indonesia, Brazil & Africa prohibited	Morphological, agricultural & nutritional characters; pest & disease resistance
VENEZUELA						
Programa de Raíces y Tubérculos A. Montaldo Univ. Cen. de Venezuela Maracay	218 cvs	Most from Venezuela	Plants	Yes	Phytosanitary certificate required	
Est. Exp. de Araure CIARCO-FONIAFA C. Arias Araurej Edo. Portuguesa	144 cvs	Colombia, Mexico & Venezuela and other Cen. and South American countries	Plants			
ZAIRE						
Programme National Manioc Station de M'Vuazi INERA T.P. Sigh Gare Mweke M'Vuazi, Bas-Zaire	250 cvs	Zaire	Plants & Stakes Seeds			

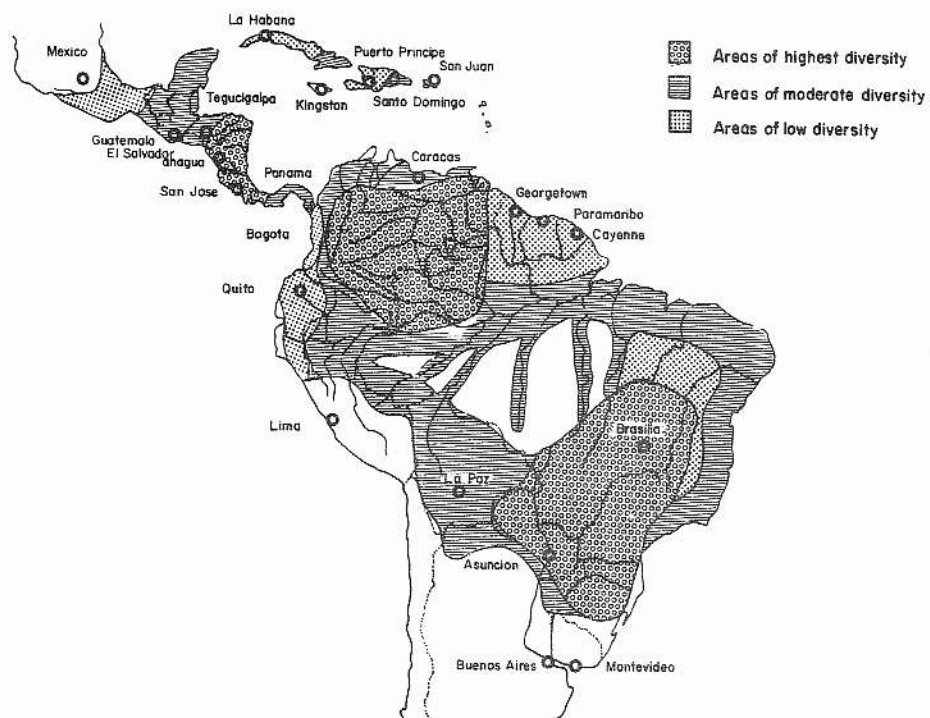


Figure 3. Areas of diversity of cassava in Latin America



Figure 4. Probable areas of genetic erosion of cultivated and wild Manihot spp. in Latin America

(c) Areas of tertiary diversity for cassava include zones where cassava is either a minor crop, where varieties seem to be rather similar across broad zones or information is lacking on the extent of cassava cultivation and diversity.

4.1.2 Danger of genetic erosion

In most areas of genetic diversity of cassava, it is a traditional crop for small farmers. As yet there has been relatively little displacement of land varieties by new ones. Nevertheless, with improved technology being developed by national and international institutes, new varieties will gradually be adopted on a larger scale. Thus there should not be major delay in attempts to preserve the existing genetic diversity. Little information exists on genetic erosion due to land clearing and development projects. Estimates of principal areas of potential genetic erosion of both cassava and the wild species are illustrated in Figure 4.

4.1.3 Areas of priority for collection

Collection priorities for cassava are outlined in Figure 5. Determination of priorities is based on consideration of areas of diversity, areas already collected, and areas in danger of genetic erosion for which information is available. Nicaragua, Honduras, Venezuela, Peru, Brazil, Bolivia and Paraguay have large regions designated as highest priority. Areas of Brazil of highest priority include parts of the Amazon basin (which has only been sparsely explored) and the southwest along the Paraguayan and Bolivian borders. Also smaller areas in the central and northeastern regions have not been fully collected. In Central America little collection has been done to date; thus the areas of collecting priorities are similar to those for areas of diversity.

4.2 Wild Manihot Species

4.2.1 Areas of diversity

Studies of centres of diversity of Manihot species have been carried out principally by Rogers and Appan (1973) and Nassar (1978). This work and evidence provided to the working groups form the basis for the conclusions below.

(a) Areas of primary diversity of wild Manihot species are (i) central, eastern and southern Brazil, Paraguay and northern Argentina, and (ii) from the western coast of Mexico across to the eastern coast and down to the southern end of the central plateau.

(b) Areas of secondary diversity extend through Central America and along the Caribbean coast of South America to north-central Venezuela. The lowlands of Bolivia, the upper Amazon region of Peru and parts of Brazil, and the Guyanas, although relatively unknown with respect to diversity of Manihot species, should be explored. Evidence of recent documentation of wild Manihot in farms in the Santa Cruz region (Bolivia) near Paraguay has been reported (Rea 1969).

(c) Areas of tertiary diversity extend through nearly all areas of lowland tropical Latin America. Those areas not included as areas of primary or secondary diversity are considered as areas of tertiary diversity.

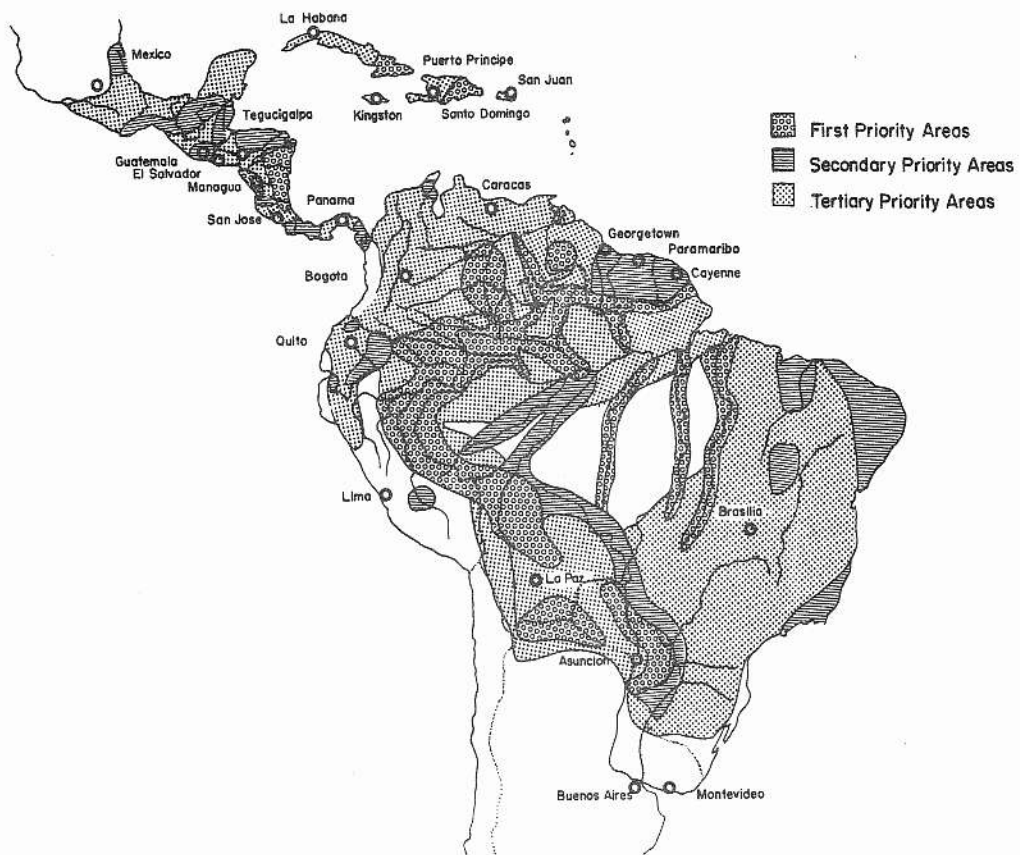


Figure 5. Priority areas for collecting cassava in Latin America

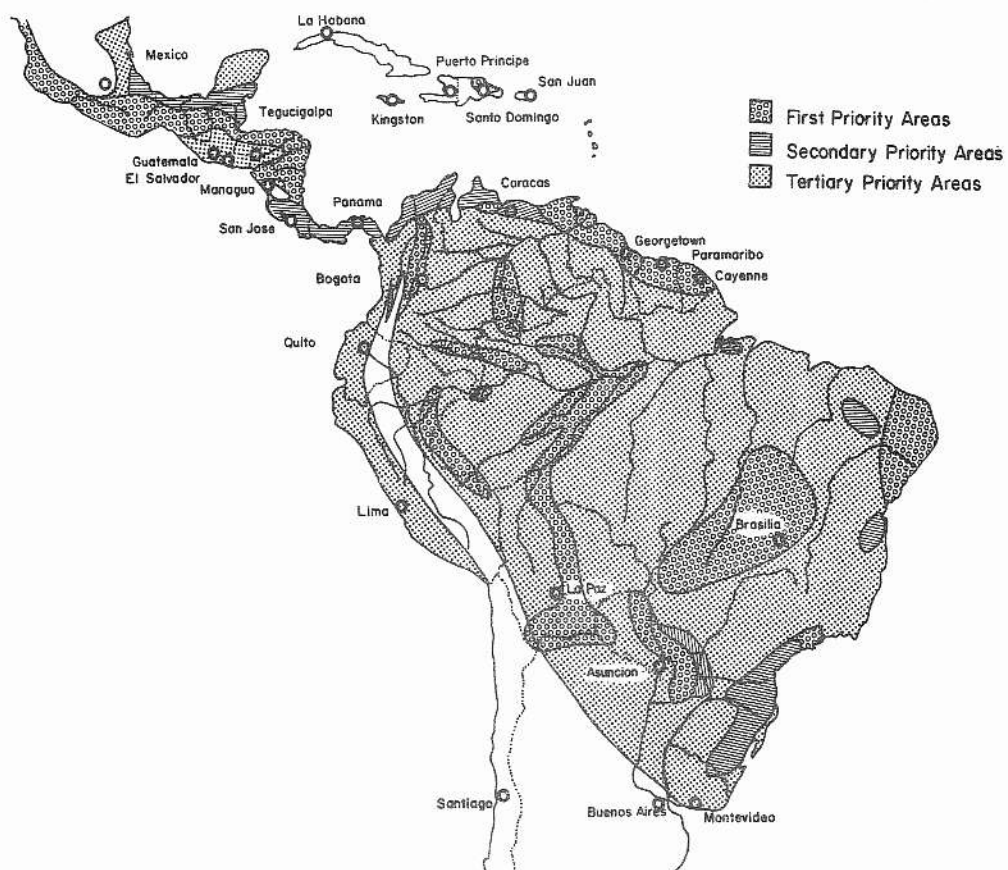


Figure 6. Priority areas for collecting wild *Manihot* species in Latin America

4.2.2 Danger of genetic erosion

Little scientific information exists on the extent of the present or potential genetic erosion. Experts in South America have expressed concern about loss of germplasm due to extensive land clearing and development projects throughout the continent. Figure 4 shows areas in which there is danger of genetic erosion. Apart from collection of material, the maintenance of reserves may be feasible in some countries where Manihot spp. exist naturally.

4.2.3 Areas of priority for collection

Because relatively little collection of wild species has taken place, the areas defined with high diversity can essentially be considered also the areas of priority for collection (Figure 5). Since some collections have been made in the Brazilian states of Goiás, Pernambuco, Paraíba and Ceará and along the western coast of Mexico, these regions could receive less emphasis initially. However, they still remain first priority areas due to the diversity of species there.

4.3 Collection Strategies

Within the priority collection areas, centres were identified which could serve as bases from which to make collection expeditions. These centres could provide the minimum of adequate facilities and resources necessary for making collecting missions. Figure 7 shows the location of these centres. Since there is overlap between some of the areas of priority for cultivated and wild Manihot, it is desirable to collect both types in these areas.

In order to accelerate action the IBPGR, in cooperation with CIAT and national organizations, has agreed to support collecting missions in the areas of priority in Latin America before publication of this report. ^{1/}

5. GENETIC DIVERSITY, GENETIC EROSION AND COLLECTION PRIORITIES IN AFRICA

Although Latin America is the centre of origin and the primary centre of diversity for cassava and shows a richer genetic variability of M. esculenta than Africa, the collection and preservation of Manihot germplasm in Africa should not be neglected. African material is well-adapted to local conditions and is important for breeding.

Cassava was introduced in the delta of the Congo River during the latter part of the sixteenth century (Jones 1959). It quickly spread inland and was adopted in the traditional farming systems in different agro-ecological regions of tropical Africa. Although commonly propagated by cuttings, self-sown seedlings frequently become established, and the more successful of them were maintained by vegetative propagation. This process gave rise to increased diversity of the crop in Africa. It arose across a broad band covering much of tropical Africa with highest diversity occurring in the western and central areas. Moderate diversity occurs in east Africa and on the island of Madagascar (Figure 8). Possible bases for collection are shown in Figure 9.

^{1/} Information on collection missions in Colombia, Cuba, Guatemala, Mexico, Peru and Venezuela in 1982-83 and on the transfer of germplasm from existing collections in Brazil, Paraguay and Argentina to CIAT headquarters in Cali, Colombia in 1982-83 can be obtained from the IBPGR secretariat.



Figure 7. Primary and secondary bases for collection of cassava and Manihot species in Latin America

Prior to defining collection priorities and strategies for cassava collecting in Africa a survey needs to be carried out to see which areas have already been collected and where there is a threat of loss of local material.

6. REVIEW OF PROCEDURES FOR CASSAVA AND WILD MANIHOT SPECIES COLLECTION IN THE FIELD

The working groups discussed the need to make collectors aware of some of the special requirements in the collection of cassava and wild Manihot species. Few persons are experienced in Manihot collection and therefore it is necessary to make procedures more widely known (see Appendix III and Appendix IV).

7. MAINTENANCE OF MANIHOT GERMPLASM

7.1 Proposed International Repositories

Existing collections of cassava are widely scattered and exchange procedures are largely undefined. Furthermore, no provision has been made for duplication for most collections, thus presenting a high risk of loss of valuable germplasm. The working groups recognized the need for an internationally organized network of repositories for Manihot species, including cassava (Table 4).

Key consideration in the designation of cassava germplasm repositories are:

- a) to have at least two duplicates for each type of material;
- b) to avoid introduction of diseases into non-infested areas; and
- c) to select institutes/countries with active cassava germplasm programmes.

Every effort should be made by the designated repository to adopt meristem culture techniques as the principal means of conservation and duplication, as outlined in Appendix V.

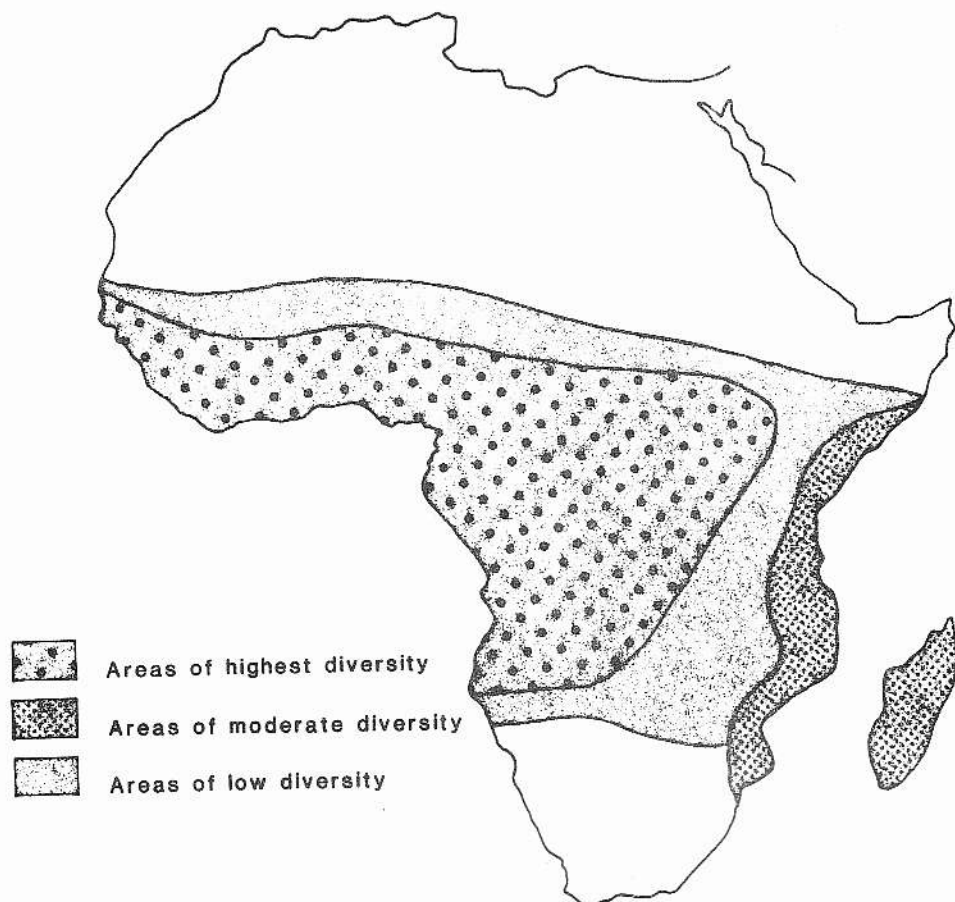


Figure 8. Areas of genetic diversity of cassava in Africa

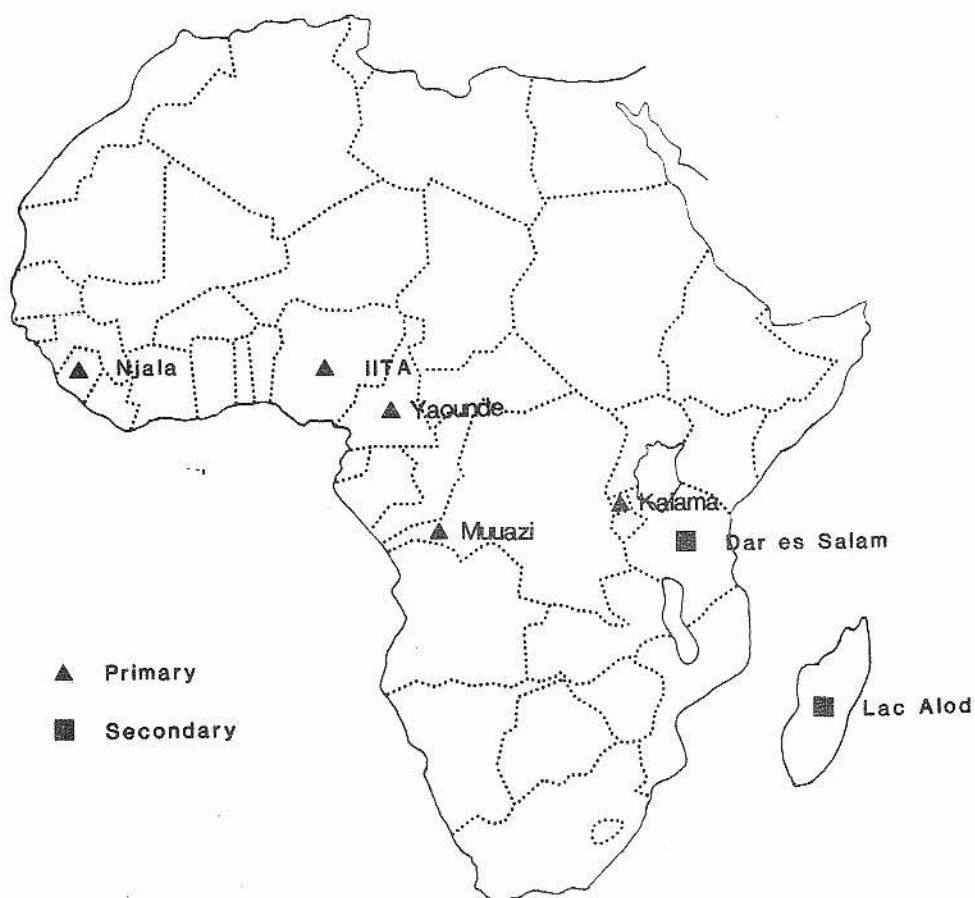


Figure 9. Bases for collection of cassava in Africa

Table 4. Possible sites for collections of cassava and Manihot spp.

Germplasm to be held	Institution/Country to be Primary Repository				
	CIAT	IITA	EMBRAPA/CNPMP (Brazil)	INIA (Mexico)	National Research Institutes in Africa
<u>Manihot esculenta</u> from Latin America	C & S *	-	C & S	-	-
<u>Manihot esculenta</u> from Africa	-	C & S	-	-	C & or S
Wild <u>Manihot</u> species from Meso-America	C & or S	-	-	C & or S	-
Wild <u>Manihot</u> species from South America	C & or S	-	C & S	-	-

* C = clonal; S = seed

7.2 Maintenance of Collections

Cassava germplasm can be maintained either vegetatively (field plantations and meristem culture) or through seeds. Major considerations and recommendations on each of these three methods as outlined by the IBPGR working groups are provided in Appendix V.

7.3 Reserves

Natural protected areas such as state parks in areas where wild Manihot species are threatened can also be important in preserving germplasm. Maintenance in natural sites provides security in face of the often difficult task of keeping wild species in cultivation, and it can preserve very large gene pools. Protected areas should complement, not substitute, the collection and preservation of these materials in germplasm repositories where they are available for breeding work and exchange.

8. QUARANTINE

- Quarantine regulations are very uneven and the increasing frequency of introductions raises the likelihood of introduction/establishment of pathogens. Therefore, measures should be taken to prevent transmission and dissemination of cassava pests and diseases between countries and regions.
- Etiological knowledge and accurate diagnosis of virus-like diseases is fragmentary, therefore rigorous virus-indexing programmes should be developed before materials are transferred between regions that have different diseases.
- Trained collectors should be used who may be able to detect potential disease and pest problems and are aware of quarantine procedures.
- Seeds appear to have a higher probability of being disease-free than vegetative material and should be given a high priority in the transfer of cassava germplasm. However, the usefulness of seed transfer will depend on the recipient's material and experience in making selections in segregating populations.

e) Meristem culture has been accepted by various countries as the safest means of receiving vegetative cassava material. It is the recommended method for the transfer of vegetative material.

f) The application of meristem techniques in the movement of clean germplasm necessitates qualified personnel and consequently training is of paramount importance. Both CIAT and IITA have considerable expertise in meristem culture and their training programmes should play an important role in the dissemination of these techniques.

A synthesis of the recommendations made by both IBPGR working groups on the transfer of cassava germplasm is presented in Appendix VI.

9. CHARACTERIZATION AND DOCUMENTATION

A draft descriptor list for cultivated cassava was prepared by the First working group, circulated by IBPGR among the experts, and discussed and finalized by the Second working group (Appendix VII). The descriptors follow the IBPGR guidelines and are primarily based on CIAT, Centro Agronómico Tropical de Investigaciones y Enseñanza (CATIE - Costa Rica) and Centro Nacional de Recursos Genéticos (CENARGEN - Brazil) descriptors.

The Second working group recognized the urgency for a first global data base for cassava germplasm covering the IBPGR minimum descriptor list (under "Characterization and Preliminary Evaluation", Appendix VII).

The Second working group also recognized the lack of basic collection information for many accessions of existing collections. In order that future collections are accompanied by more complete background data, a standardized field collection format was proposed (Appendix IV). This form is simplified so that it can be utilized by both inexperienced and experienced collectors and it is also designed for both cultivars and wild species.

As collection of Manihot species expands in the future, it will become necessary to have descriptors for their characterization and evaluation. The descriptor list (Appendix VII) would probably be inappropriate for wild Manihot species, but the general feeling among the experts consulted is that the present state of knowledge of the wild species is inadequate for the preparation of a more satisfactory list. This should await further collection of living specimens. However, a simplified taxonomic key for field collectors of wild Manihot, describing collections to some level between genus and species, should be prepared.

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APPENDIX I

PARTICIPANTS IN THE TWO CASSAVA WORKING GROUP MEETINGS

A. Second Working Group on Cassava Genetic Resources, convened by IBPGR in Rome, 2-4 February 1982

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APPENDIX I
(Continued)

The following persons attended part of the meeting to provide specialist contributions:

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B. First Working Group on Cassava Genetic Resources, convened by CIAT on behalf of IBPGR in Cali, Colombia, 9-11 December 1980

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MAJOR WORLD CASSAVA PROGRAMMES

A. EMBRAPA (Brazil)

Brazil is the main centre of origin and diversification of species of the genus Manihot, presenting valuable genetic variability which encompasses primitive land-races, improved cultivars of M. esculenta and many wild species. Cassava is cultivated throughout Brazil, from 4° N to 33° S latitude with 30% of the world production. Brazil was the world's largest producer in 1978.

The roots of cassava are important in Brazil as the principal source of food for the people of the north and northeastern regions. Recently, the promising new alternative of cassava as raw material for alcohol production has opened.

Despite the great significance of cassava, very little is known about the genetic variability of primitive and cultivated cassava and wild species existing in Brazil. Few advanced cultivars have been obtained through systematic breeding work.

The principal objective of cassava genetic resources work is enlargement and enrichment of the genetic variability through introductions of collected primitive and cultivated material, as well as collection of wild species - whose genetic characters potentially useful for the improvement of M. esculenta - are still little known.

Considering the different Brazilian ecosystems where cassava is cultivated, EMBRAPA, through its National Centre for Genetic Resources (CENARGEN) and in agreement with the National Cassava Centre (CNPMPF), has established cassava collections in regions representative of those ecosystems. Thus, the network of Cassava Germplasm Banks consists of six collections, located in the coastal north region (Belem, Para State), continental north region (Manaus, Amazonas State), northeast region (Pacajus, Ceará State), southeast region (Linhares, Espírito Santo State), south region (Itajai, Santa Catarina State) and the National Centre of Cassava and Fruit Research (Cruz das Almas, Bahia State), the latter being the Central Bank of Cassava Germplasm.

The National Genetic Resources Programme of Cassava intends to site an additional cassava germplasm bank in the centre-west region. In addition to the above-mentioned major cassava collections, there are smaller ones, distributed throughout the country, belonging to universities or state experiment stations (see Figure 10).

Maintenance of cassava germplasm in Brazil is still in vivo. Although the tissue culture technique has been used for germplasm exchange, multiplication, and clonal cleaning, it is not yet used for long-term conservation. However, it is CENARGEN's objective to preserve, in the future, the cassava germplasm in meristem form.

At present there are about 1,500 cultivars maintained in collections distributed throughout the country. About half of these cultivars are kept in the Cassava Central Bank in Cruz das Almas, Bahia, where evaluation and characterization of 520 cultivars have already been made and the data is computerized. The characterization and evaluation information for each accession, now partially stored in the CENARGEN Data Bank, will be periodically published in a cassava germplasm catalogue.

APPENDIX II
(Continued)

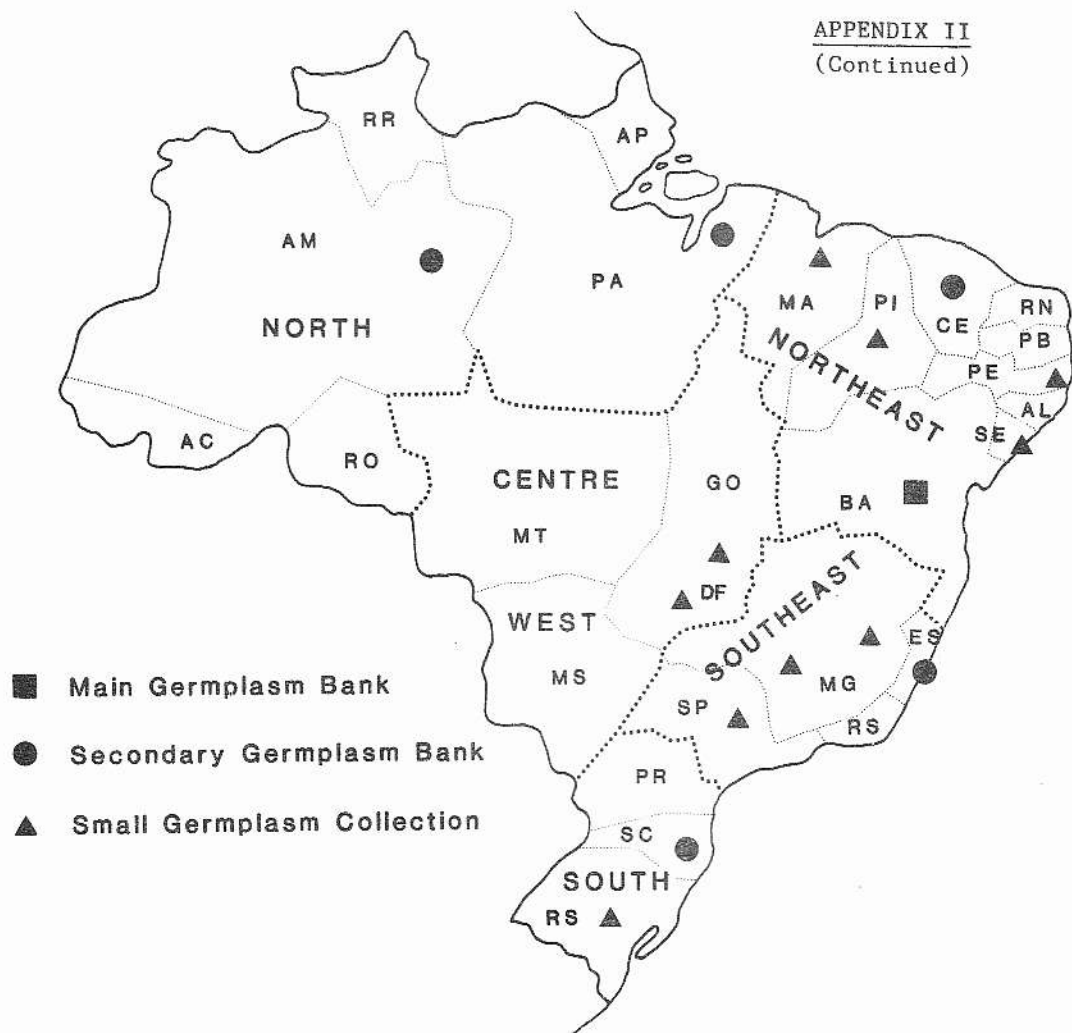


Figure 10. Cassava germplasm banks in Brazil

Germplasm Collections

The expansion of the area of cultivation of cassava in Brazil for both fuel and food production, and the desirability for yield increases, require intensive breeding work for cassava in Brazil. Consequently, availability of wide genetic diversity in the living collections is critical.

The incorporation of new genes from wild species to the crop, especially genes for disease resistance, may prove to be a successful line of work. The feasibility of such a technique is shown by IITA researchers in Africa by their successful incorporation of genes from M. glaziovii into M. esculenta.

Priority for collection is based on the genetic diversity present, the danger of destruction of the habitats of wild species, the speed of replacement of old local selections by advanced cultivars and the history of collecting work in the area.

Collection objectives are:

- 1) to incorporate landraces of cassava into the cassava bank network and
- 2) to collect samples of every wild species of Manihot occurring in Brazil, and maintenance of such germplasm in living collections or active banks, so that its potential for the improvement of cassava can be ascertained.

The schedule of field trips is:

- 1981 - One expedition to the States of Espirito Santo, Bahia, Sergipe and Alagoas (Already completed).
- 1982 - One expedition to the States of Pernambuco, Paraiba and Rio Grande do Norte.
- 1983 - One expedition throughout the State of Goias.
- 1984 - One expedition to the States of Amazonas and Acre and the Federal Territory of Rondonia.
- 1981-1984 - Occasional collection of Manihot germplasm during each collection mission undertaken by CENARGEN scientists for other priority crops.

Methodology and Strategy of Work

October is the ideal month for the collection of stakes and whole plants in Brazil; March and April are the best months for seed collection. Information on the timing of the crop in the very diverse areas of the country is being compiled as well as information on the life cycle of the wild species occurring in each area so that the schedule of each field trip will guarantee the best possible results.

All the samples collected will be first planted or germinated at CENARGEN in Brasilia, for multiplication. Later they will be transferred to the most adequate germplasm bank for characterization, evaluation, additional multiplication and, eventually, for direct use in breeding programmes.

The herbarium specimens of wild Manihot species will be carefully studied by CENARGEN specialists in the genus Manihot. Information on the availability of seeds and/or living plants will be included in the herbarium labels.

B. CIAT

An extensive collection of cassava cultivars from South America had already been assembled at CIAT when its board of trustees approved the formation of a root and tuber crops programme in mid-1971. One of the first major decision of the programme was that efforts would be concentrated on cassava, rather than on the whole range of tropical root crops. The CIAT cassava programme has defined its objectives as follows:

- a) To develop cultural practices based on low input levels and to develop germplasm which is responsive to the improved management in order to increase cassava yield in areas where cassava is presently grown.

APPENDIX II

(Continued)

- b) To develop germplasm and management practices based on medium input levels in order to increase cassava production in the acid infertile soils of the lowland tropics.
- c) To develop systems that can be used to reduce the perishability of cassava permitting a more efficient use of cassava for either direct or indirect consumption by humans.
- d) To provide assistance and information to national and local agencies on the evaluation and adaptation of the new technologies to local conditions.
- e) To strengthen national cassava research and development programmes so that they can effectively carry out their role.

The cassava programme is divided into three major sections which have considerable overlap. The first section is devoted to developing and testing production technology, the second develops improved processing and utilization methods, and the third adapts and transfers technology to specific regions.

The basis for genetic improvement of the crop at CIAT is the collection of about 2,800 accessions from most of the cassava-growing countries of the Americas. It is maintained as a field collection and is in the process of being transferred also into plantlet maintenance under laboratory conditions. Characterization and evaluation is being carried out at CIAT headquarters as well as four other sites in Colombia representing different edapho-climatic conditions. Germplasm is freely available to interested persons or programmes as true seed or meristem tip cultures. Considerable effort also is being applied to training of scientists from national programmes in the maintenance, transfer and subsequent utilization of cassava germplasm.

C. IITA

Since cassava's introduction into the African continent at the end of the 16th century, it has become widely accepted, being the preferred staple food in many parts of the continent. African cassava accounts for about 40 percent of the world production and more than 50 percent of the area is devoted to cultivation of this crop. In Africa the trend in production shows a steady increase.

Since cassava is very tolerant to drought, its acreage in the drought-affected areas in northern Africa has been dramatically increasing. Many African countries prone to drought are now emphasizing cassava cultivation.

Although cassava has played such an important role in Africa, improvement in this crop has been given relatively little attention. The average cassava yield in Africa is slightly over 6 tons per hectare: about half of that in South America. Many cassava diseases and/or pests are widespread in Africa. Cassava mosaic disease is present and serious only in Africa and India and cassava bacterial blight disease is very serious in several African countries. Recently cassava mealybug and green

APPENDIX II
(Continued)

spider mite have been accidentally introduced into Africa from Latin America, causing serious damage in major cassava producing zones. It must be emphasized that the future development of improved cassava varieties, utilizing African germplasm, can make a useful contribution to the economy and to the quality of life on the continent.

The International Institute of Tropical Agriculture (IITA) established the Root and Tuber Improvement Programme in 1971. Although this programme covers cassava, yams, sweet potato, and cocoyams, cassava receives the highest priority. The broad objectives are to develop improved cultural practices and varieties with high stable yields, high quality, and plant characteristics suitable for efficient cropping systems.

Programme objectives

The specific objectives for cassava improvement at IITA are:

- 1) high yield in terms of dry matter production per unit of land and time in both monoculture and mixed cropping systems;
- 2) resistance to, and cultural control of, economically important diseases and insects;
- 3) improved quality in terms of consumer acceptance, nutritional value, and processing characteristics; and
- 4) improved plant type: canopy and root characteristics. and adaptation to a wide range of environments.

At IITA a large quantity of germplasm has been assembled in seed form from Africa, Latin America (especially from Brazil and CIAT) and Asia. This has been evaluated for resistance to the major economic diseases and for agronomic traits. Sources of resistance to diseases including CMB, CBB, and anthracnose disease and to pests such as cassava mealybug and green spider mite have all been identified and are being used for breeding resistance to these pests.

The Root and Tuber Improvement Programme now consists of a core programme at IITA and two cooperative cassava programmes in Nigeria and Zaire. Through staff visits and the exchange of information and material, the programme has established cooperative links with many national programmes and institutions in Africa, Asia and Latin America (particularly CIAT).

D. SOUTHEAST ASIA

The crop was introduced into India in the early nineteenth century and spread into other parts of the region. The indigenous variability is rather limited, and maintained as locally-adapted clonal populations.

Cassava is produced in nearly all countries of Southeast Asia. Indonesia is the principal producer in the region with an area of 1.3 million hectares and production of 12.1 million tons in 1977 (FAO, 1977). The other major producers in the region are Thailand and India. Total production of cassava in Southeast Asia has increased four-fold between 1969-71 and 1977-79, from 3.2 to 14 million tons.

APPENDIX II

(Continued)

Cassava is grown primarily for human consumption as a supplement to rice in most Southeast Asian countries except for Thailand. Thailand is not only the second largest producer in the area, it is also the principal cassava-exporting nation in the world, with exports of over 6 million tons of dried cassava in 1981.

Cassava collections are held by various national programmes, including Indonesia (700 accessions), Malaysia (865 accessions), India (1,800 accessions) and Thailand (348 accessions). In all of these programmes, however, the number of local cultivars is small, and most of the accessions have resulted from introduction of true seed with a limited genetic base.

Evaluation of germplasm has been made in India, Malaysia, the Philippines and Thailand, and active breeding programmes exist in these four countries.

PROCEDURES FOR CASSAVA AND WILD MANIHOT SPP. COLLECTION IN THE FIELD

A. Manihot esculenta

1. For cultivated cassava, collection in the form of stem pieces (stakes), the normal propagative material, is most appropriate. There may be some instances when it is inconvenient to collect stakes, in which case true seeds may be collected. Since cassava is a heterozygous plant, segregation occurs in a population of plants from true seed.
2. Plants to be sampled in the field should be nearly mature to mature if possible.
3. Pull plant before cutting any branches to inspect roots for symptoms of "frog skin" disease, a virus-like systemic disease which should not be introduced into germplasm maintenance areas.^{1/}
4. Avoid cutting stakes from clones affected by bacteriosis, superelongation or virus diseases.
5. Cut a few stakes of about 50 cm. each. Tie together stakes from the same clone, and label with two water resistant tags. The tags should contain information on: Date, Common name and Field collection number.
6. Complete collection forms for each collection (See Appendix IV).
7. Treat stakes with a fungicide/insecticide mixture. A treatment used at CIAT consists of 3,000 ppm each of Orthocide (Captan) and Bavistin (BCM) plus 1 ml/l water of Malathion EC. Treatment is for five minutes after which stakes are allowed to dry.
8. Cut ends of stakes may be covered with paraffin to prevent desiccation. If possible stakes should be maintained in a shaded cool area for the duration of the expedition.
9. At the germplasm repository, plant the stakes from each clone in small well-labelled plots for evaluation and multiplication if necessary.
10. If meristem culture facilities are to be used, some of the stakes collected, or those later produced from the multiplication phase, should be covered at the upper end with paraffin to prevent desiccation. Plant the stakes in small pots and use the sprouts as a source of meristems.

B. Wild Manihot spp.

1. Seed collection should be the primary objective optimizing genetic diversity and ease of collection.
2. In the field, a bag is placed over an unripe fruit until dehiscence takes place.

^{1/} See "Field Problems in Cassava", CIAT, 1976, for symptoms of diseases mentioned in this Appendix.

APPENDIX III

(Continued)

3. The bags and fruit are collected after maturation.
4. Stakes may also be collected according to "procedures for cassava collection in the field" outlined under heading A. Rooting potential of stakes vary widely among species.
5. For those species which set no fruit and for which rooting from stakes is not possible, the whole plant must be collected.
6. The optimum collection time for wild species (stakes and whole plant) is at the end of the dormant period, i.e. at the end of the dry season/beginning of the rainy season, when the new growth begins.
7. A collection form should be filled out at the time of collection (See Appendix VI).
8. A pressed botanical specimen should accompany each accession. A photograph is also useful.

APPENDIX IV

IBPGR COLLECTION FORM (MANIHOT)

Descriptors in this column MUST be filled in

GENUS: _____

SPECIES: _____

SUBSPECIES: _____

COLLECTOR'S NUMBER: _____

COLLECTING INSTITUTE: _____

DATE OF COLLECTION: _____

COUNTRY OF COLLECTION: _____

PROVINCE/STATE: _____

LOCATION OF COLLECTION SITE

nearest town/village: _____

distance (in Km): _____

direction: _____

LATITUDE OF SITE: _____ N S

LONGITUDE OF SITE: _____ E W

ALTITUDE OF SITE: _____ (m)

COLLECTION SOURCE (circle one)

wild	1	village market	5
farmland	2	commercial market	6
farmstore	3	institute	7
backyard	4	other (specify)	8

STATUS OF SAMPLE (circle one)

wild	1	primitive cultivar/landrace	4
weedy	2	advanced cultivar (bred)	5
breeder's line	3	other (specify)	6

LOCAL NAME: _____

NUMBER OF PLANTS SAMPLED: _____

PHOTOGRAPH (circle one): yes no

Photo number: _____

TYPE OF SAMPLE (circle one)

vegetative	1	seed	2	both	3
------------	---	------	---	------	---

HERBARIUM SAMPLE (circle one): yes no

QUANTITY OF MATERIAL (number of seeds or plant

samples): _____

Descriptors in this column SHOULD be filled in

PART USED (circle one): root shoot

PRIMARY USE

GROWTH HABIT

human food - fresh	1	tree	1
human food - dried/processed	2	shrub	2
animal food - fresh	3	vine	3
animal food - dried/processed	4	other	4
starch extraction	5		
other (specify)	6		

SPECIAL QUALITY OF ACCESSION

yield	1	disease resistance	5
starch content	2	pest resistance	6
eating quality	3	edaphic tolerance	7
storability of roots	4	other	8

DISEASES/PESTS PRESENT AND SEVERITY

(Severity: 1 = Little damage; 2 = Moderate damage; 3 = Severe damage).

DISEASES/PESTS

SEVERITY

ASSOCIATED WILD & WEEDY SPECIES & CROPS

(specify): _____

TOPOGRAPHY (circle one)

VEGETATION (circle one)

marshy	1	rainforest	1
food plain	2	wet forest	2
riparian	3	moist forest	3
flat	4	dry forest	4
rolling hills	5	very dry forest	5
hilly	6	thorn woodland	6
mountainous	7	desert scrub	7
other	8	desert	8
		other	9

SOIL TEXTURE (circle one)

sandy	1	clay	5
sandy loam	2	silt	6
loam	3	organic	7
clay loam	4	other	8

DRAINAGE (circle one)

poor moderate good excessive

SLOPE (circle one)

level or nearly level (< 4°)	1
moderate slope (4-14°)	2
steep slope (> 14°)	3

OTHER OBSERVATIONS: _____

APPENDIX V

RECOMMENDATIONS OF THE WORKING GROUPS ON THE MAINTENANCE OF CASSAVA GERMPLASM COLLECTIONS

For storage and maintenance the following points were outlined by the IBPGR working groups:

1. Clonal materials should be maintained as field plantations according to the following criteria:
 - 1.1 Area where materials are maintained should be as free as possible of disease and insect pests which could result in losses of clonal material or create difficulties in transfer of clean planting material to other sites.
 - 1.2 A minimum of 3-5 plants is considered necessary for practical maintenance. If a plantation is also to be used as a source of production of stakes for planting of other trials, more plants will be required.
 - 1.3 Cassava can be maintained in field plantings as a perennial plant, but periodic renewal every one or two years is desirable to avoid problems of excessive vegetative growth, cumulative disease and insect problems and to generally facilitate maintenance.
 - 1.4 The distance between plots of different clones should be adequate to prevent undue competition among the plots.
2. As techniques for cassava meristem culture are now well-developed, the clonal materials, wherever possible, should be converted into meristem cultures as a means of storage. Meristem culture is a viable system for clonal repositories and for inter-country exchange because of its freedom from micro-organisms, small space requirements and high propagation potential. Recent developments at CIAT have shown that cassava meristem-derived cultures maintained in vitro under "minimal growth" conditions (reduced temperature and altered media composition) slow their growth rate to the degree that the culture transfer period is extended to at least two years. Viability rates near 100% secure the retrieval of 3-6 plants per culture stored as single shoots with high phenotype stability. Further investigations on the storage of multiple shoot cultures should provide higher propagation rates. The storage room (4 x 3 x 2.5 m) at CIAT can hold over 3,000 accessions, replicated 5 times, which as field plantation would otherwise use nearly 8 hectares of land.

Research needs to be continued to combine meristem culture with cryogenic methods (e.g. use of liquid nitrogen) as a means to store germplasm in the future, and to evaluate phenotype stability over long-term storage.

3. True seeds also provide a means of preserving genepools and they have the advantage of being easily handled in storage. Seeds stored at 5°C and 60% RH at IITA have maintained their viability for 10 years. However, this method has certain limitations. Random crossing hardly occurs within accessions because only a fraction of

APPENDIX V

(continued)

the plants flower at the same time. Some accessions do not flower at all when they are grown at germplasm maintenance and evaluation sites. Further, cassava shows very strong inbreeding depression, so preservation by self-pollination (or by crossing identical clones) is not practical or desirable. Adapted genotypes can not be preserved by seed propagation. When Manihot germplasm is preserved by seed, a sufficient number of seeds should be collected from crosses to preserve the non-fixed alleles of an accession.

APPENDIX VI

WORKING GROUPS' RECOMMENDATIONS ON TRANSFER OF CASSAVA MATERIAL

1. Movement of collected material to primary repositories should be only through a meristem culture system or true seeds taken from plants that appear healthy.
2. Collected material should be tested for its state of health by a proper research institution, or passed through an intermediate plant quarantine station for detection of possible disease symptoms or signs of new pest attacks. If something is detected the material should be promptly destroyed. Infected meristem material in stock may be kept in isolation for a reasonable period if it can be cleaned of phytopathogens to a reasonable degree of certainty.
3. CIAT and IITA should continue to emphasize research on testing the state of health of collected cassava material. Work at these centres should focus on the development of improved techniques for freeing cassava material from virus and virus-like pathogens as well as for their rapid and reliable detection.
4. New important recommendations deserving much attention could come from a series of workshops being sponsored by the United Nations Development Programme (UNDP) and various CGIAR International Centres to discuss quarantine regulations and germplasm exchange for cassava and potatoes; and also from the International Consultation on Safe and Efficient Movement of Germplasm held in June 1982 at CIAT.
5. The IBPGR should assist the primary repositories in the transfer of duplicates of material already stored in national institutes.

DESCRIPTOR LIST FOR CASSAVA (MANIHOT ESCULENTA)

PREFACE

This descriptor list has been prepared in an IBPGR standard format following advice on descriptors and descriptor states from the crop experts throughout the world. The IBPGR encourages the collection of data on the first four categories of this list: 1. Accession; 2. Collection; 3. and 4. Characterization and preliminary evaluation. The IBPGR endorses the information in categories 1 - 4 as the minimum that ideally should be available for any one accession. Other descriptors are given in categories 5 onwards that will enable the simple encoding of further characterization and evaluation data and which can serve as examples for the creation of additional descriptors in the IBPGR form by any user.

Although the suggested coding should not be regarded as the definitive scheme, this format has the full backing of the IBPGR and is promoted worldwide. The descriptor list given here provides an international format and thereby produces a universally understood 'language' for all plant genetic resources data. The adoption of this scheme for all data encoding, or at least the production of a transformation method to convert other schemes to the IBPGR format, will produce a rapid, reliable and efficient means for information storage, retrieval and communication. This will greatly assist the utilization of germ-plasm throughout the international plant genetic resources network. It is recommended, therefore, that information should be produced by closely following this descriptor list with regard to: ordering and numbering descriptors; using the descriptors specified; and using the descriptor states recommended.

Any suggestions for modifications will be welcomed by the IBPGR Secretariat, Rome.

The IBPGR now uses the following definitions in genetic resources documentation:

- i) passport data (accession identifiers and information recorded by collectors);
- ii) characterization (consists of recording those characters which are highly heritable, can be easily seen by the eye and are expressed in all environments);
- iii) preliminary evaluation (consists of recording a limited number of additional traits thought desirable by a consensus of users of the particular crop).

Characterization and preliminary evaluation will be the responsibility of the curators, while further characterization and evaluation should be carried out by the plant breeder. The data from further evaluation should be fed back to the curator who will maintain a data file.

The following internationally accepted norms for the scoring or coding of descriptor states should be followed as indicated below:

- a) measurements are made in metric units;
- b) many descriptors which are continuously variable are recorded on a 1-9 scale. The authors of this list have sometimes described only a selection of the states, e.g. 3, 5 and 7 for such descriptors. Where this has occurred the full range of codes is available for use by extension of the codes given or by interpolation between them - e.g. in 8. (Pest and disease susceptibility) 1 = extremely low susceptibility and 8 = high to extremely high susceptibility;
- c) presence/absence characters are scored as + (present) and 0 (absent);
- d) for descriptors which are not generally uniform throughout the accession (e.g. mixed collection, genetic segregation) mean and standard deviation could be reported where the descriptor is continuous or mean and 'x' where the descriptor is discontinuous;
- e) when the descriptor is inapplicable, '0' is used as the descriptor value. E.g. If an accession does not form flowers, a 0 would be scored for the following descriptor.

Flower colour

- 1 White
- 2 Yellow
- 3 Red
- 4 Purple

APPENDIX VII
(Continued)

- f) blanks are used for information not yet available;
- g) standard colour charts e.g. Royal Horticultural Society Colour Chart, Methuen Handbook of Colour, Munsell Color Charts for Plant Tissues are strongly recommended for all ungraded colour characters (the precise chart used should be specified).
- h) leaf and petiole data should be scored on first fully expanded leaf when the plant is 6-8 months old; stem data should be scored when the plant is near harvest.

PASSPORT

1. ACCESSION DATA

1.1 ACCESSION NUMBER

This number serves as a unique identifier for accessions and is assigned by the curator when an accession is entered into his collection. Once assigned this number should never be reassigned to another accession in the collection. Even if an accession is lost, its assigned number is still not available for re-use. Letters should occur before the number to identify the genebank or national system (e.g. MG indicates an accession comes from the genebank at Bari, Italy, PI indicates an accession within the USA system)

1.2 DONOR NAME

Name of institution or individual responsible for donating the germplasm

1.3 DONOR IDENTIFICATION NUMBER

Number assigned to accession by the donor

1.4 OTHER NUMBERS ASSOCIATED WITH THE ACCESSION (other numbers can be added as 1.4.3 etc.)

Any other identification number known to exist in other collections for this accession, e.g. USDA Plant Introduction number (not collection number, see 2.1)

1.4.1 Other number 1

1.4.2 Other number 2

1.5 SCIENTIFIC NAME

1.5.1 Genus

1.5.2 Species

1.6 PEDIGREE/CULTIVAR NAME

Nomenclature and designations assigned to breeder's material

1.7 ACQUISITION DATE

The month and year in which the accession entered the collection, expressed numerically, e.g. June = 06, 1981 = 81

1.7.1 Month

1.7.2 Year

1.8 DATE OF LAST REGENERATION OR MULTIPLICATION

The month and year expressed numerically, e.g. October = 10, 1978 = 78

1.8.1 Month

1.8.2 Year

1.9 ACCESSION SIZE

Approximate number of seeds or plants of accession in collection

1.10 NUMBER OF TIMES ACCESSION REGENERATED

Number of regenerations or multiplications since original collection

1.11 TYPE OF MAINTENANCE

- 1 Vegetative - field culture
- 2 Vegetative - tissue culture
- 3 Seed
- 4 Combination of above (Specify in the NOTES descriptor, 11)

2. COLLECTION DATA

2.1 COLLECTOR'S NUMBER

Original number assigned by collector of the sample normally composed of the name or initials of the collector(s) followed by a number. This item is essential for identifying duplicates held in different collections and should always accompany sub-samples wherever they are sent

2.2 COLLECTING INSTITUTE

Institute or person collecting/sponsoring the original sample

2.3 DATE OF COLLECTION OF ORIGINAL SAMPLE

Expressed numerically, e.g. March = 03, 1980 = 80

2.3.1 Month

2.3.2 Year

APPENDIX VII
(Continued)

2.4 COUNTRY OF COLLECTION OR COUNTRY WHERE CULTIVAR/VARIETY BRED

Use the three letter abbreviations supported by the Statistical Office of the United Nations. Copies of these abbreviations are available from the IBPGR Secretariat and have been published in the FAO/IBPGR Plant Genetic Resources Newsletter number 49

2.5 PROVINCE/STATE

Name of the administrative subdivision of the country in which the sample was collected

2.6 LOCATION OF COLLECTION SITE

Number of kilometres and direction from nearest town, village or map grid reference (e.g. TIMBUKTU7S means 7 km south of Timbuktu)

2.7 LATITUDE OF COLLECTION SITE

Degrees and minutes followed by N (north) or S (south), e.g. 1030S

2.8 LONGITUDE OF COLLECTION SITE

Degrees and minutes followed by E (east) or W (west), e.g. 7625W

2.9 ALTITUDE OF COLLECTION SITE

Elevation above sea level in metres

2.10 COLLECTION SOURCE

- 1 Wild
- 2 Farm land
- 3 Farm store
- 4 Backyard
- 5 Village market
- 6 Commercial market
- 7 Institute
- 8 Other (specify in the NOTES descriptor, 11)

2.11 STATUS OF SAMPLE

- 1 Wild
- 2 Weedy
- 3 Breeders line
- 4 Primitive cultivar (landrace)
- 5 Advanced cultivar (bred)
- 6 Other (specify in the NOTES descriptor, 11)

APPENDIX VII
(Continued)

2.12 LOCAL/VERNACULAR NAME

Name given by farmer to cultivar/landrace/weed

2.13 NUMBER OF PLANTS SAMPLED

Approximate number of plants collected in the field to produce this accession

2.14 PHOTOGRAPH

Was a photograph taken of the accession or environment at collection?

- 0 No
- + Yes

2.15 TYPE OF SAMPLE

- 1 Vegetative
- 2 Seed
- 3 Both

2.16 PART USED

- 1 Root
- 2 Shoot
- 3 Both

2.17 PRINCIPAL USES

- 1 Human consumption - fresh
- 2 Human consumption - dried or processed
- 3 Animal consumption - fresh
- 4 Animal consumption - dried or processed
- 5 Starch extraction
- 6 Other (specify in the NOTES descriptor, 11)

2.18 HERBARIUM SPECIMEN

Was a herbarium specimen collected?

- 0 No
- + Yes

2.19 OTHER NOTES FROM COLLECTOR

Collectors will record ecological information. For cultivated crops, cultivation practices such as irrigation, season of sowing, etc. will be recorded

CHARACTERIZATION AND PRELIMINARY EVALUATION DATA

3. SITE DATA

3.1 COUNTRY OF CHARACTERIZATION AND PRELIMINARY EVALUATION

3.2 SITE (RESEARCH INSTITUTE)

3.3 NAME OF PERSON IN CHARGE OF CHARACTERIZATION

3.4 SOWING DATE

3.4.1 Day

3.4.2 Month

3.4.3 Year

3.5 HARVEST DATE

3.5.1 Day

3.5.2 Month

3.5.3 Year

4. PLANT DATA

4.1 VEGETATIVE

4.1.1 Colour of unexpanded apical leaves

- 3 Light green
- 5 Dark green
- 7 Green - purple
- 9 Purple

4.1.2 Colour of first fully expanded leaf

- 3 Light green
- 5 Dark green
- 7 Green - purple
- 9 Purple

4.1.3 Shape of central lobe (see Figure 11)

- 1 Oblanceolate
- 2 Linear
- 3 Elliptic
- 4 Pandurate (Obovate with pair of basal lobes)
- 5 Lanceolate
- 6 Combination of above (specify in the NOTES descriptor, 11)

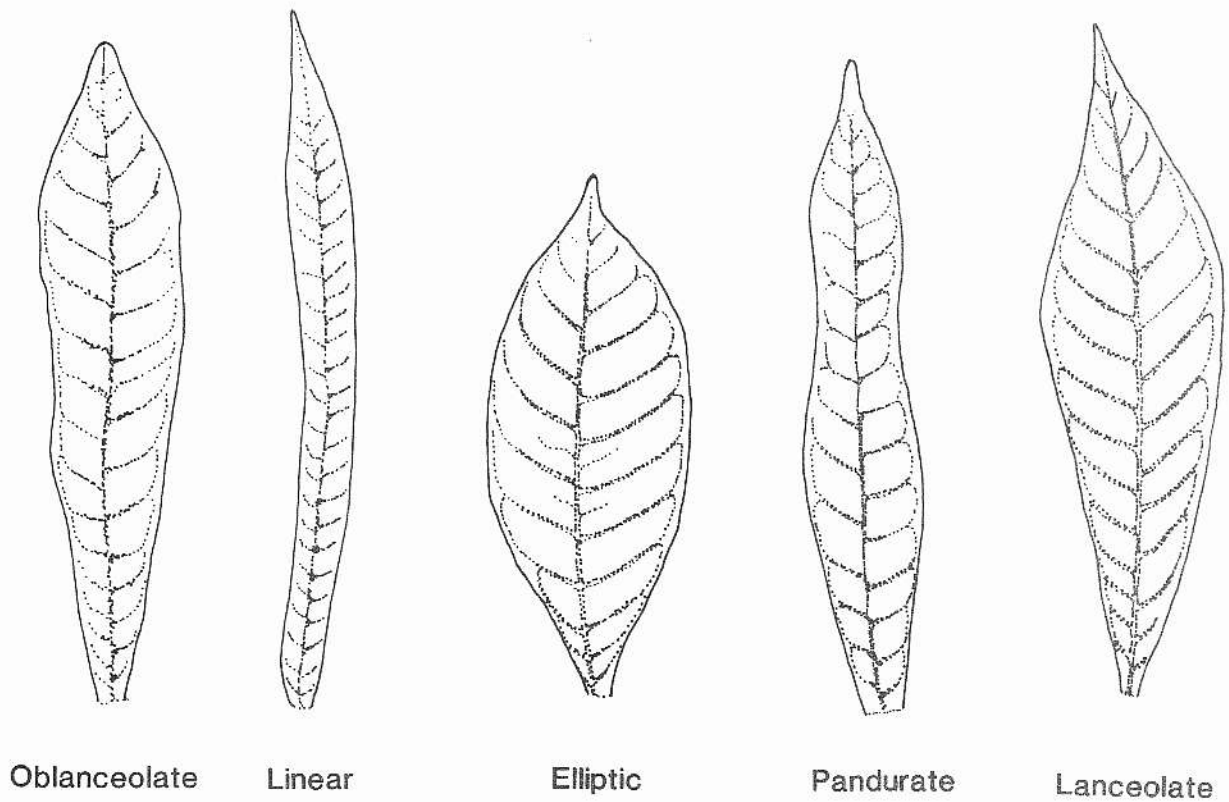


Figure 11. Shape of central lobe

APPENDIX VII
(Continued)

4.1.4 Petiole length

- 0 Petiole Absent
- 3 Short (5-10 cm)
- 5 Medium (15-20 cm)
- 7 Long (25-30 cm)

4.1.5 Petiole colour

- 3 Light green
- 5 Dark green
- 7 Green - purple
- 9 Purple

4.1.6 Pubescence of young leaves

- 0 Absent
- 3 Little pubescence
- 5 Moderate pubescence
- 7 High pubescence

4.1.7 Stem colour

- 1 Silver green
- 2 Light brown or orange
- 3 Dark brown

4.1.8 Number of levels of branching

Actual number of levels (see Figure 12)

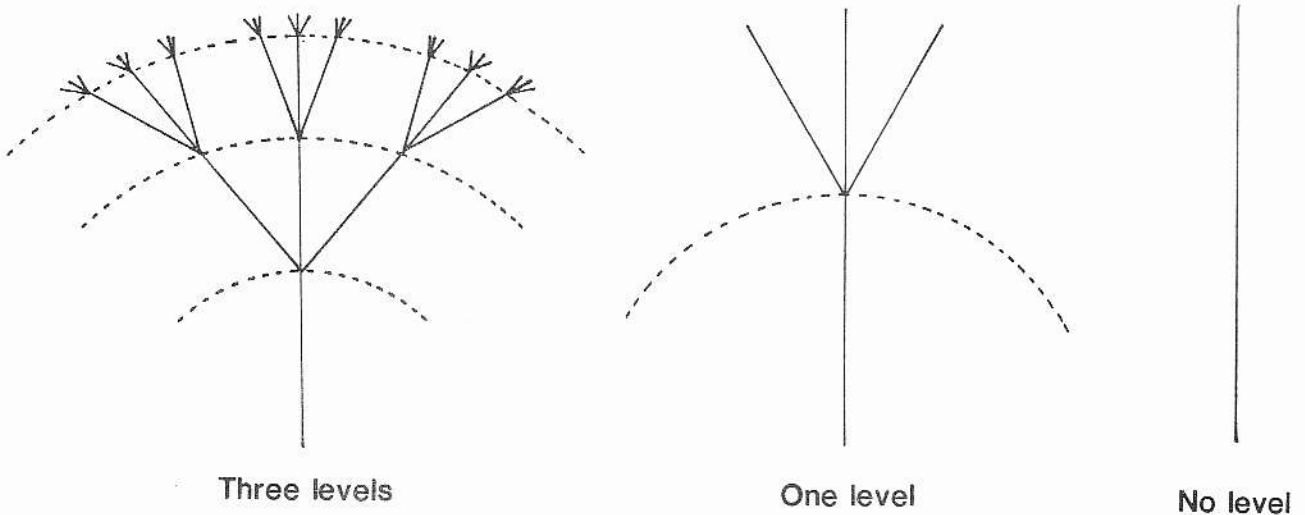


Figure 12. Number of levels of branching

4.1.9 Angle of branch (if branching)

Angle between vertical plane and first branches

- 0 Not branching
- 3 15-30°
- 5 45-60°
- 7 75-90°

4.1.10 Height of first apical branch (if branching)

In cm (see Figure 13)

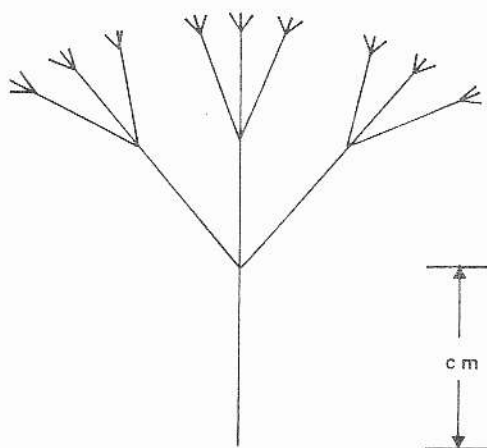


Figure 13. Height of first apical branch

4.1.11 Height of plant (to top of canopy)

In cm

4.1.12 Storage root surface colour

- 1 White or cream
- 2 Light brown
- 3 Dark brown

4.1.13 Storage root pulp colour

Immediately after being out open

- 1 White or cream
- 2 Yellow
- 3 Pink

APPENDIX VII

(Continued)

4.1.14 Estimate of storage root cyanide content

E.g. by picric acid method, after removing cortex (inner skin)

- 3 Low
- 5 Medium
- 7 High

4.2 INFLORESCENCE AND FRUIT

4.2.1 Flowers

- 0 Absent
- + Present

FURTHER CHARACTERIZATION AND EVALUATION

5. SITE DATA

5.1 COUNTRY OF FURTHER CHARACTERIZATION AND EVALUATION

5.2 SITE (RESEARCH INSTITUTE)

5.3 NAME OF PERSON IN CHARGE OF EVALUATION

5.4 SOWING DATE

5.4.1 Day

5.4.2 Month

5.4.3 Year

5.5 HARVEST DATE

5.5.1 Day

5.5.2 Month

5.5.3 Year

6. PLANT DATA

6.1 VEGETATIVE

6.1.1 Percent germination of stakes

Actual percentage

APPENDIX VII
(Continued)

6.1.2 Initial vigour

- 3 Low
- 5 Intermediate
- 7 High

6.1.3 Number of leaf lobes

6.1.4 Length of central lobe

In cm

6.1.5 Width of central lobe

In cm

6.1.6 Leaf vein colour

- 3 Light green
- 5 Dark green
- 7 Green - purple
- 9 Purple

6.1.7 Distribution of anthocyanin pigmentation in petiole

- 0 Absent
- 1 Top part
- 2 Central part
- 3 Totally pigmented

6.1.8 Angle of petiole insertion

Angle between branch and petiole

- 0 No petiole
- 3 15-30°
- 5 45-60°
- 7 75-90°

6.1.9 Prominence of leaf scars

Measured on fresh scars (see Figure 4)

- 3 Little prominence
- 5 Moderately prominent
- 7 Prominent

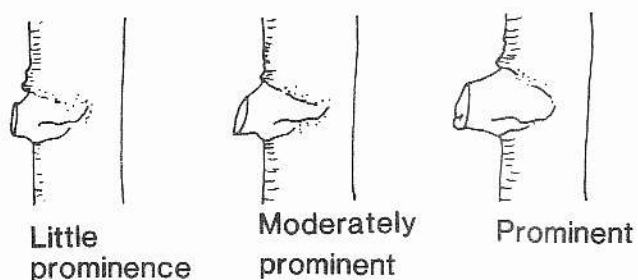


Figure 14. Prominence of leaf scars

6.1.10 Length of stipules

- 3 Short
- 5 Medium
- 7 Long

6.1.11 Margin of stipules

- 1 Lacinate
- 2 Serrate
- 3 Entire
- 4 Other (specify in the NOTES descriptor, 11)

6.1.12 Growth habit of young stem

- 1 Straight
- 2 Zig-zag

6.1.13 Plant form

- 1 Compact
- 2 Open
- 3 Parasol
- 4 Cylindrical
- 5 Erect

6.1.14 Time to first apical branching

Associated with formation of inflorescence, in weeks from planting

6.1.15 Time to second apical branching

Weeks from planting

6.1.16 Total fresh weight of foliage and stems per plant

In kg

6.1.17 Storage root peduncle

- 0 Absent (sessile)
- 3 Short
- 5 Intermediate
- 7 Long

6.1.18 Storage root form (see Figure 15)

- 1 Conical
- 2 Conical-cylindrical
- 3 Cylindrical
- 4 Fusiform
- 5 Irregular
- 6 Combination of above (specify in the NOTES descriptor, 11)

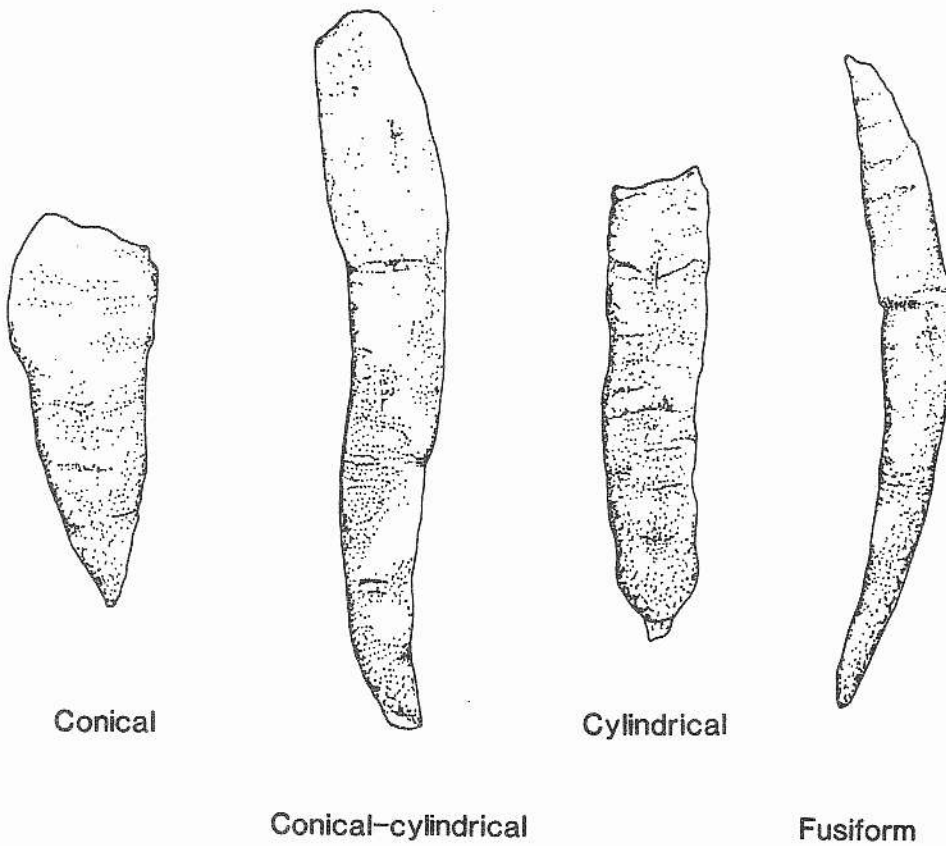


Figure 15. Storage root form

6.1.19 Storage root constrictions (see Figure 16)

- 0 Absent (not distinct)
- + Present (distinct)

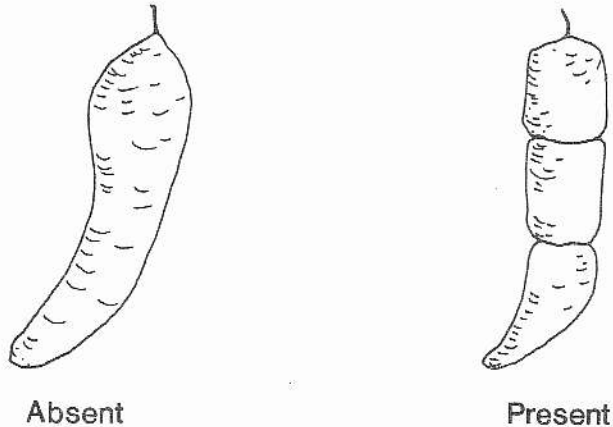


Figure 16. Storage root constrictions

6.1.20 Position of roots (see Figure 17)

- 1 Tending toward vertical
- 2 Tending toward horizontal
- 3 Irregular

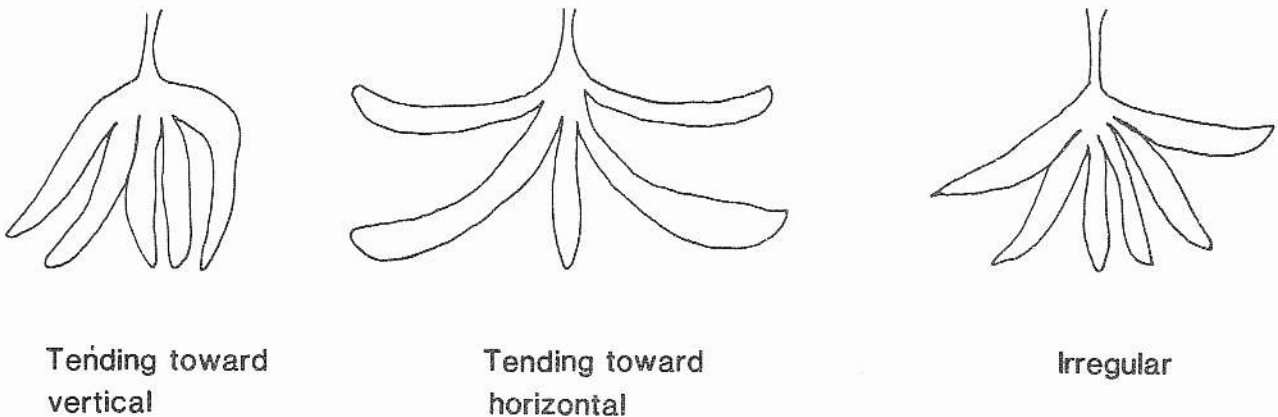


Figure 17. Position of roots

6.1.21 Storage root surface texture

- 3 Smooth
- 5 Medium
- 7 Rough

6.1.22 Storage root length

- 3 Short
- 5 Medium
- 7 Long

6.1.23 Storage root diameter

- 3 Narrow
- 5 Medium
- 7 Wide

6.1.24 Number of storage roots per plant

6.1.25 Total fresh weight of storage roots per plant

Measured in kg

6.1.26 Ease of root periderm (outer skin) removal

- 3 Easy
- 7 Difficult

6.1.27 Ease of root cortex (inner skin) removal

- 3 Easy
- 7 Difficult

6.1.28 Colour of outer surface of storage root cortex

- 1 White or cream
- 2 Yellow
- 3 Pink
- 4 Purple

6.1.29 Amount of rotted storage roots per plant

- 3 Low
- 7 High

6.1.30 Storage root dry matter percentage

Actual percentage

6.1.31 Percent fibre content

Actual percentage

6.1.32 Percentage of commercial roots

Specify commercial criteria in NOTES descriptor, 11

6.1.33 Post-harvest deterioration

Qualitative evaluation of physiological deterioration ^{1/}

- 3 Little
- 5 Moderate
- 7 High

6.1.34 Consumer acceptability

- 3 Low
- 5 Medium
- 7 High

6.1.35 Harvest index

Fresh storage root weight (6.1.25) / total plant weight (6.1.16 + 6.1.25)

6.1.36 Earliness

Proportion of root dry matter yield at 6-8 month compared with root dry matter yield at 12-14 months

^{1/} The quantitative method described in the CIAT 1979 Annual Report may be used:

"Deterioration was allowed to progress from the proximal end only through a 15 cm undamaged section by covering the distal end with PVC film. Transverse cuts made after three days at 2 cm intervals and scored on a 0-10 area-based scale produced a profile of deterioration down the root."

Specify method used in the NOTES descriptor, 11.

6.2 INFLORESCENCE AND FRUIT

6.2.1 Colour of sepals

- 1 White or cream
- 2 Orange
- 3 Green
- 4 Red
- 5 Purple

6.2.2 Colour of disc

- 1 White or cream
- 2 Orange
- 3 Green
- 4 Red
- 5 Purple

6.2.3 Colour of stigma

- 1 White or cream
- 2 Orange
- 3 Green
- 4 Red
- 5 Purple

6.2.4 Colour of ovary

- 1 White or cream
- 2 Orange
- 3 Green
- 4 Red
- 5 Purple

6.2.5 Colour of anthers

- 1 Cream
- 2 Yellow
- 3 Other (specify in the NOTES descriptor, 11)

6.2.6 Length of sepal

In mm

6.2.7 Width of sepal at widest point

In mm

6.2.8 Female flowers without staminoids

0 Absent
+ Present

6.2.9 Pollen

0 Absent
+ Present

6.2.10 Fruit set ^{1/}

0 Absent
+ Present

6.2.11 Length of fruit capsule

In mm

6.2.12 Diameter of fruit capsule

In mm

6.2.13 Exocarp of fruit

3 Smooth
7 Rough

6.3 SEED

6.3.1 Length of seed

In mm

6.3.2 Diameter of seed

In mm

6.3.3 Main colour of seed

1 Brown
2 Grey

^{1/} If fruit set is absent, enter 0 for descriptors 6.2.11, 6.2.12 and 6.2.13.

6.3.4 Secondary colour of seed

- 1 Brown
- 2 Black

6.3.5 Colour of caruncle

- 1 White or cream
- 2 Pink or red
- 3 Purple

7. STRESS SUSCEPTIBILITY

Scored on a 1-9 scale, where

- 3 Low susceptibility
- 5 Medium susceptibility
- 7 High susceptibility

7.1 LOW TEMPERATURE

7.2 HIGH TEMPERATURE

7.3 DROUGHT

7.4 HIGH SOIL MOISTURE

7.5 LOW AMBIENT RELATIVE HUMIDITY

7.6 SALINITY

7.7 LOW PH

7.8 LOW PHOSPHOROUS

8. PEST AND DISEASE SUSCEPTIBILITY

Scored on a 1-9 scale, where

- 3 Low susceptibility
- 5 Medium susceptibility
- 7 High susceptibility

8.1 PESTS

8.1.1 Others (specify in the NOTES descriptor, 11)

8.2 FUNGI

8.2.1 Others (specify in the NOTES descriptor, 11)

8.3 BACTERIA

8.3.1 Others (specify in the NOTES descriptor, 11)

8.4 VIRUS AND MYCOPLASM

8.4.1 Others (specify in the NOTES descriptor, 11)

9. ALLOENZYME COMPOSITION AND ZYMOTYPE

This may prove to be a useful tool to characterize cassava

10. CYTOLOGICAL CHARACTERS AND IDENTIFIED GENES

11. NOTES

Give additional information where descriptor state is noted as 'Other' as, for example, in descriptors 2.10, 4.1.3, etc. Also include here any further relevant information